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Essentials of

Orthopaedics and Applied Physiotherapy

Jayant Joshi | Prakash Kotwal

3rd Edition

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Essentials of Orthopaedics and Applied Physiotherapy

THIRD EDITION

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Dedication

Dr Jayant Joshi left for his heavenly abode on 2 Februaruy 2015. He had completed the work on the third edition manuscript just 4 days before his death.

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Preface to the third edition

Prakash Kotwal

It is indeed a pleasure to present the third edition of the book *Essentials of Orthopaedics and Applied Physiotherapy*. Bringing out a new edition provides an opportunity to update the book in accordance with the recent advances in the subject. This is exactly what has been done with this edition of the book. Most of the chapters have been revamped with addition of new/better photographs and tables for better understanding.

This edition contains 39 chapters, against the 26 in the second edition. The bigger chapters have been split into multiple chapters, organized region wise in body, with a view to update the chapters and easy accessibility to a topic.

The project of writing this book was conceptualized with the intention of providing knowledge about orthopaedic conditions and procedures to the physiotherapy students, practising physiotherapists and orthopaedic surgeons alike. The book was also meant to discuss the physiotherapy protocols after an orthopaedic procedure or treatment. To take this intention further, selected physiotherapy procedures/manoeuvres are being provided along with this edition of the book. The videos of the physiotherapy procedures have proper citations in the text. The videos comes at no extra cost, demonstrating the correct methods of physiotherapy procedures/manoeuvres.

I take this opportunity to pay homage to my co-author, Mr Jayant Joshi, who passed away a few months back. He was the main inspiration behind starting this book project. His passion and dedication for this book was so great that he completed the majority of the manuscript just before he passed away.

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I would like to express my gratitude to all those who helped me in the preparation of the manuscript of this book.

I thank Mrs Kanchan Mittal for accepting the task of completing the physiotherapy part of the book.

My friends Siddharth and Reena Mishra deserve a special mention and thanks for undertaking the clinical photography job with a professional finesse. I would like to thank my colleagues Dr Bhavuk Garg, Prof. Shah Alam Khan, Dr Md Tahir Ansari and Dr Abhinav Agarwal for providing certain clinical photographs for this book. I am also grateful to Dr Vivek Shankar for his extensive help at various stages of the preparation of manuscript.

I owe my life to my parents, Shri P.D. Kotwal and Mrs Usha Kotwal, and career to Mr P.S. Samvatsar and Mrs Sushma Samvatsar.

Last, but not the least, special thanks to my wife, Arundhati, for the encouragement, patience and the unconditional support in my professional pursuit.

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Preface to the first edition

Jayant Joshi

Prakash Kotwal

Physiotherapy has come of age and is now an integral part of orthopaedic practice. In fact, orthopaedics *per se* is incomplete in the management of a patient without physiotherapy. Orthopaedic physiotherapy is one of the major specialities of the science of physiotherapy and plays a significant role in restoring full function at the earliest.

There are a large number of books on orthopaedics and physiotherapy but each deals with the subjects as a separate entity. As such, it is not always convenient to refer to them to get an overall view of the total therapeutic management.

Therefore, a need was felt to bring out a book with an interspeciality therapeutic approach to get the overall picture of the total therapeutic management. We sincerely hope that this book, the first of its kind, would fill this gap and would provide useful guidance not only to the students of physiotherapy and practising physiotherapists but also to the orthopaedic surgeons, physiatrists and others engaged in the rehabilitation of the physically handicapped.

Most of the chapters in this book start with a treatise on relevant applied anatomy, predisposing factors, clinical features, diagnosis and comprehensive orthopaedic and

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physiotherapeutic management of all the common orthopaedic conditions including fractures and dislocations. A large number of line diagrams and photographs have been used to describe the various aspects of diagnosis and treatment of a particular condition. Some of the latest research works have also been included in the References for further reading on the subject. Tables have been used, wherever necessary, to present the matter in a concise or comparative form.

We are grateful to Professor P Chandra and Professor PK Dave for their constant guidance and encouragement during the preparation of this book. Our special thanks are due to our spouses, who tolerated our passion for this book, supported and assisted us while we were working on the manuscript. We are also thankful to Mr Viney Patil, Mr Kamalakar Patil, Ms Sweta, Mr Tara, Mr Tiwari, Mr Anil and others for their co-operation and assistance.

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CHAPTER 1

Orthopaedics and physiotherapy

OUTLINE

- Goal and role of both the sciences
- Orthopaedic disorders
- Systematic approach
- Principal methods of orthopaedic management
- Orthopaedic physiotherapy and cardiopulmonary conditioning
- Chest physiotherapy
- Cardiopulmonary resuscitation or ABC of life support

The term *orthopaedics* is derived from two Greek words *orthos* and *pedios*. Orthos means straightening and pedios means child. Originally the field of orthopaedics was limited to manipulating and correcting the deformed limbs in children. The age-old definition of this science is grossly wrong. Nowadays, the remarkable spurt of advancements in the technology has revolutionized the whole process of orthopaedic management; from correcting deformities in children, it has progressed to the level of organ replantation.

Similarly, the field of physiotherapy which used to be limited to massage and simple movements to the joints following fracture has developed into an independent specialty of medical sciences. Its nonpharmacological exercise-oriented approach and multidisciplinary

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applicability has widened its horizons tremendously. Besides therapy, its preventive role is being recognized all over the globe. However, the science of physiotherapy has a special hand-and-glove relationship with orthopaedics, as it plays a predominant role in the management of the whole gamut of orthopaedic sciences. To quote one of the reputed orthopaedic surgeons of India, Late Prof P Chandra, Emeritus Professor, All India Institute of Medical Science, New Delhi, 'The success of orthopaedic treatment depends largely on a physiotherapist. The surgeon should never pick up the knife unless he/she has a competent physiotherapist.'

Goal and role of both the sciences

The ultimate goal of orthopaedic treatment as well as orthopaedic physiotherapy is to restore the maximum possible physical independence to a patient, in performing the physical tasks involved in the activities of daily routine (ADR) and occupation (before injury or altered occupation after rehabilitation) within the limits of disability or the disorder (Fig. 1-1).

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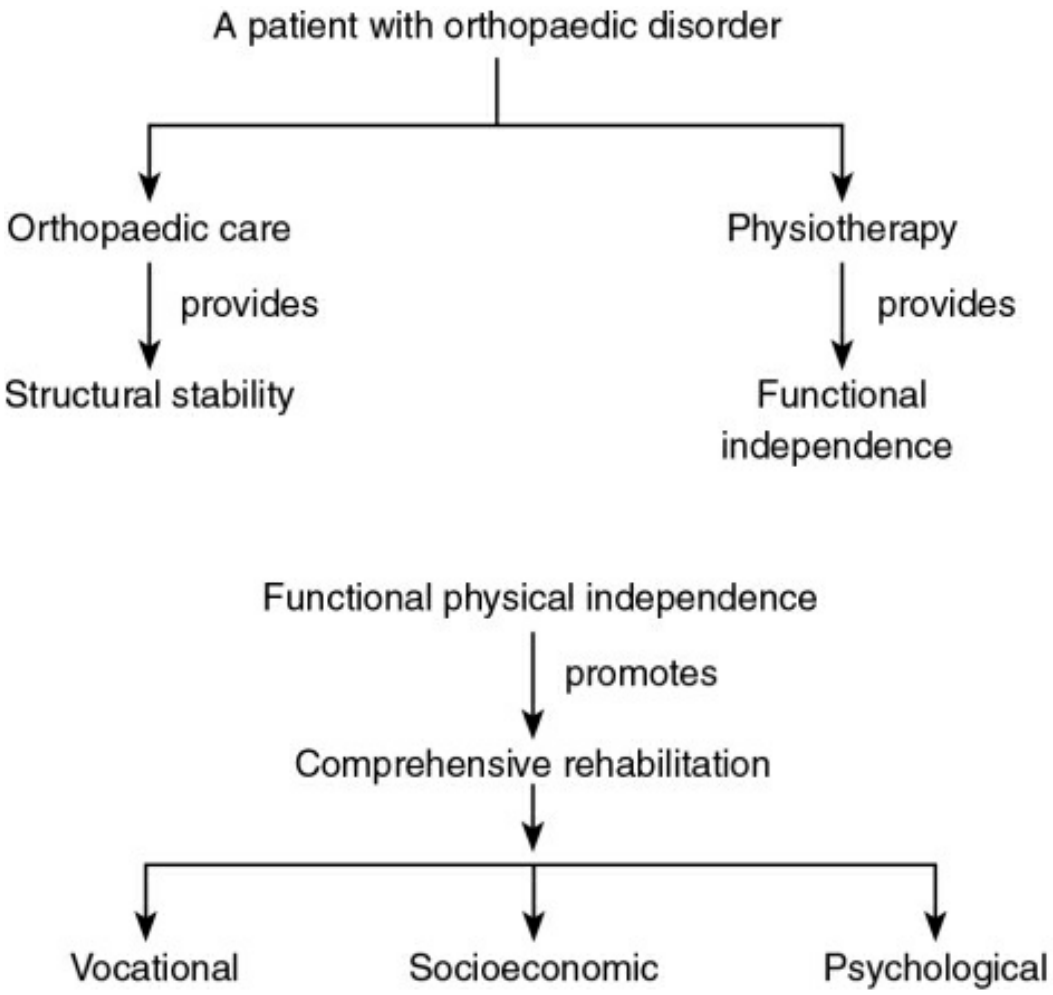

FIG. 1-1 Goal and role of orthopaedics and physiotherapy.

Orthopaedic management provides the basic structural stability to the body, whereas physiotherapy works towards achieving the maximum functional restoration.

Orthopaedic disorders

The disorders in orthopaedics are broadly classified into two categories:

1. Traumatic (Table 1-1) and

2. Nontraumatic (Table 1-2)

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Table 1-1
Major Traumatic Orthopaedic Disorders

Bone Injuries	Soft Tissue Injuries
• Fractures • Subluxations • Dislocations • Multiple trauma involving multiple fractures, injury to the soft tissue and visceral organs (e.g., caused by RTA, earthquake)	Injury to the • Muscles • Ligaments • Blood vessels • Nerves • Skin • Fascia • Other connective tissues like joint capsule, synovium, bursae

Abbreviation: RTA, road traffic accident.

Table 1-2
Major Nontraumatic Orthopaedic Disorders

	Disorder	Aetiology	Example
1.	Pathological fractures	• Occur as a result of weakening of the bone due to generalized or localized bone disease	• Fracture due to metastatic lesion, a fracture through the bone cyst, or due to osteoporosis, etc.
2.	Congenital anomalies	• Mostly developed during intrauterine period	• Congenital absence of bones • CTEV, scoliosis, congenital dysplasia, etc.
3.	Developmental disorders	• Developed due to faulty development of bone or cartilage	• Achondroplasia • Paget disease • Osteochondritis
4.	Infective diseases	• As a result of infection by microorganisms	• Osteomyelitis • Tuberculosis • Septic arthritis
5.	Metabolic diseases	• As a result of imbalances in mineral exchange between the bone reservoir and intracellular fluid regulated by hormones and local factors	• Rickets • Osteoporosis • Hyperparathyroidism
6.	Endocrinal disorders	• As a result of hormonal imbalances	• Hypothyroidism (cretinism) • Hypopituitarism (dwarfism)
7.	Inflammatory disorders	• Inflammation which progresses to the bones and joints systemic soft tissue from diseases	• Rheumatoid arthritis • Ankylosing spondylitis
8.	Neoplasia (tumours)	• Development of benign or malignant tumours of the bone	• Osteoma (benign) • Osteosarcoma (malignant)

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9.	Degenerative joint disorders	• Wear and tear of the joint cartilage	• Osteoarthritis • Spondylosis
10.	Neuronal and muscular disorders	• Could be congenital, acquired, developmental, infective or due to compressive pathology	• Cerebral palsy • Neuropathy • Poliomyelitis
11.	Regional musculoskeletal conditions of the neck, spine, upper and lower limbs	Soft tissue lesions due to • Overuse of specific muscles and joints, or trauma • Wrong postural habits • Lack of exercise, etc.	• Sports injuries • Cervical spondylosis • Low back pain • Adhesive capsulitis (frozen shoulder)

Abbreviation: CTEV, congenital talipes equino varus.

Some common traumatic disorders are listed below.

- Fracture: When there is discontinuity at the outermost hard layer of the bone (cortex).

- Subluxation: When a joint is only partially displaced from its compact original position with the retention of some articular contact.

- Dislocation: When a joint is displaced from its compact natural anatomic configuration with partial or complete disruption of the joint capsule and the ligaments.

- Strain: When a muscle or a ligament is torn as a result of excess violence.

- Stress: When the ligaments protecting the joint are injured due to sudden excessive twisting violence to the joint.

Systematic approach

Correct diagnosis is the key to the successful management of a patient.

The following criteria help to arrive at the diagnosis:

1. Sound basic knowledge of the subject including the latest developments in the field

2. Critical clinical and physical examination and objective evaluation of the patient provide definite clues to a provisional diagnosis

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3. Correct interpretation of the results of evaluation including investigations confirms the diagnosis

4. Appropriate patient-oriented therapy

5. Educating the patient on preventing the recurrence of the disorder or disease as well as wilful acceptance of healthy exercising lifestyle

Steps in the process of evaluation towards diagnosis (tables 1-3 and 1-4)

1. Observational analysis

2. History taking

3. Collection of subjective data from a patient

4. Objective clinical data, through physical examination and evaluation

5. Functional evaluation

Table 1-3

Steps in Orthopaedic and Physiotherapeutic Evaluation

1.	Observational analysis	• To observe the patient for obvious physical discrepancies, e.g., posture, gait, deformity when the patient is ambulatory	• Overall physical status • Areas of major physical disability
2.	History of onset and course of the disorder or disease	• Offers broad classification of the present episode and possible pathology, e.g. • Is it traumatic or nontraumatic? • Is it congenital or acquired? • Is it associated with • Fever, chill, rigors, sweating (possible infective pathology) • Seasonal variation (possible inflammatory pathology) • Constitutional symptoms like rapid weight loss, anorexia (e.g. neoplasia) • Hormonal imbalance (e.g. hypothyroidism, hypopituitarism) • Joint pain at advanced age (degenerative disorder)	• Identification of the major category of disorder: • Traumatic or nontraumatic • Congenital or acquired • Infective disorder • Inflammatory disorder • Metabolic disorder • Endocrinal disorder • Certain orthopaedic disorders are commonly encountered at certain age groups and related to sex

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		• Age and sex (certain orthopaedic diseases are common at certain age groups and sex) Developmental diseases • Occur later during the growing period	
3.	Subjective data collection	• Information from the patient regarding • Occupation • Subjective perception of the present episode and its overall impact	• To guide physical rehabilitation, schedule • To decide therapeutic approach
4.	Objective examination and evaluation	• To evaluate and record the informative data through physical examination • Inspection • Carefully inspect skin health, wounds, scars, stretchability, sensation, etc. • Objective evaluation of tenderness, swelling, deformity, atrophy • Palpation • For temperature difference, anatomical integrity of the bones and joints, interrelationship of the bony prominences and soft tissues (e.g., presence of nodules) • Movements: Evaluation of passive as well as active ROM at the joints • Muscle functions: Critical evaluation of strength, endurance, flexibility, tone, movement control and coordination • Sensory status: Critical evaluation of the sensations, kinaesthetic and proprioceptive, touch, pinprick and the reflexes • Joints: Examine the joints for stability, integrity, musculoskeletal stretchability, ROM and deformity	Provide objective data to • Plan therapeutic programme • Judge therapeutic response of the patient and the prognosis of recovery
5.	Functional evaluation	• To critically assess the physical efficacy of performing the various activities of daily routine (ADR) • Detailed evaluation of the neuromusculoskeletal deficiencies hindering the ADRs	• Provides guidance in formulating individualized therapeutic prescription – to improve deficient functional performance

Abbreviations: ADRs, activities of daily routine; ROM, range of motion.

Table 1-4

Specific Orthopaedic and Physiotherapy Examinations to Reach Final Diagnosis

Specific Orthopaedic Examination to Reach the Final Diagnosis	Specific Physiotherapy Examination to Plan Therapeutic Programme
• Radiography To evaluate skeletal integrity It could be • Plain radiography • Contrast radiography (e.g., arthrography) • CT scan: Provides detail of	• Body structure, body weight, height and body composition • Overall physical capacity to withstand exercise and any contraindications • Accurate goniometric measurement of ROM, deformities, etc. • Detailed assessment of muscle functions • Muscle power (strength), especially of the functional groups • Endurance

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the skeletal lesion (with 3-dimensional reconstruction) • MRI: Provides better delineation of the soft tissues and to some extent, changes in the bone • Angiography, biopsy and other relevant diagnostic laboratory tests • Radioisotope bone scan • PET scan • Open or closed biopsy (FNAC)	• Flexibility • Tone (hypertonia, hypotonia or atonia) • Examination of the joints • Details of the movement patterns, movement control and coordination and balance • Neuromuscular integrity by EMG, stimulation, RD test • Gait pattern analysis • Diagnostic physical tests to identify the site and extent of the soft tissue or neuronal injury (e.g., musculotendinous complexes, ligaments, lesions of the central nervous system and peripheral nerves

Abbreviations: CT, computed tomography; EMG, electromyogram; FNAC, fine-needle aspiration cytology; PET, positron emission tomography; RD, reaction of degeneration; ROM, range of motion.

It not only provides definite clues to the final diagnosis but also greatly assists in formulating the therapeutic procedures.

Functional evaluation

- Evaluation of the whole body's efficacy to perform ADR and occupation-related physical tasks, recording specific deficiencies blocking a particular activity

- Detailed neuromusculoskeletal evaluation of the individual-deficient segment obstructing the function, e.g., range of motion (ROM), muscle functions, movement control and coordination, balance, sensorium and ambulatory status, gait pattern and efficacy in managing slopes, stairs

Note: Extensive stepwise evaluation is not always necessary or possible. A single step may be adequate to arrive at the diagnosis.

Principal methods of orthopaedic management

Basically the following two principal methods are used in the treatment:

- Conservative

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- Surgery

Conservative method

Appropriate pharmacological agents:

- To reduce pain
- To control inflammation
- To control infection by microorganisms
- To control reflex muscular spasm
- Rest to the injured area by proper positioning of the injured limb
- To immobilize the injured or diseased area by
- Strapping
- Plaster of Paris (POP) slab/cast
- Orthosis
- Skin or skeletal traction
- Graded manipulation and serial POP casting to correct deformity
- Joint manipulation under GA to mobilize stiff joint
- Closed reduction and manipulation with or without GA to correct anatomical alignment of broken bones (fractures) or dislocated joints

Surgery

- Open reduction and internal fixation (ORIF) to fix fractured bones

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- Replacement of fractured or diseased bones or joints by artificial components, e.g., arthroplasty

- Bone grafting to fill up a gap, strengthening the bone or to stimulate the growth of bone in fractures nonunions

- Osteotomy – producing fracture to correct bony deformity, or malalignment of a joint

- To adjust the line of weight bearing or to correct limb length disparity

- Arthrodesis – fusion of the joint in a functional position when no alternative is available to facilitate function

- Reconstructive surgery – to repair the damaged soft tissues like nerve, muscle, fasciae, etc.

- Vertebroplasty – use of bone cement to fill up the gap and strengthen the diseased or broken vertebrae

- Replantation – reattachment of the severed part of the limb (e.g., hand, digits)

Preventive role of physiotherapy

1. Preventive: Primary and secondary prevention (Table 1-5)

2. Restorative: To restore the near-normal functional status (Table 1-6)

3. Rehabilitative: To restore the maximum possible functional independence within the limits of the disease and the disability (Table 1-7)

Primary prevention and secondary prevention: Mainly it refers to the prevention of traumatic lesions and life-threatening conditions like coronary heart disease (CHD), hypertension and

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hypercholesterolaemia.

Secondary prevention and/or better control of the disease:

Development of complications is common not only following fractures but even after contacting any disease, which has adverse effects on the progress of recovery. These hazards can be effectively dealt with by critical regular monitoring and taking instant controlling measures.

Table 1-5

Preventive Role of Physiotherapy in Orthopaedics

Primary prevention of • Fracture • Dislocation • Subluxation • Strains, sprains • Common soft tissue disorders	Methods • Exercise training (endurance) to optimize physical fitness • Concentrated musculoskeletal conditioning of the areas susceptible to injury • Guidance on correct body mechanics • Guidance to control or avoid activities susceptible to injury • Sports- and occupation-related musculoskeletal conditioning • Guidance on the work as well as rest-related wrong postural attitudes
Secondary prevention of • Expected common complications following injury – fractures, dislocations, subluxation, etc. • Complications due to rigid immobilization (e.g. POP cast, skeletal traction)	• Rest, adequate support and frequent monitoring for the signs and symptoms of the expected complications • Guidance to the patient on the signs and symptoms of the possible complications
• Complications due to prolonged recumbency • Soft tissue tightness, contractures • Joint stiffness • Pressure sores • Generalized weakness and muscular atrophy • Reduced respiratory efficiency • Generalized detoning of all the systems of the body • Recurrence of the earlier disorder	• Full ROM exercise and passive stretching at the suspected sites • Frequent positional changes in bed, skin care, protection of pressure points • Gradually progressive exercise • Chest physiotherapy • Early initiation of progressive functional activities, PRE, earliest introduction of ambulatory training • Emphasis and guidance to continue exercises as taught

Table 1-6

Restorative Role of Physiotherapy in Orthopaedics

• Reduction and	Methods

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control of • Pain and tenderness • Swelling • Reflex muscular spasm	• Comfortable positioning, rest and appropriate physiotherapy modality • Early cryotherapy • Limb elevation compression bandage • Pain-free early isometrics and active repetitive movements to the distal joints, cryotherapy
• Early initiation of functional restoration	Formulating exercise training prescription to improve • Muscle functions • Joint ROM must restore functional ROM earliest • Neuromuscular coordination and joint control–movement coordination • Motivation of a patient to perform functional activities independently or with assistive aids • Using suitable modality as per the needs (e.g., massage, SWD, ultrasonic therapy) • Monitoring progress with regular re-evaluation • Providing necessary guidance to prevent recurrence • Use of specialized exercise techniques like PNF, manipulation and mobilization and manual therapy as per the needs • Restore the preinjury physical status

Abbreviations: PNF, proprioceptive neuromuscular facilitation; ROM, range of motion; SWD, shortwave diathermy.

Table 1-7

Rehabilitative Role of Physiotherapy in Orthopaedics

• For patients suffering from severe involvement or irreversible systemic damages, e.g., quadriplegics, paraplegics and neuronal diseases like cerebral palsy: To provide maximum functional independence within the limits of the disease and the disability	Methods • Improving the strength and the function of the paretic muscle groups • Identify and strengthen muscle groups to compensate for the weaker or paralysed muscles and introduce functional training at the earliest • Strengthen the compensatory mechanisms to substitute or assist the functional activity • Early provision of assistive aids and devices to assist function • Concentrate on functional training with aids • Training on the alternative mode for performing function, e.g., when ambulation is not feasible, preparing and teaching the patient on wheelchair ambulation • Use of specialized exercise techniques like PNF and Bobath to improve movement control, posture, balance, movement coordination, motor and sensory re-education, transfers, balance, ambulation and self-sufficiency in performing the activities of daily routine and the activities involved in the occupation or work

Abbreviation: PNF, proprioceptive neuromuscular facilitation.

Moreover, physiotherapy has emerged as great asset due to its exercise-oriented approach. Its salutary effect helps in

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1. increasing the efficiency of all the organs and the systems of the body.

2. increasing the immune responses of the body.

3. positively influencing the psychological status.

Role of physiotherapy in orthopaedics

Combination of all these benefits with physical fitness plays a key role as a preventive specialty.

Planning of physiotherapeutic programme

After critical evaluation, depending upon the expected role (i.e., preventive, restorative or rehabilitative), a comprehensive physiotherapy prescription is formulated to adequately meet the individual needs of a patient.

A large number of physiotherapeutic modalities are available to pick and choose from. However, exercise remains the basic mode of treatment. Assistive modalities provide assistance in the relief from pain and swelling and help in movement re-education and functional restoration (Table 1-8). Besides, specialized exercise techniques like proprioceptive neuromuscular facilitation (PNF), Bobath Brunnstrom and Maitland, and specialized techniques like manipulation and mobilization and manual therapy are initiated.

Table 1-8
Planning of Physiotherapeutic Programme

Basic Mode of Treatment	Assistive Mode of Treatment
Exercise[a]: To improve (a) Joint functions • Static and dynamic stability • Achieving normal or functional ROM (b) Muscle functions • Strength • Endurance • Flexibility • Tone (c) Movement • Character	Massage • Cryotherapy • Thermotherapy • Electrical stimulation • Interferential currents • Ultrasonic therapy • TENS • Maintenance and use of orthotic, prosthetic and functionally assistive devices to support, protect, hasten the process of recovery or to perform functional activities

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• Control • Coordination (single and multiple joints) • Sensory motor re-education (d) Balance • Static and dynamic balance (e) Functional training: To achieve self-sufficiency in performing the ADR at home and at work place with or without aids	

Abbreviations: ADR, activities of daily routine; ROM, range of motion; TENS, transcutaneous electrical nerve stimulation.

[a]Exercise is a multifactorial common entity and varies from life-saving manoeuvres like ABC of life support and emergency chest physiotherapy to functional restoration and rehabilitation.

However, the success of a therapeutic programme heavily depends upon how efficiently patients perform exercise on their own.

Exercise specificity

Our inborn lethargy towards exercise even in normal health is compounded further by pain, weakness and depression. Moreover, therapeutic exercise for benefits needs to be done several times. Under such circumstances, motivating and educating a patient to perform exercise efficiently and repetitively calls for certain must-be observed principles:

- Spend enough time in explaining the why and how of exercises. Being exercise-oriented professionals, somehow we tend to forget – that the patient also knows about exercises as well as we do.
- Ideally use the better part or normal limb or use a method of 'SELF-DEMONSTRATION', audiovisual media, diagrams, etc., for the patient to understand the correct methodology of exercise.
- Always begin with the simplest possible exercise.
- Select exercise in a preferential order as per the demand of the patient's condition.
- Select minimum number of very specific exercises and teach only one exercise at each sitting till a patient grasps it and performs it

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with maximum efficiency.

- Always check the specificity of previously taught exercise before proceeding to the next exercise.

- As far as possible, the exercise regimen should be competitive and based on the functional ADRs.

- To break the monotony of exercise but, at the same time, to ensure several repetitions, teach one exercise in the different fundamental positions of the body (e.g., exercise of knee flexion–extension can be performed in all the fundamental postures of the body (Fig. 1-2).

(A)

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(B)

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(C)

(D)

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(E)

FIG. 1-2 Performance of same movement (e.g. knee flexion) in various body postures: **(A)** supine, **(B)** low sitting **(C)** high sitting, **(D)** prone lying, **(E)** standing. It helps to break the monotony of exercise and encourages repetitions.

By this approach, a patient's acceptance of exercise is ensured.

General plan of physiotherapeutic management in orthopaedics

A. **Acute multitrauma: prehospital care**

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- Make a quick assessment of the patient's general condition by reviewing the vital signs.
- If needed, immediately start emergency measures to save life, e.g. ABC of life support (cardiorespiratory resuscitation).
- Control bleeding.
- Provide temporary support splinting to an injured limb and measures to prevent further damage.
- Arrange for immediate safe transfer of a patient to the nearest hospital or emergency management facility.

B. **Routine cases treated conservatively**

- Perform critical evaluation to assess the degree of major physical problems.
- Formulate exercise prescription on an individual basis.
- Initiate educating a patient on simple but specific exercise training as well as functional training programme.
- Cultivate interest in exercise lifestyle emphasizing its health benefits.
- Monitor the conducting of the exercise training and the efficiency of patient's performance, and use special exercise techniques.
- Plan a weekly or biweekly goal of expected improvement

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and review the progress critically by objective and subjective evaluation.

- Educate the patient on the don'ts and teach to prevent recurrence.

C. **Cases treated by surgery**

- Make preoperative assessment and conditioning (in preplanned surgical patients).
- Make preoperative evaluation and education – on the postoperative exercise training sessions and functional training schedules.
- Prescribe necessary orthotic devices or aids needed for postsurgical functional training.
- Plan weekly goal of expected recovery.
- Review at regular intervals to ensure recovery.
- Cultivate patient's interest in accepting exercise lifestyle as a disease preventive entity.

Planning of physiotherapeutic management

Due to the great variety of modalities and specialized treatment techniques, it is extremely difficult to generalize the therapeutic programme of physiotherapy. It is further complicated by the severity of the dysfunction, prognosis of recovery and individual variations.

Based on the expected duration of rehabilitation, patients are broadly classified into the following three categories (Table 1-9):

Table 1-9

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Classification of Patients on the Basis of the Approximate Time Required for Rehabilitation

1. Short duration (3–6 weeks)	• Simple neuromusculoskeletal disorders or undisplaced uncomplicated fractures
2. Intermediate duration (12–30 weeks)	• Fractures and/or dislocations of major bones and joints • Crush injuries; with complications • Early detected bone diseases
3. Long duration (30–52 week or more)	• Conditions needing long periods of recumbency • Patients with low physical capacity • Patients with irreversible neuronal damages or bone diseases • Recurrent systemic diseases like rheumatoid arthritis • Loosening of the artificial implants needing revision or multiple surgeries • Delay in reporting for treatment after developing complications • Failure in motivating patients even with uncomplicated disorders

Short-duration rehabilitation patients: This includes patients with simple, reversible neuromusculoskeletal dysfunctions, mostly involving soft tissues or simple fractures. The dysfunction is completely resolved within 3–6 weeks by appropriate physiotherapy measures.

- Control of pain and swelling by selecting appropriate modality
- Provide adequate supporting aid to prevent further damage, and pain due to movement at the injured area
- Encouraging pain-free isometrics progressing gradually to full ROM exercise against resistance
- Effective home management programme, postural guidance and guidance to avoid recurrence
- Correct use of aids and appliances whenever prescribed

Intermediate-duration rehabilitation patients: This includes fractures or fracture dislocations of major bones and joints associated with complications, repetitive surgery, or not so complicated fractures, but patients have associated diseases (e.g., rheumatoid arthritis, pathological fractures, tumours). Functional independence in such a patient may require 12–30 weeks.

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The basic physiotherapy remains same as mentioned for short-duration patients, however, with the following modifications.

Considering the complexities involved, there are more chances of slow rate of progress, difficulties in the performance of exercise and greater chances of developing soft tissue or joint contractures. The following treatment programme is instituted:

- Educate patients on simple but selective specific exercises.
- Provide support splint to prevent contractures and stiffness of functionally important joints or soft tissues.
- Provide functional training like changing position in bed, sitting up, shifting, transfers, standing and ambulation.
- Prescribe assistive aids as early as possible.
- Provide all the possible encouragement to put in hard efforts towards self-sufficiency.

Long-duration rehabilitation patients: This category includes patients with extensive irreversible damages with prognosis of poor recovery.

These patients require extensive long duration rehabilitative physiotherapy to bring them to the level of achieving functional independence. It may take 30–52 weeks or even more and sometimes, the patient may still remain dependent on physical assistance, particularly patients with irreversible neuronal damage, congenital anomalies, etc.

Concept of total rehabilitation: 'To bring a patient to the level of self-sufficiency in vocational, socioeconomic and psychological status, through restoration of physical independence in performing the occupational tasks and ADRs within the limits of the disease and the disability.'

How is physiotherapy the mainstay of total rehabilitation of a severely handicapped patient?

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Physiotherapy not only contributes significantly to achieving physical (functional) independence but also indirectly promotes vocational potentials which, in turn, augment the psychological status of a patient leading to the attainment of socioeconomic security (Fig. 1-3).

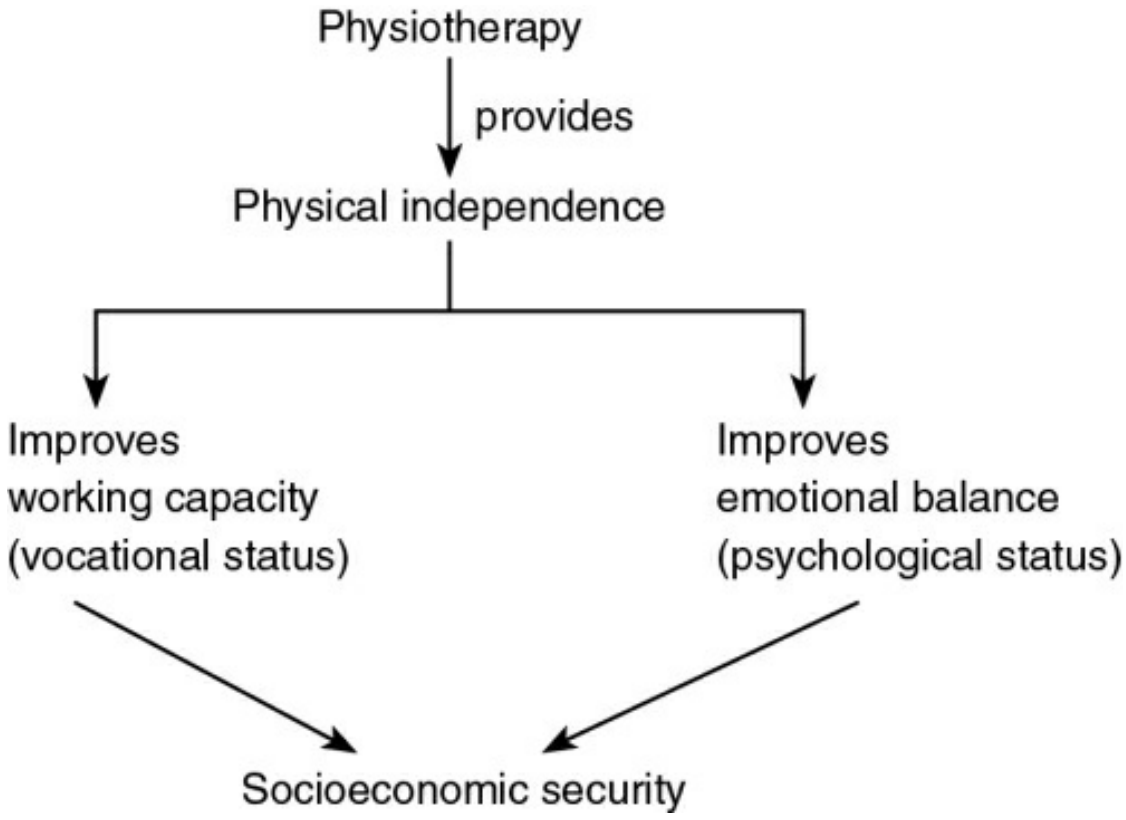

FIG. 1-3 Role of physiotherapy in the total rehabilitation of a severely handicapped patient.

Role of physiotherapy in total health care

A. **Primary prevention**: Structured exercise training and its regularity have been proved to play a significant role in the primary prevention of contacting serious injuries and diseases like:

- Coronary artery disease (CAD), cardiovascular disease (CVD)

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- Certain cancers
- Hypertension
- Fractures and soft tissue injuries
- NIDDM
- Obesity

It is mainly through achieving optimal level of physical fitness and overall increase in the body's immunity.

B. **Secondary prevention**: When the disease has already occurred, regular structured exercise programme has been proved to assist in the arrest of its progression and improve responses to its basic therapy (e.g. antihypertensive drugs).

Education and integration of exercise lifestyle

Physical inactivity and wayward eating habits are the major causative factors in inviting all these diseases; therefore, educating, emphasizing and integrating an exercise lifestyle in every orthopaedic patient is the responsibility of the physiotherapist.

Why is it ideal to integrate orthopaedics with an exercise-oriented lifestyle?

- Longer duration of recumbency or immobilization of the lower limbs for injuries or disease
- Longer periods of reporting to the department for treatment
- Home visits for treatment
- Most importantly, exercise-oriented therapy

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Today's physiotherapy approach demands major emphasis on integrating and educating the patient on an exercise-oriented lifestyle (ELS) without giving an opportunity to say 'I HAVE NO TIME' or any other excuse.

Areas needing special consideration for earlier and better results

- **Avoid late referral:** Irrespective of the mode of orthopaedic management employed, the patient should be referred for physiotherapy on the same day and regularly thereafter to avoid preventable complications like swelling, joint pain and stiffness, and generalized detoning.

- **Preoperative education:** Educating a patient on the postoperative care, and the exercise regimen on the contralateral normal limb or by self-demonstration greatly enhances the recovery.

- **Early weight bearing and ambulation:** The present trend of early ambulation may lead to fear complex, discomfort and limp. Instead, efforts should be made to achieve prerequisites of ease in ambulation like adequate ROM, muscle strength, balance and coordination. Considering the advantages of erect upright posture, well-supported graduated sustained standing, weight transfers, practising stepping, i.e., practising forward and backward stepping in supported static standing should be encouraged as early as possible. However, independent ambulation should not be enforced in a hurry before achieving adequate pain-free stability.

- **Cardiorespiratory endurance:** Considering the tremendous increase in the incidence and magnitude of RTAs, cardiovascular, metabolic, neoplastic disorders and obesity, integration of cardiorespiratory conditioning training is ideal as well as inescapable. Therefore, every physiotherapist is duty bound to impart lifestyle exercise along with orthopaedic care.

Orthopaedic physiotherapy and

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cardiopulmonary conditioning

Cardiopulmonary conditioning (CPC) is an exercise-oriented procedure which results in the improvement of endurance of cardiac and pulmonary systems. It works on the principle of overload, allowing adequate intake of oxygen and its transport efficiently to the working muscles.

CPC has been proved to be a major contributory factor in the primary as well as secondary prevention of cardiovascular diseases. However, the overall benefits of CPC are of much greater significance to us. The benefits of CPC are as follows:

1. It improves all the physiological parameters of the cardiopulmonary system (Table 1-10).

2. It provides a wide range of benefits to the various systems of the body (Table 1-11).

3. It also greatly influences the neuromusculoskeletal systems of the body with salutary influences on the psychological status of the patient (Table 1-12).

Table 1-10

Influence of CPC on Cardiovascular Parameters

Increases	Decreases
Blood supply to heart and stroke volume	Resting heart rate and BP
Oxygen uptake and utilization	Exercise HR and BP.RPP (double product)
Beneficial blood cholesterol (HDL)	Harmful blood cholesterol (LDL)
Exercise tolerance and functional capacity	Oxygen demands of the heart and psychic stress

Abbreviations: BP, blood pressure; HDL, high-density lipoprotein; HR, heart rate; low-density lipoprotein; RPP, rate pressure product.

Table 1-11

Overall Benefits of CPC

Improves

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Haemodynamics
Hormonal production
Metabolism
Glucose tolerance
Thyroid and lung functions

Table 1-12
Benefit of CPC Closely Related to Routine Physiotherapy

Improvement in
Neuromusculoskeletal system
Muscular strength and endurance
Flexibility of the joints and muscles
Neuromuscular coordination
Exercise tolerance, functional capacity and *joie de vivre*
Psychological status

Considering the overall benefits, integration of CPC in routine orthopaedic physiotherapy will certainly be instrumental in providing early and better results besides preventing musculoskeletal and cardiovascular problems.

To integrate CPC in routine orthopaedic physiotherapy, it is not necessary to alter the basic regime planned for an orthopaedic dysfunction. It only needs certain modifications in the exercise regime to incorporate the principles of CPC.

Methodology and principles of CPC

1. Preliminary screening

2. Clinical examination and evaluation

3. Formulating specific exercise prescription

Preliminary screening

Preliminary screening is done to ensure safety to the patient. Firstly, the medical history and the investigation reports are scrutinized to identify the presence of any serious cardiovascular disease. Secondly,

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the patient should be carefully observed for the presence of any potential risk factors for cardiovascular disease – CVD (Table 1-13). Such patients should first be referred for medical clearance. When no such problem is present, the patient can safely be included for CPC.

Table 1-13
Potential Risk Factors (RF) for CVD

Lifestyle RF	Obesity, smoking, sedentary lifestyle, excessive use of alcohol and stressful personality
Medical RF	Diabetes, hypertension, hyperlipidaemia, rheumatic fever or congenital heart disease
Hereditary RF	Family history of heart disease

Clinical examination and evaluation

(a) **Assessment of cardiopulmonary parameters is done at rest, during exercise and also during recovery:** Monitoring heart rate, blood pressure and double product (HR × systolic BP) assesses the cardiac response to exercise with a rough estimate of myocardial oxygen consumption.

(b) **Exercise tolerance:** As the requirements of the conditioning involve vigorous exercise to be continued for a longer period, it is imperative to evaluate the functional capacity or the exercise tolerance of the patient. It can be evaluated by various simple tests in nonrisk patients and is ideally monitored by graded exercise tests (GXT) like treadmill test, bicycle ergometry and arm crank ergometry for patients with cardiopulmonary disease or with present risk factors. The exercise puts physiological stress on the cardiopulmonary system and puts volume load on the left ventricle, quickly increasing the oxygen uptake by lungs with rapid increase in the heart rate. Systolic BP is also increased with increased cardiac output. Diastolic BP usually remains steady with increasing energy requirements.

Simple tests: These are called *performance, field* or *fitness tests.* Broad estimation of aerobic capacity, cardiopulmonary

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status and exercise tolerance can be done by these tests.

Distance test: The distance covered in a 12-min walk, jog or run is measured. The heart rate is checked at 2, 6 and 9 min during the full 12-min protocol.

Time test: Time taken by an individual to cover 2–4 km is recorded.

Both these tests can be done on a wheel chair in patients with weakness or paralysis of the lower extremities.

Crompton test: In this test, the pulse is recorded after 3 min of rest in a supine position. Pulse is rerecorded immediately on standing. The difference indicates overall simple heart performance. The difference of 4 beats is an indicator of total fitness, whereas the difference of more than 20 is an indicator of poor cardiovascular fitness.

Step test: After 3 min of relaxation in a chair, the pulse is recorded. Then the subject is made to step up and down a 16-inch step. The patient begins with the left leg up, then the right leg is stepped up; after that, the left leg is brought down, to be followed by the right leg; this completes one step. The speed of stepping is kept at 1 step every 3 s or 20 steps in a minute (in 80 counts/min). This is done continuously for 2 min. Then the subject relaxes in a chair and the pulse is re-recorded after 1 min rest. Excellent to good capacity is assumed if the difference between the pulse rates is within 10 counts, but the difference of more than 40 beats is an indicator of poor fitness.

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GXT: These are more specific tests than the tests described earlier. Here the load is gradually increased with equal grades. The cardiovascular response to the increasing load is monitored to a certain level. This level could be till the heart rate reaches up to 85% of the age-predicted maximal heart rate; then it is known as *submaximal graded exercise test* (submax. GXT). When the test is continued till the patient attains the level of age-predicted maximal heart rate (e.g., totally fit person), it is called *maximal graded exercise test* (max. GXT).

This test can be performed by using simple wooden steps of varying height. However, more precise monitored graded tests are performed with treadmill, ergocycle or arm crank ergometry, etc.

Graded step test: This test is done as described earlier; only the step height is increased gradually from level stepping to a 16-inch step (Fig. 1-4) and the test is conducted for 3 min at each level (Table 1-14) followed by 1-min rest at each level – when the pulse rate and BP are monitored (American Heart Association Publication, 1979, 1989).

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(D)

FIG. 1-4 Graded step test. **(A)** Left foot over the step at count one. **(B)** Right foot over the step at count two. **(C)** Left foot back to the floor at count three. **(D)** Right foot back to the floor at count four.

Table 1-14
Graded Step Test

Stage	Stepping on	Time/Rest Ratio	Steps/min	Counts
I	Level	3:1 min	20	80
II	4-inch step	3:1 min	20	80

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III	8-inch step	3:1 min	20	80
IV	12-inch step	3:1 min	20	80
V	16-inch step	3:1 min	20	80

The test is to be monitored carefully and the exercise, heart rate and BP are recorded at the end of each of five stages of the test as indicated in Table 1-14.

The test is continued till the desired level (age-predicted maximal or submaximal) is reached. It should be conducted carefully and should be discontinued if any signs of intolerance appear.

Termination of the test: The test must be terminated, immediately, if the following symptoms or signs appear:

1. Progressive angina or chest discomfort

2. Progressive drop in the systolic blood pressure or heart rate

3. Undue dyspnoea

4. Raised BP – systolic from 230 to 250 mm Hg and diastolic exceeding 130 mm Hg or falls below the resting level

5. Undue fatigue

6. Musculoskeletal pain and discomfort

7. Pale and clammy skin (signs of vasoconstriction)

8. Feeling of dizziness

9. Atrial fibrillation

10. Atrial tachycardia

11. Progressive ST changes (elevation, widening of the QRS complex)

12. Ventricular tachycardia (30 or more consecutive beats). Before testing, it is absolutely essential to identify patients who are

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vulnerable and need special precautions

13. Patient's request to stop

Vulnerable Group

- ☐ Patients with risk factors
- ☐ Asymptomatic but with abnormal exercise test
- ☐ Dysrhythmias induced or aggravated with activity
- ☐ Patients with significant hypertension and with low functional capacity

Special Precaution Group

- ☐ Anaemia with haemoglobin below 10 mg/100 mL
- ☐ Uncontrolled metabolic diseases like diabetes, thyrotoxicosis and myxoedema
- ☐ Uncontrolled congestive heart failure (classes III and IV)
- ☐ Acute myocarditis or cardiomyopathy within past 1 year
- ☐ Uncontrolled hypertension
- ☐ Dysrhythmias
- ☐ Significant cardiac enlargement
- ☐ Moderate-to-severe valvular disease

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- Recent pulmonary embolism (PE)
- Inappropriate BP response to exercise
- Painful limbs, as the test involves vigorous exercise, it can be administered only to the normal or near normal limbs (Table 1-15)

Table 1-15
Physical Disability and the Exercise Tolerance Test

Test	Normal or Near Normal Extremities
Graded step test	Lower extremities
Stationary bicycle ergometer	Lower extremities
12-min run, jog, walk test	Lower extremities
Climbing and descending 40 steps	Lower extremities
Arm crank ergometer	Upper extremities
12-min wheelchair propelling	Upper extremities

Recovery: At the conclusion of the test, heart rate (HR), BP and ECG are monitored during the recovery. These should return to near resting level within 2–8 min. Abrupt increase in BP, HR or ST changes during recovery indicate abnormality.

(c) **Evaluation of pulmonary function:** Estimation of the vital capacity (VC) and 1-s forced expiratory volume (FEV_1) can be done by a simple spirometer test.

Nonforced expiration of air through the mouth (clamping the nose) which is followed by maximum inhalation gives the measure of VC. For measuring FEV_1, the breath is held briefly following maximal inhalation, the subject exhales as hard and as fast as possible. These tests can provide the initial evidence for early cardiopulmonary disorders, especially in individuals complaining of unexplained dyspnoea on exertion.

Note: The conditioning or target range begins at 60% of maximal HR

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and is safe up to 75% of MHR. Ideal training range is between 70% and 85% of MHR or the range of oxygen uptake between 57% and 78% of maximal aerobic capacity (VO_2 max).

Exercise tolerance can adequately be assessed by the patient's own subjective rating of the perceived exertion – RPE (Table 1-16), where each grade corresponds near to the level of HR (e.g., grade 11 on the RPE scale corresponds close to the HR of 110; (Borg, 1970).

Table 1-16
Borg Scale of Perceived Exertion

Grade	Perception of Exertion
6–7	Very, very light
8–9	Very light
10–11	Fairly light
12–13	Somewhat hard
14–15	Hard
16–17	Very
18–19–20	Very, very hard

After assessing the haemodynamic cardiorespiratory response to the exercise test and the overall exercise tolerance, suitable exercise prescription is formulated on an individual basis.

Principles of formulating exercise prescription

Certain basic principles need to be followed while planning an exercise prescription for CPC. They are as follows:

(i) **Education on the self-determination of HR:** The HR is determined by counting the radial pulse manually for 10 s. It is then multiplied by 6 to get the HR (beats) per minute. The patient needs to be educated on this important aspect to monitor the HR during rest as well as exercise.

(ii) **Calculating the range of target HR:** The predicted maximum HR can be calculated by deducting the age of the patient from 220.

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However, whenever stress test is available, the accurate exercise HR can be calculated by the Karvonen equation:

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$$\mathrm{HR} = ((\mathrm{MHR} - \mathrm{RHR}) \times \text{required } \% \text{ of MHR for exercise}) + \mathrm{RHR}$$

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To calculate age-predicted maximum heart rate, subtract patient's age from 220. Thus, for a 60-year-old patient, maximum heart rate would be 220 – 60 = 160 beats/min.

The target range of exercise heart rate for a 60-year-old person can be calculated as follows:

60% of the maximum heart rate will be $\frac{160 \times 60}{100} = 96$

75% of MHR will be 120.

85% of the MHR will be 136.

The target heart rate range for the 60-year old patient will be from 96 to 136 (60–85% of MHR). The target range of heart rate for various age groups is illustrated in Table 1-17 and Fig. 1-4.

(iii) **Exercise specificity:** This is concerned with the three important factors of the exercise programme:

- ***Intensity:*** The prerequisite for the CPC is to overload the oxygen transport system to the heart. This is possible only when the exercise is continuous and the target HR range is maintained throughout the stimulus phase of the exercise. The intensity should exceed the usual mild demands, but must fall short of producing excessive fatigue. The appropriate level of training leads to exertion with perspiration. There is an increase in the rate of breathing but the patient will not be out of breath (talk test). There is a feeling of pleasant tiredness but not an unpleasant fatigue.

- ***Duration:*** The duration of conditioning exercises should be brief to begin with, increasing gradually. It could be

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begun at 15 min and increased gradually to 30–45 min. Minimum total time should be 3 h a week.

- ***Frequency:*** The frequency of exercise sessions should be at least three sessions a week. It should not be done on successive days. This frequency of three times a week provides an option to concentrate on the orthopaedic problem on the remaining 4 days of the week.

(iv) **Mode of exercises:** Isotonic or dynamic mode is the best mode of exercise. The movements should be continuous rhythmic involving the larger muscle groups. Continuous mode can be changed to intermittent mode but the interval has to be very brief and activity at a slower pace is continued even during this brief interval. Slow-paced activity reduces physiological demand, and the levels of lactic acid, thereby reducing muscle fatigue. This, in turn, facilitates stronger effort when vigorous exercise is begun again, allowing extra resistance at reduced physiological demand. It also slows down the rate of respiration reducing breathlessness, which is particularly useful in patients with respiratory insufficiency.

Table 1-17

Agewise Target Heart Rate

Age	Avg. max. HR	HR Target Zone					
		60%	70%	75%	80%	85%	90%
20	200	120	140	150	160	170	180
25	195	117	136	146	156	165	175
30	190	114	133	142	152	161	171
35	185	111	130	138	148	157	166
40	180	108	126	135	144	153	162
45	175	105	122	131	140	148	157
50	170	102	119	127	136	144	153
55	165	99	115	123	132	140	148
60	160	96	112	120	128	136	144
65	155	93	108	116	124	131	139
70	150	90	105	113	120	127	135

Isokinetic mode of exercise is ideal as resistance is accommodated

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according to the force of muscular contraction.

Isometric mode of exercise is generally contraindicated or done with caution. Isometrics provoke Valsalva manoeuvres, rhythm alterations and pressor responses. Therefore, it is contraindicated in patients with hypertension or done carefully, monitoring the BP responses.

The exercise programme should be directed to involve larger muscle groups to facilitate augmentation of the heart rate. To avoid fatigue to one particular limb or muscle group, it should alternate between the lower limbs, upper limbs and the trunk. Unilateral limb exercise is not adequate; therefore, simultaneous movements of either the upper limbs or the lower limbs are necessary.

Phases of conditioning exercise

Conditioning exercises are to be done in three different phases:

Warm-up phase: This phase is the initial phase of conditioning. It facilitates the necessary adaptations of myocardium, joints, skeletal muscles, tendons and ligaments to prepare the body for the vigorous conditioning phase. The efficiency of muscular contraction is greatly improved due to increased circulation; the raised temperature decreases the viscosity of blood. It also helps to reduce the chances of musculoskeletal injury. Continuous rhythmic aerobics or calisthenic movements are used to gradually increase the heart rate close to the level of 60% of MHR. Warm up can be given for 5 min.

Stimulus, endurance or conditioning phase: This is the most important phase of conditioning. It is a progression over the warm-up phase as the heart rate is increased to the training level from 60% to 70%, 75% or even 85% of MHR. This phase needs careful monitoring to maintain the training range of heart rate as well as vigilance for any adverse symptoms. It consists of more vigorous dynamic exercises alternating the movements and the body segments with very brief intervals. This could be begun for 10–15 min initially, gradually increased to 30–40 min. Exercise equipment can be used to attain and maintain the target range.

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Cool-down phase: It is the phase of gradually tapering down the intensity of the exercise. Exercises at low level help maintain sufficient cardiac output following vigorous exercise. It helps to transport and remove the waste products of metabolism by augmenting the venous drainage. Abrupt termination of exercise may lead to excessive demand of myocardial oxygen consumption thus elevating the heart rate. Increased hypotension may result in the decrease of blood supply to the brain leading to light headedness, dizziness or even fainting. Eliminating lactic acid along with metabolic wastes also reduces the chances of developing muscular soreness. Slowing the pace of conditioning exercise and the movements of slow stretching of the musculotendinous complexes are ideal. It is to be done for 5 min.

Ideally, relaxation techniques should follow the cool-down phase. Besides, inducing an overall feeling of betterment, these techniques are instrumental in reducing heart rate, blood pressure and even cardiac dysrhythmias.

Integration of CPC

The detailed physical evaluation of the orthopaedic problem should be analysed in relation to the prerequisites of conditioning.

Warm-up phase: According to the CPC needs of this phase, weak or involved limb/limbs can be included in the exercise programme, as the exercises during this phase are to be performed with lower intensity.

Stimulus or conditioning phase: This phase needs continuous, intensive and vigorous exercise. Therefore, stronger components of the body should form the basis during this phase.

Cool-down phase: This phase involves active slow stretching procedures of the musculoskeletal structures of the involved limb. It can be used advantageously either alone or in association with the contralateral limb.

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However, exercise planning for conditioning needs to be done on an individual basis and therefore no rigid procedures can be enlisted.

Example of integration

For the planning of a therapeutic programme, the basic needs of the patient's therapy are important.

A young man with traumatic paraplegia will need the following:

Strength – in the upper extremities to ease transfer activities and ambulation

Endurance – to propel wheelchair, and ambulation with aids and appliances

Flexibility – to facilitate self-care

All these basic needs should be incorporated as per the requirements of the CPC as follows:

Warm-up phase (5 min)

- Neck and trunk movements
- Arm movements with light dumbbells
- Passive bilateral hip, knee flexion

Stimulus or conditioning phase (beginning with a 10-min exercise session and working up gradually to at least 30 min, only three times a week)

- Pulley weights
- Prone push-ups
- Arm crank ergocycle

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- Ambulatory activities with wheelchair or ambulatory aids (Fig. 1-5)
- Rowing
- Wheelchair push-ups (Fig. 1-6)

Cool-down phase (5 min)

- Back stretch – prone and supine
- Leg stretch
- Arm stretch

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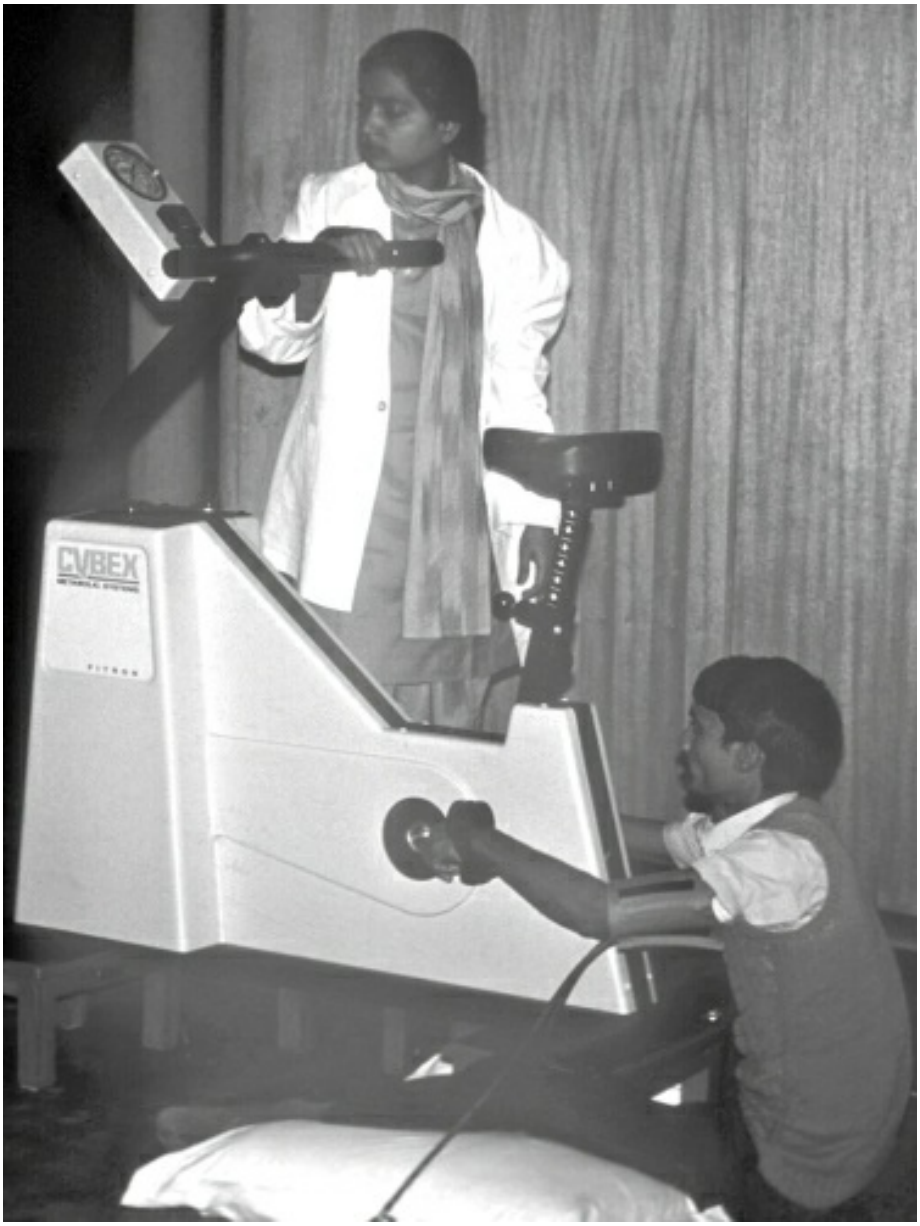

FIG. 1-5 Arm crank ergometry in a paraplegic to assess exercise tolerance.

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FIG. 1-6 Six- or 12-min wheelchair propelling test, to assess exercise tolerance in a paraplegic.

Therefore, incorporation of CPC in routine orthopaedic physiotherapy procedures for a mild neuromusculoskeletal dysfunction and gradually progressing to a major physical handicap assumes high priority. Every effort should be made, whenever possible, to practise such an integrated approach.

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Chest physiotherapy

Chest physiotherapy has a vital role to play not only in medical or surgical chest conditions but also in surgical procedures involving spine, pelvis, extremities and abdomen.

Chest physiotherapy also plays a significant role in the prevention of common postoperative complications, or in reducing their severity when they occur. It is also instrumental in the early return of the patient to his/her preoperative status.

Objectives of chest physiotherapy

1. ***To help remove secretions***

Percussion – Cupped hands are applied rhythmically to the thorax. Precautions include rib fractures, costo chondritis, haemoptysis, blood coagulation problems, dysrhythmias, pain, severe dyspnoea, pneumothorax and increased bronchospasm.

Shaking – Following inspiration, a 'bouncing' or 'thumping' manoeuvre is applied to the rib cage.

Vibration – Isometric cocontraction of the arms is applied to the thorax; it is usually used in conjunction with shaking, percussion and postural drainage positioning.

2. ***To help clear the airway***

Cough – Forcefully expelling air following a deep inhalation and closing of the glottis to expel mucus.

Forced expiration technique – One or two forced expirations with relatively low lung volumes, the glottis is not closed.

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Ideal for patients with chronic obstructive pulmonary disease (COPD).

Huffing – Similar to a cough with an open glottis. Patient may say Ha, Ha during expiration.

Assisted coughing – Similar to the Heimlich manoeuvre done during expiration.

3. ***To improve gaseous exchange and increase lung volume***

Three breathing exercise techniques are useful:

1. Diaphragmatic breathing
2. Segmental breathing
3. Pursed lip breathing

Physiotherapeutic approach

The approach of a physiotherapist should basically be problem oriented, to prevent or minimize the expected complications following surgery.

Early identification of patients who are at risk of developing complications is of primary importance. This is done by preoperative observations and assessment of various parameters in relation to the patient's condition, planned surgical procedure and the patient's physical work requirements for job as well as for hobbies.

Risk factors likely to cause postoperative complications

- Preexisting history of respiratory disorder, CV disorder, haemophilia, circulatory insufficiency (e.g., varicose veins, venous stasis)

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- Malignant disease
- Diabetes
- Poor nutritional status
- Obesity
- Alcoholism
- Smoking
- Low breathing capacity due to acquired or congenital musculoskeletal deformity or diseases like scoliosis, kyphosis, pectus carinatum (pigeon chest), pectus excavatum (funnel chest), barrel chest and ankylosing spondylitis
- Delayed prothrombin time

Subjective assessment

In subjective evaluation, it is important to know the duration, severity, pattern and factors associated with the following when present:

- Dyspnoea or breathlessness
- Orthopnoea or breathlessness while lying flat
- Paroxysmal or nocturnal dyspnoea
- Cough
- Sputum and haemoptysis
- Type of chest pain: pleuritic, tracheitic, musculoskeletal, angina or pericarditis
- The chief disturbing factors as expressed by the patient

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Objective assessment

It is vital to record other relevant information about the symptoms, past and present medical history, clinical and laboratory investigations and also physiotherapeutic evaluation.

- *Respiratory rate* (normal adult: 12–16 breaths/min)
- *Chest expansion* (normal adult: 3–5 cm)
- *Breath sounds:* Auscultation with stethoscope during inspiration is useful in detecting sputum retention. The opening of the alveoli and small airways during inspiration produces sharp crackling sound or continuous musical sound. These added breath sounds indicate alveolar narrowing and mucus retention. It helps in localizing the area of retention, its detachment and elimination. It can be correlated with the other signs of retention (Table 1-18).
- *Forced vital capacity (FVC)*
- *Forced expiratory volume in 1 s* (FEV_1): Measurement of FVC and FEV_1 can be done by spirometry. The ratio of FEV_1 to FVC provides a direct measure of the degree of airway obstruction. The ratio of less than 75% is graded as *mild,* less than 60% graded as *moderate* and less than 40% is graded as *severe* (American Thoracic Society, 1986).
- *Peak expiratory flow (PEF)*
- *Values of arterial blood gases:* Normal values in adults:
- pH = 7.35–7.45
- PaO_2 = 80–100 mm Hg
- $PaCO_2$ = 35–45 mm Hg

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- HCO_3 = 22–26 mmol
- Base excess = –2 to +2
- *Flow volume curves*
- *Chest radiograph*
- *Strength and endurance of the muscles of respiration*
- *Pattern of respiration* including the efficiency of diaphragm or the degree of substitution by the accessory muscles of respiration
- *Range of body temperature* (normal adult 36.5–37.5°F)
- *Heart rate* (normal adult between 60 and 100 beats/min)
- *Blood pressure* (normal adult between 95/60 and 145/90)
- *Body weight* (normal adult BMI = 20–25 kg/m^2)
- *Exercise tolerance* – tested by 6-min distance walk test (SMD) or 12-min walk test

Table 1-18
Signs of Sputum Retention

Auscultation	Localized or scattered short and sharp interrupted crackles, which may move with coughing
	A continuous musical sound or wheeze may be present or absent
Sputum	Thick, more viscid of any colour
Other signs	Pyrexia, ineffective coughRespiratory muscle weakness

Besides these, observation of fingertips for clubbing, colour of eyes, cyanosis, jugular venous pressure (JVP) and peripheral oedema provide important clues.

Assessment of patients in ICCU

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- Measurement of central venous pressure (CVP), pulmonary artery pressure (PAP) and intracranial pressure (ICP) is important

- Mode of ventilation (e.g., supplemental oxygen positive airway pressure, intermittent positive pressure ventilation)

- Route of ventilation (e.g., mask, endotracheal tube tracheostomy)

Depending upon the correct and critical interpretation of assessment, therapeutic regime is to be planned on an individual basis.

After assessment, the physiotherapy has two basic functions:

(a) Preoperative guidance and training

(b) Postoperative management

Before dealing with these two aspects, it is important to know the possible postoperative complications.

Common complications following general anaesthesia

1. (a) Excessive bronchial secretions and their stagnation

(b) Reduction of lung volume

(c) Reduction of functional residual capacity (FRC)

2. Postoperative pain

3. Deep vein thrombosis (DVT)

4. PE

1. ***Reduction of the lung volume and FRC, and accumulation of secretions***

- General anaesthesia provokes irritation of the bronchial

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mucosa, inhibits ciliary movement and promotes excessive bronchial secretions and their retention. There is impairment in the movement of mucus. This mucus plugging may lead to regional hypoventilation, airway obstruction and may even cause collapse of the lung tissue distal to the obstructed airway, or may even precipitate infection.

- There is marked reduction in the lung volume.
- The FRC may be reduced between 18% and 30%.
- There is respiratory depression and the efficiency of collateral ventilation is decreased markedly.
- Abdominal distension may be present limiting the excursion of the diaphragm.
- The pleural cavity may also be reduced due to gas or fluid.

All these factors result in marked deficiency in the whole process of the normal respiratory cycle.

2. ***Postoperative pain***

Persistent postoperative pain causes reduction in the lung volume, inhibits the clearance of bronchial secretions and may even cause spasm of the trunk muscles. All these factors also result in marked inefficiency of the mechanism of respiration, as it adversely affects the patient's active cooperation to perform exercise to eliminate secretions.

3. ***DVT*** (Fig. 1-7)

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The DVT or PE may occur as a result of damage to the vessel wall, venous stasis or changes in the blood clotting factors. A clot or thrombus may be formed in the deep veins of the pelvis or in the calf vein-plexus in the soleus muscle. Patients with earlier history of DVT, varicose veins, venous stasis, obesity, malignant disease, hypercoagulability of blood and advanced age are more prone to develop DVT. Therefore, such patients need critical monitoring following surgery of abdomen, pelvis and lower extremity. A thrombus formed in the deep vein may produce local inflammatory changes or may migrate to the lung resulting in PE.

The thrombus formation becomes obvious only by the end of a week or 10 days following surgery. Early signs of inflammation are pain, tenderness and warmth over the calf region with a mild rise in the body temperature. The positive sign of DVT is the increase of pain on passive dorsiflexion of the foot (Homans sign).

Treatment: Accurate diagnosis of DVT in the suspected patients is possible with venography or phlebography.

Anticoagulant therapy and aspirin, with graduated elastic stockings, are the effective measures to treat DVT. Embolectomy, by using cardiopulmonary bypass, and heparin followed by oral anticoagulant therapy are the measures to control PE.

Vigorous ankle, foot and toe movements, elastic stockings, ambulation at the earliest, mechanical electrical stimulation of the calf muscle during surgery and special boots to

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accelerate venous return which produce intermittent pressure on the limb could be helpful in the prevention of these complications. Therefore, active vigorous movements of toes with limb elevation, whenever possible, should be concentrated throughout the period of two weeks following surgery as an effective preventive measure.

4. ***PE***

The signs of PE:

- Central chest pain or pleuritic pain
- Severe breathlessness, haemoptysis or cyanosis. Pulmonary angiography or scan can confirm the diagnosis of PE

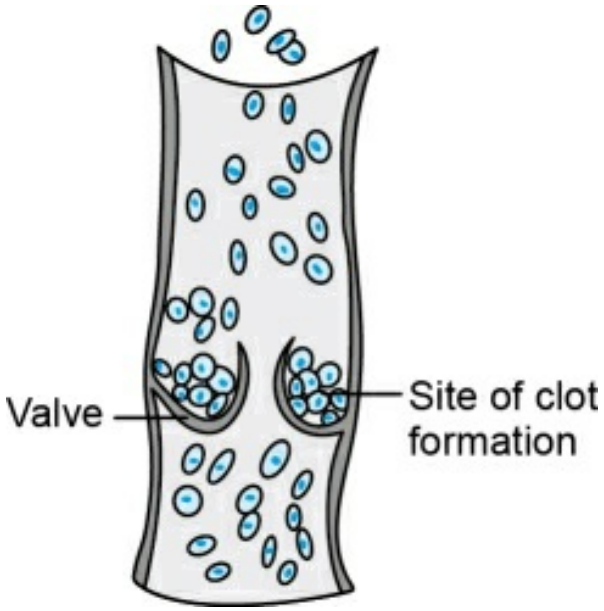

FIG. 1-7 Deep vein thrombosis (DVT) (longitudinal section of a vein): development site of DVT inside the vein..

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Physiotherapeutic management

1. ***Preoperative guidance and training***

After evaluation and planning of a type of surgical procedure, the physiotherapist must apprise the patient about the detrimental effects of general anaesthesia.

The patient should be made aware of the procedures to minimize the ensuing complications during immediate and late postoperative phases. Ideally, sessions on sequentially progressive postsurgical therapeutic regime should be taught during this preoperative period.

2. ***Postoperative physiotherapeutic management***

The basic function of physiotherapy is firstly to improve breathing control by training of normal tidal breathing, making it relaxed and least exerting, and secondly, to eliminate postsurgical secretions. This is achieved by (a) positioning of the patient and (b) teaching and practising active cycle of breathing techniques (ACBT).

(a) **Positioning of the patient:** To increase FRC as well as preventing lung collapse, upright erect posture should be assumed as early as feasible. The ambulation is resumed at the earliest possible opportunity; it could be assisted and well supported.

(b) **Breathing techniques:** The basic techniques of chest physiotherapy are known as the ACBT.

Components of ACBT are (a) breathing control or normal

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relaxed breathing, (b) thoracic expansion technique or inspiratory control technique and (c) forced expiration technique or expiratory control technique.

(a) **Breathing control technique:** It is a technique of relaxed, smooth, normal tidal breathing, primarily using the lower chest. Formerly known as *diaphragmatic breathing technique*, it is actually accomplished by the coordinated activity of the abdominals, external and internal oblique muscles, the scalene muscles and the diaphragm.

Advantages

- Improves inspiratory control

- Minimizes the work of breathing

- Helps to relieve breathlessness at rest and on exertion

- Facilitates return of the normal patterns of breathing

- Improves ventilation of the bases of lungs preventing collapse, hyperventilation and fatigue

Technique: The patient is positioned in a relaxed sitting position, with back, head and shoulders fully supported and the abdominal wall fully relaxed. It can be performed even in the high side lying position. Hands are placed on the anterior costal margins. The patient is taught to breathe out as quietly as possible sinking down the lower ribs and the abdomen without any force. It must be remembered that forced or prolonged expiration will increase the work

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of breathing and may even increase air flow obstruction.

This is followed by a gentle, active phase of deep inspiration through the nose. Passage of air through the nose allows the air to be warm, humidified and filtered before it reaches the upper airway. During this phase of inspiration, the abdomen should bulge out to its fullest extent. A careful watch is needed to ensure that the upper chest and the accessory muscles (e.g. sternomastoid, trapezius) are not over-used as this may result in early fatigue due to increased oxygen consumption caused by the excessive work of the accessory muscles of respiration.

(b) **Thoracic expansion technique or inspiratory control technique:** It is a technique of deep breathing with effort and emphasis on active inspiration as against relaxed effortless techniques of breathing control.

Advantages

- Assists in losing of excessive bronchial secretions

- Facilitates the movement of secretions

- Assists in the re-expansion of the lung tissue

- Improves lung volume and mobilizes the thoracic cage, promoting air flow through the collateral ventilatory channels, thus getting air exactly behind bronchial secretions

- Improves ventilation–perfusion relationship

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- Prevents collapse of the lung tissue

Technique: After deep inspiration with maximum expansion of the thoracic cage, air is held for 3 s like in *pranayama* (Chapter 38). This is followed by relaxed passive expiration. As it is a tiring procedure, there should be a pause for relaxation after four to five deep breaths. The patient may feel dizzy owing to hyperventilation. Ideally, every four to five expansion exercises should be followed by a pause for relaxation by repeating the breathing control technique.

This technique can be performed in half-lying position with the knees slightly flexed over a pillow or sitting on an upright chair or stool.

This technique is specially important during early postoperative phase to prevent lung collapse, facilitate mobilization of secretions and decrease atelectasis (Ward, Danziger, Bonica, Allen & Bowes, 1966). The clearance of secretions can be facilitated further by performing the technique in an appropriate postural drainage position (Table 1-19). Whenever feasible, chest clapping, shaking and vibrations may be incorporated for more effective drainage of the secretions.

The manoeuvres of chest clapping, shaking and vibrations are contraindicated or done very carefully in patients with the following:

- Osteoporosis of ribs

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- Metastatic deposits affecting the ribs or vertebral column
- Haemoptysis
- Acute pleuritic pain
- Active pulmonary infections (e.g., tuberculosis)

Contraindications for postural drainage:

- Recent severe haemoptysis
- Hypertension
- Cerebral oedema
- Aortic and cerebral aneurysms
- Acute asthma, emphysema, or dyspnoea

(c) **Forced expiration technique or expiratory control technique:** Excessive bronchial secretions are eliminated by this technique of forceful expiration. It is a combination of one or two forceful expirations (huffs or coughs) followed by intermittent periods of breathing control to prevent possible occurrence or sudden increase in the bronchial spasm. The important part of the clearance mechanism by huff or cough is the narrowing, dynamic compression and collapse of the airways towards the mouth (West, 1992). The technique may incorporate chest percussion and/or vibratory chest shaking.

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To mobilize and clear peripheral secretions, huffing or coughing is initiated from the mid-lung volume, i.e., following a medium-size inspiration. Air is squeezed out forcefully by using the abdominal and chest wall with the mouth open. However, it should be longer to reach and loosen the secretions from the peripheral airways.

To clear the secretions that have already reached to the more proximal airways, huffing or coughing has to be initiated from the high lung volume, i.e., following full deep inspiration.

A rapid flow of secretions results when a forced expiratory effort is made with coughing against a closed glottis which raises intrathoracic pressure. Then, when the glottis opens abruptly there occurs a large pressure gradiant between the alveolar pressure and the upper tracheal pressure, resulting in rapid flow of secretions. To produce a huff, a forced expiratory effort is made with the glottis remaining open. This compresses the intrathoracic trachea and bronchi, dislodging and moving the mucus up the bronchial tree.

Technique: To produce effective elimination of secretions by huff or cough, it is mandatory to take a deep breath before coughing. Strong contractions in the abdominal muscles are needed to produce effective cough. A single continuous huff down the same lung volume or a series of huffs and coughs without intermittent inspirations could be used.

After one or two huffs or coughs there should be a pause of varying durations of 5–20 s for relaxation or relaxed

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breathing (breathing control). Gravity-assisted postural drainage positions may be valuable in patients with excessive secretions (Hofmyer, Webber & Hodson, 1986).

Modifications in the ACBT: Although ACBT constitutes (a) breathing control, (b) thoracic expansion and (c) forced expiration techniques, this sequence may not always be adequate if the secretions are not lost enough to be eliminated. In such a situation, it may become necessary to perform additional or more than one manoeuvre of thoracic expansion technique (Fig. 1-8). It must be remembered to add breathing control techniques in between thoracic expansion and forced expiration technique.

Reassessment and revision of breathing techniques for evaluation of its efficacy and to maintain patient's compliance are necessary at regular intervals.

ACBT done in gravity-assisted positions is also an alternative method of clearing secretions, and can be safely used if the ACBT is not productive.

If the cause of reduced lung volume is atelectasis or lobar collapse due to retained secretions, the patient may fail to respond to ACBT. It may be necessary to adopt measures like antibiotics, oxygen therapy or mechanical adjuncts like periodic continuous positive airway pressure (PCPAP), intermittent positive pressure breathing (IPPB) or positive expiratory pressure (PEP) mask. Incentive spirometry may be considered along with the ACBT in gravity-assisted positions.

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3. ***Postoperative pain***

1. Adequate doses of analgesics should be given to control pain and its effects on respiratory efficiency. If not successful, inhalation of Entonox (mixture of nitrous oxide and oxygen in equal amounts) in sitting posture with manual hyperinflation or IPPB. It facilitates ACBT.

2. TENS: Low-intensity, high-frequency transcutaneous electric nerve stimulation (TENS) inhibits transmission of pain via small diameter nociceptive fibres, through the activation of large diameter A fibres (e.g., pain following fracture of ribs).

3. Passive movements to the joints away from the immobilized joints can also be used to provide pain relief.

4. Relaxation techniques and relaxing postures like *Shavasana* or TM may also help in reducing the intensity of pain.

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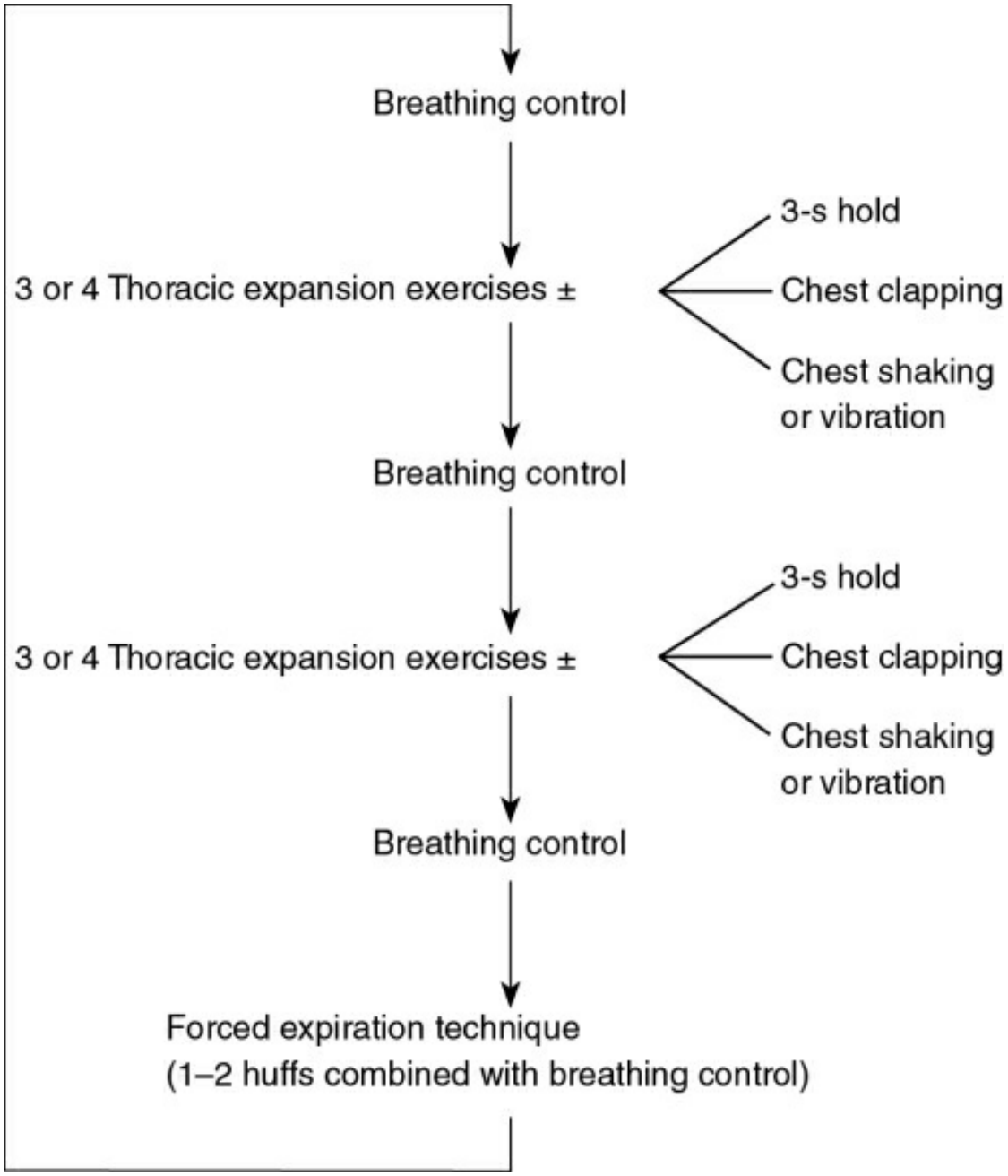

FIG. 1-8 Active cycle of breathing techniques.

Table 1-19
Gravity-Assisted Postural Drainage Positions

Lobe			Position	
Upper lobe	1, 2	Apical bronchus,	1	Sitting upright

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		Posterior bronchus		
	(a)	Right	2(a)	Lying on the left side horizontally, turned 45° on to the face, resting against a pillow, with another supporting the head
	(b)	Left	2(b)	Lying on the right side, turned 45° on to the face, with three pillows arranged to lift the shoulders 30 cm (12 inches) from the horizontal
Lingula	3	Anterior bronchus	3	Lying supine with the knees flexed
	4	Superior bronchus	4 and 5	Lying supine with the body one quarter turned to the right maintained by a pillow under the left side from shoulder to hip
	5	Inferior bronchus		The chest is tilted downwards to an angle of 15°; foot end of the bed raised to 35 cm (14 inches)
Middle lobe	4	Lateral bronchus	4 and 5	Lying supine with the body one quarter turned to the left maintained by a pillow under the right side from shoulder to hip
	5	Medial bronchus		The chest is tilted downwards to an angle 15°; foot end of the bed raised to 35 cm (14 inches)
Lower lobe	6	Apical bronchus	6	Lying prone with a pillow under the abdomen
	7	Medial basal (cardiac) bronchus	7	Lying on the right side with the chest tilted downwards to an angle of 20°; foot end of the bed raised to 45 cm (18 inches)
	8	Anterior basal bronchus	8	Lying supine with the knees flexed, buttocks resting on a pillow and the chest tilted downwards to an angle of 20°; foot end of the bed raised to 45 cm (18 inches)
	9	Lateral basal bronchus	9	Lying on the opposite side with pillow under the hips, the chest tilted downwards to an angle 20°; foot end of the bed raised to 45 cm (18 inches)
	10	Posterior basal bronchus	10	Lying prone with a pillow under the hips and chest tilted downwards to an angle of 20°; foot end of the bed raised to 45 cm (18 inches)

Alternative breathing techniques as adjuncts to chest physiotherapy

1. ***Autoassisted positive pressure breathing or glossopharyngeal breathing (GPB)***

This breathing technique is a form of positive pressure ventilation produced voluntarily by the patient as a 'trick movement'. It is effective in patients who are able to breath spontaneously but who have inadequate power to cough or clear the secretions. The patient gulps down boluses of air into lungs by using mouth, lips, tongue, soft palate,

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pharynx and larynx.

Technique: To begin with, the mouth and the pharynx are filled with air by depressing the cricoid cartilage and the tongue. Then the lips are closed and the air is trapped in the chest by the larynx acting as a valve, when the mouth is opened for the next gulp. Then the floor of the mouth and the cricoid cartilage are raised to the normal position, while the air is pumped through the open larynx into the trachea and soft palate, preventing the leakage of air through the nose. VC can be increased by adding several glossopharangeal gulps. This technique is extremely useful in patients with reduced VC as a result of paralysis of the respiratory muscles, e.g., tetraplegics, poliomyelitis.

2. ***Autogenic technique of draining secretions***

In this technique, the drainage of secretions is achieved by the following three phases by maximizing the air flow within the airways:

Phase I – unstick: A phase of getting adherent secretions mobilized or released by breathing at the low lung volume.

Phase II – collect: A phase of collecting together the mucus secretions in the middle airways by tidal breathing.

Phase III – evacuate: A final phase of evacuation of the secretions collected in the middle airways by breathing at higher lung volume. Coughing or huffing can be incorporated to improve drainage. Alternatively, it can be practised by breathing around the tidal volume and

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holding the breath for 2–3 s at each inspiration followed by forceful expiration

3. ***Manual hyperinflation***

Mobilization and clearance of excessive secretions can be assisted along with reinflation of the areas of lung collapse in intubated patients by this technique.

Technique: This is done by using a hyperinflation bag. The bag is connected to the endotrachial or tracheostomy tube. It is squeezed to inflate the lungs with a slow but deep inspiration. At full inspiration, after a brief pause, brief and quick chest compressions are applied and the bag is quickly released to attain high expiratory flow rate. Suction is applied following six to eight breaths and, if possible, the patient is encouraged to attempt coughing. When the respiratory muscles are paralysed, besides manual hyperinflation, rib springing is more effective. Manual pressure is given through the phase of expiration and it is maximized at the end of expiration to squeeze out residual air. Then the pressure is released quickly to allow optimal expansion during inspiration.

4. ***Respiratory muscle training***

The procedure is aimed to improve the strength and endurance of respiratory muscles. The patient is trained to perform resistive respiration through special devices, keeping the breathing frequency, tidal volume and inspiratory or expiratory time constant. By adjusting the degree of resistance and length of time, strength as well as

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endurance of the respiratory muscles can be improved. The efficacy of the procedure can be judged by evaluating maximal inspiratory mouth pressure ($P_{i\ max}$) and maximal expiratory mouth pressure ($P_{e\ max}$). This type of training is extremely useful in respiratory muscle paralysis following cervical or high thoracic spinal injuries.

5. ***PEP device***

(a) *Mask device:* Flak in 1984 devised a mask and reported a better sputum yield by PEP on peripheral airways and collateral channels in postoperative patients. Either low-pressure (10–20 cm H_2O) or high-pressure (50–120 cm H_2O) PEP may be used depending upon the degree of adherence of the secretions. The device uses a face mask with a one-way valve to which expiratory resistance can be applied.

(b) *Flutter device:* It is a simple portable device like a dry spirometer with a blowing pipe with a series of small openings at the top of the bowl. A small density ball-bearing is enclosed in a small cone in the bowl. Following full inspiration and a hold of 2- to 3-s, air is slowly but completely blown with lips sealed around the mouth piece creating PEP. It improves lung function, oxygenation and expectoration of bronchial secretions (C. Liardet and S.A.Vario Raw, Switzerland, Personal communication, 1990).

6. ***Intermittent Positive Pressure Breathing (IPPB)***

This technique is aimed at the maintenance of positive airway pressure through the phase of inspiration. Thus, the

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airway pressure returns to atmospheric pressure during expiration. It reduces the work of breathing during inspiration and augments tidal volume. It helps in clearing bronchial secretions in semicomatose, neuromuscular disease patients or patients with chest infection.

7. ***Continuous positive airway pressure (CPAP)***

This technique maintains positive pressure through both the phases, inspiration and expiration. This is possible only when the patient's inspiratory flow rate always remains at a higher level. (CPAP is produced by using a high flow generator device with mouth piece and nose clip or a mask. It reduces the work of breathing and improves functional residual capacity (FRC).)

8. ***Incentive spirometry***

It is a simple mechanical device where the patient breathes in slow and deep to a preset volume, and then holds the breath for 2–3 s at full inspiration, with emphasis on the expansion of the lower chest. This device assists greatly in the prevention of postoperative pulmonary complications. It prevents lung collapse by increasing ventilation to the dependant parts of the lung.

9. ***Drug inhalers***

Various handy devices are available for effective inhalation of drugs. A correct technique is necessary to make inhalation reach the bronchi effectively.

After expiration, putting the inhaler in the mouth, the drug

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should be released with slow and deep inspiration lasting to the count of 30 or approximately 10 s. A nebulizer which breaks solution to be inhaled into droplets, suspended in a gas, is a better device. Bronchodilators, corticosteroids, antibiotics and analgesic drugs can be effectively inhaled by this method. Use of mucolytic agents like hypertonic saline (3–7%), when inhaled before physiotherapy, has been found to be effective in the clearance of secretions.

10. ***Humidification***

It may become necessary to use humidification when airway humidification or mucociliary escalator does not function (e.g., endotracheal on tracheostomy tube insertion). Various types of humidifiers are available. The choice depends upon the purpose. Ultrasonic humidifiers are ideal; being an irritant, these promote coughing.

11. ***Oxygen therapy***

Impairment of tissue oxygenation needs extra oxygen during inspiration. It has to be monitored carefully by recording oxygen saturation or blood gas analysis. Oxygen therapy may be administered by a fixed performance device exceeding the patient's inspiratory flow rate, or by a variable performance device, where the oxygen flow is less than the patient's minute volume.

The IPPB device and nebulizers are many a times powered by compressed oxygen, oxygen being used as a driving gas. Portable oxygen cylinders may be used for improving the ambulatory status during SMD test or training to

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improve breathlessness.

Caution

Critical assessment and careful monitoring of the efficacy of alternative techniques as well as adjuncts used to facilitate chest physiotherapy is a must before deciding on any therapeutic technique on an individual basis.

Cardiopulmonary resuscitation or abc of life support

A recent WHO statement that the lives of over 50% of patients following acute myocardial infarction could have been saved if instantaneous application of resuscitation speaks volumes of its importance. Therefore, it is a must-know not only for clinicians but also for each and every individual.

It is a simple manual technique which can be performed in any cardiopulmonary emergency.

Indications for CPR

- Violent orthopaedic polytrauma
- Drowning
- Electric shock
- Drug intoxication
- Suffocation

Early identification

Unconsciousness

Severe hypoxia of brain leads to unconsciousness. It rapidly spreads to the myocardium resulting into spontaneous heart failure.

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Therefore, quick restoration of airways (A), breathing (B) and circulation (C) (or ABC of life support) is the immediate priority to save life.

Identify the system failure

First identify the system failure; is it a respiratory failure, a circulatory failure, or a failure of both?

Respiratory failure can be identified by feeling for the breath at the nostrils and normal up and down movement of the ribcage, whereas circulatory failure can be identified by the absence of the central carotid/radial pulse.

Basic principles of CPR

1. To restore average normal rate of breathing of 8–12 ventilations/min (or one ventilation for every 5 s), done by direct blowing of air into the victim's mouth.

2. To restore circulation, manual rhythmic chest or myocardial compressions are given at the average normal heart rate of 60 beats/min (or one compression every minute).

Methodology of CPR

Airway clearance: Roll the victim on the back (supine) on a hard flat surface.

- Clearance of airways that may be obstructed due to the accumulation of saliva and other exudates.

- Open the airways to the maximum by giving well supported head tilt position (sometimes positioning and clearance itself may restore spontaneous respiration).

Breathing (Fig. 1-9):

- Maintaining head in a backward tilted position, block both

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the nostrils with index finger and the thumb and open the victim's mouth by using 'jaw thrust'.

- Take full-deep breath.
- Quickly seal the victim's open mouth with your mouth and forcefully blow air into the victim's mouth.
- Now remove mouth, allowing the victim to breath out passively, listening carefully and feeling for the exhaled air.
- The slow up and down chest movement is an indicator of effective ventilation.

(A)

(B)

STEPS

- Maintain victim's head tilted downwards to open up the airway.
- Open up the jaw of the victim.
- Take a deep breath.
- Block the victim's nostrils.
- Seal victim's mouth completely by your own mouth.
- Forcefully blow air into the victim's open mouth (A).

CONFIRMATION

- Remove the mouth.
- Quickly turn your head and carefully listen or feel for the air being exhaled by the victim (B).
- Keeping watch on the rise and fall of the chest, rhythmic chest movement confirms the restoration of respiration.
- Frequency of ventilation: on average 12 ventilations per minute or 1 ventilation after 5 seconds.
- Seal victim's mouth completely by your own mouth.

NOTE

Alternatively, mouth to nose ventilation can be employed

- When blood, vomitus, or other fluids are blocking the air entry through the mouth
- It is mechanically more acceptable.

FIG. 1-9 (A AND B) Pulmonary resuscitation.

Caution

No attempt is to be made to turn a victim with injury to the cervical spine or fascial fractures to supine head tilting position.

Patients with fascial injuries need removal of blood stain, debris

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and pulling tongue forward before initiating ventilation.

Circulation (Fig. 1-10):

- Keeping the victim in supine position, loosen clothes and bare the chest.
- Identify the centremost notch on the ribcage where the margins of the ribs join (xiphisternal junction).
- Determine a central point on the sternum at about three-finger distance above the tip of the xiphoid.
- Place the heel of one hand at that point.
- Place the other hand exactly above the hand placed earlier, so that the hand and fingers are at right angles to the long axis of the sternum.
- Now position your shoulders exactly above the hands, keeping elbows straight and using the weight of the upper body, conduct smooth but definitive series of chest compressions at the rate of 60 compressions/min (i.e., 1 compression/s). At each compression, the ribcage is pushed downwards with a sudden jerk. There will be an elastic recoil of the rib cage as soon as the force of compression is released instantaneously. Give a slight pause before the next compression. Continue the cycle of compression till the restoration of circulation is evident.
- Each compression results in the ejection of blood from the ventricles (ventricular systole).

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- Momentary pause following each compression results in filling of the blood into ventricles (ventricular diastole).

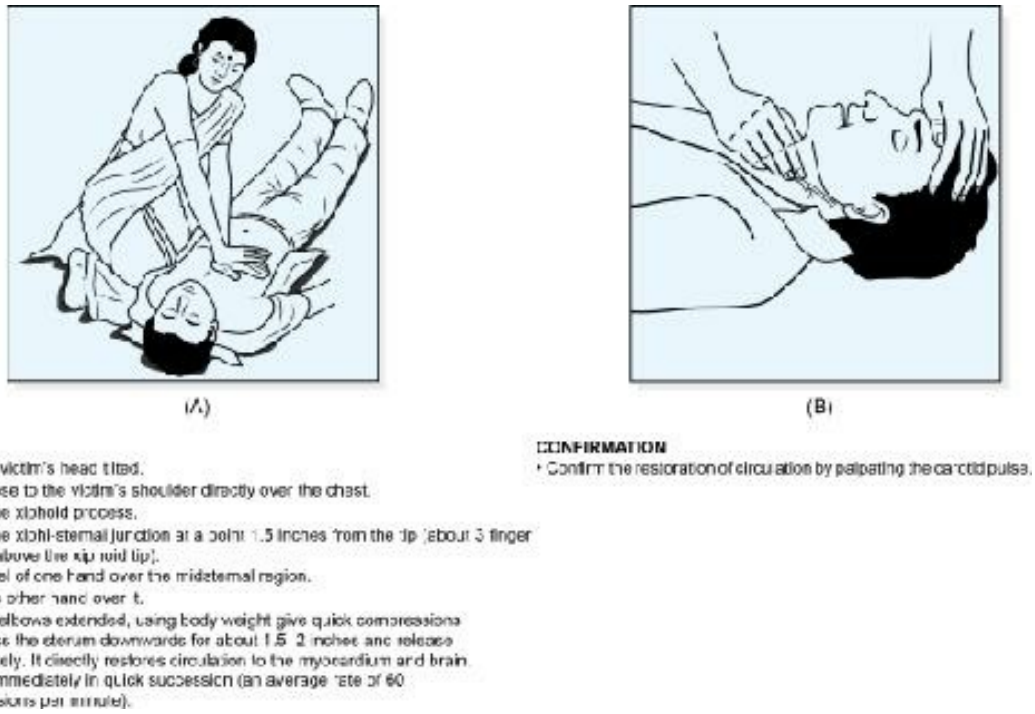

FIG. 1-10 (A AND B) Circulatory resuscitation.

Ensure the restoration of circulation by palpating the carotid pulse following each compression cycle.

Failure of both the systems

In the event of the failure of both the systems, ideally two rescuers should be available to maintain smooth continuity.

However, only a single person has to manage the failure of both the systems by switching on alternately from one system to the other. In such an event, average normal chest compressions of 60 beats/min and an average normal rate of respiration is maintained by 15:2 ratio of chest compressions to lung inflation has to be completed every 15 s by quick switch overs.

Caution

This process of resuscitation once begun should be continued till the

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restoration of the system failure, sometimes even up to the moment the patient reaches the hospital emergency ward.

Tests for the successful application of life supports:

1. The adequacy of cerebral circulation

- Test by pupillary reaction

2. Adequacy of respiration

- Return of the slow up and down movement of the chest (rib cage)

3. Adequacy of circulation

- Return of the central carotid pulse, its volume and rhythm
- CPR in infants and children
- Avoid exaggerated head-tilt
- For artificial ventilation, rescuer's mouth should be covering both the nose and the open mouth
- Smaller breathes needs to be delivered at a faster rate of one every 3 s
- For cardiac arrest, give external cardiac massage.
- For external cardiac compressions, use the heel of only one hand or the index and the middle fingers
- The sternal depressions are smaller: 0.75–1 inch for infants

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and 1–1.5 inches for children

- The rate of chest compression should be faster about 100 beats/min

Precordial Thump (Fig. 1-11)

Precordial thump is performed when a cardiac arrest occurs without hypoxia.

Only one quick and strong hard blow is delivered over the midsternal area by the ulnar aspect of the hand with forearm supinated.

If there is no restoration of heart beats, the conventional method of the cycle of chest compressions is initiated instantly.

Normal and functional range of movements at various joints are depicted in Table 1-20.

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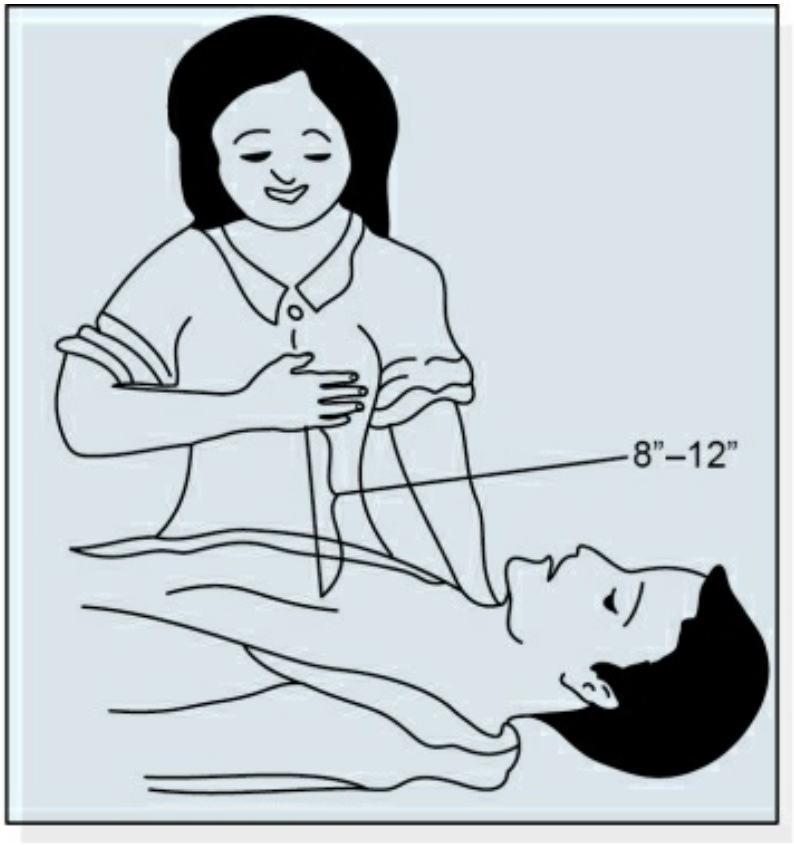

For witnessed cardiac arrest without generalized hypoxia:

- A quick hard blow is given over the midsternum with ulnar aspect of the hand.
- The thump is to be delivered in a straight line from a distance of 8–12 inches from the midsternal area.
- Only one quick and strong thump has to be delivered within ONE MINUTE of cardiac arrest.
- If there is no immediate response BASIC LIFE SUPPORT is initiated instantly.

FIG. 1-11 Precordial thump.

Table 1-20

Normal and Functional Range of Movements at Various Joints (in Degrees)

Joint	Movement	Normal ROM	Functional ROM	Joint	Movement	Normal ROM	Functiona ROM
Hip	Flexion	0–125–130°	90–110°	*Shoulder joint*	Flexion-elevation	0–170–180°	0–120°
	Extension	0–20°	0–5°		Abduction-elevation	0–170–180°	0–120°

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	Abduction	0–45–50°	0–25°		Extension	0–60°	0–30–40°
	Adduction	0–40–45°	0–20°		Abduction (true)	0–90°	0–60–70°
	External rotation	0–45°	0–15°		External rotation (with arm in abduction and elbow flexed to 90°)	0–90–100°	0–45°
	Internal rotation	0–40–45°	0–20°		External rotation with elbow in extension	0–70°	0–30°
Knee	Flexion	0–130–140°	0–110°		Internal rotation with arm in abduction	0–80°	0–45°
	Extension	0	0–5° of terminal extension		Internal rotation with elbow in extension	0–70°	0–45°
Ankle	Dorsiflexion or extension	0–20°	0–10°	*Elbow joint*	Flexion	0–135–140°	0–90°
	Planar flexion or flexion	0–45°	0–20°		Extension	0°	20–30° short of terminal extension
	Inversion	0–35°	0–25°	*Forearm*	Supination	0–80–90°	0–50°
	Eversion	0–10°	0–10°		Pronation	0–80–90°	0–50°
Toes				*Wrist joint*	Flexion	0–75°	0–50°
Metatarsophalangeal joints	Flexion	0–30–35°	0–10°		Extension	0–70–75°	0–30°
	Extension	0–70°	0–60–65°		Radial deviation	0–20°	0–10°
Interphalangeal joints	Flexion	0–50–80°	0–10°		Ulnar deviation	0–35–40°	0–15°
	Extension	0–80°	0–60–65° [a]	*Finger joints*	Flexion (MCPs)	0–90°	0–5°
Cervical spine	Flexion	0–50–55°			(PIPs)	0–100°	0–7°
	Extension	0–70°			(DIPs)	0–70°	0–8°
	Lateral flexion or flexion to either sides	0–45°		*Thumb*			
	Rotation to either sides	0–80–85°		CM joint	Extension	0–45–50°	0–50
Thoracolumbar spine	Flexion	0–60°			Abduction	0–70°	0–50°
	Extension	0–35–40°		MP joint	Flexion	0–70–80°	0–50°
	Lateral or side flexion to either side	0–25–30°		IP joint	Flexion	0–70–80°	0–20° short of full extension
	Rotation to either side	0–20–25°					

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Abbreviations: DIP, distal interphalangeal; MCP, metacarpophalangeal; PIP, proximal interphalangeal.

[a]Joshi and Gopinath (1991).

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CHAPTER 2

The bones and the joints

OUTLINE

- Human skeleton
- Structural and microscopic composition of a bone
- Development and growth of a long bone
- General structure of a long bone
- Blood supply to a long bone
- Joints
- Broad classification of joints

Bone is a highly specialized tissue designed to perform multiple vital functions of the body. Some of them are as follows:

- It gives shape to the body in the form of the human skeleton
- It gives protection to the body's vital organ systems by forming compact cavities (e.g., chest cavity protecting the heart and the lungs)
- It forms a major organ of our life, i.e., movement through systematic arrangement of the joints and muscular attachments
- It serves as a storehouse for important nutrients and minerals (e.g.,

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99% of the body's calcium is stored in the bones) required to maintain the perfectly balanced metabolism of our body

- The body's defence in the form of WBCs and platelets are also produced in the bone marrow.

- Although it appears to be an inactive solid mass, bone factually is a very active tissue, e.g., immediately following a fracture, the activity of bone formation begins at the fractured bony ends. Therefore, fracture reduction and achieving a correct anatomical alignment of the fractured bony ends must be done as early as possible.

Human skeleton

The systematic and schematic arrangement of bones of various shapes and sizes forming the basic structure of the body is known as the *skeleton* (Fig. 2-1).

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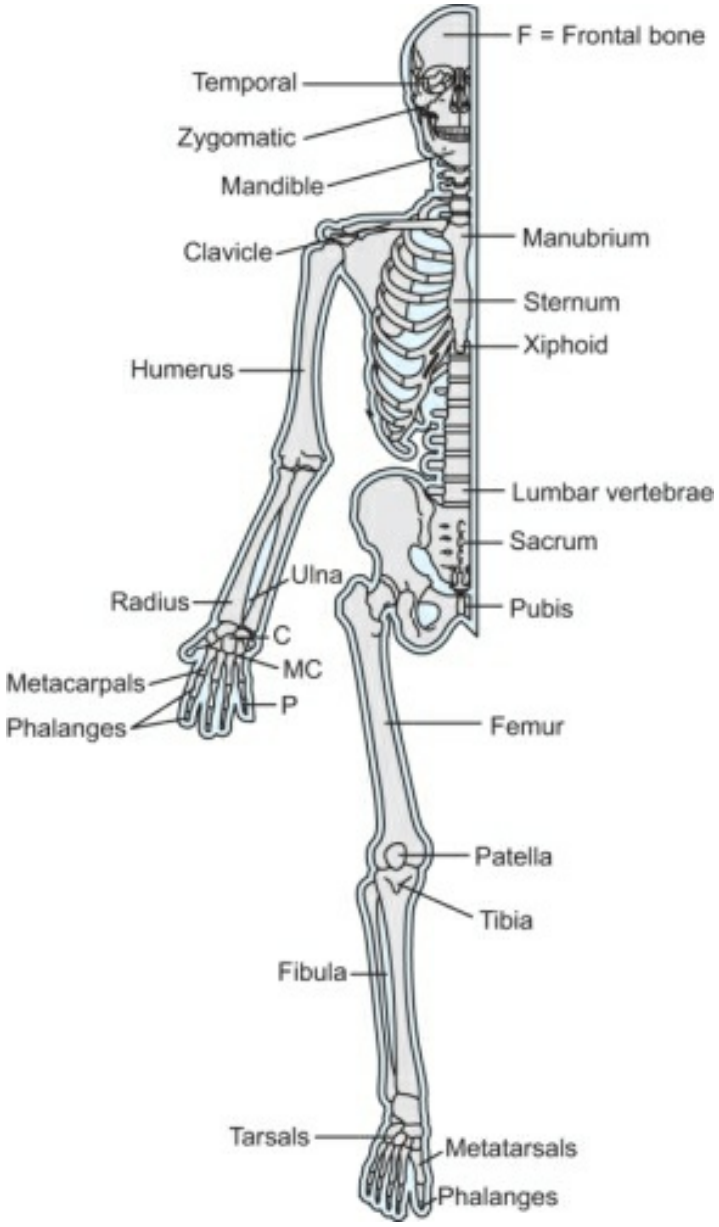

FIG. 2-1 Human skeleton.

The bones and the joints in a human skeleton are so organized that they provide the basic stability to the body to facilitate the required functional mobility.

The stability to the body is provided by the girdles and the functional mobility is provided through the limbs and their joints.

The skeleton is composed of 206 bones and is categorized into two basic types:

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1. *Axial skeleton* – It is composed of 80 bones and forms the upright axis of the whole body.

2. *Appendicular skeleton* – It is composed of 126 bones which mainly include both the shoulder and the hip girdles and the long bones of both the upper and lower extremities (Table 2-1).

Table 2-1
Bones in the Axial and Appendicular Skeleton

Axial Skeleton	Number	Appendicular or Skeleton	Number
• Skull		• Shoulder girdle	
• Cranium • Face	8 14	• Clavicle • Scapula	2 2
• Vertebral column		• Upper extremity	
• Cervical vertebrae • Thoracic vertebrae • Lumbar vertebrae • Sacrum [a] • Coccyx [b]	7 12 5 1 1	• Humerus • Radius • Ulna • Carpals • Metacarpals • Phalanges	2 2 2 16 10 28
• Sternum • Manubrium • Body • Xiphoid process	1 1 1	• Hip girdle • Os coxa	2
• Ribs	12 pairs		
• Hyoid	1	• Lower extremity	
• Ear ossicles • Malleus • Incus • Stapes	2 2 2	• Femur • Tibia • Fibula • Patella • Tarsals • Metatarsals • Phalanges	2 2 2 2 14 10 28
Total	80		206

[a]Sacrum is composed of 5 fused bones.

[b]Coccyx is composed of 3–5 fused bones.

Types of bones

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The 206 bones of the human skeleton are shaped and sized according to their functions.

1. **The long bones (e.g., femur, tibia):** These serve as levers to facilitate muscular action.

2. **Short bones:** These are generally found where only limited movements are required. Mainly, these bones provide strength and stability to the strong muscular action by providing a stable base (e.g., carpal bones).

3. **Flat bones:** These are composed of a thin layer of cancellous bone covered on both the sides by a parallel layer of compact bones, (e.g., skull, scapula, pelvic bones). The scapula provides free but stable mobility to the shoulder and arm, whereas the skull and the pelvis protect vital soft organ systems.

4. **Irregular bones:** These are irregular in shape with small bony appendages, e.g., vertebrae. These bones provide stable flexibility to the trunk while protecting the spinal cord.

5. **Sesamoid bones:** These are small rounded or triangular bones which develop in the substance of a tendon or fascia to protect and facilitate muscular action, e.g., patella – a typical resemblance to the 'sesame seed'.

Structural and microscopic composition of a bone

A bone consists of two major portions: cortex and medulla.

Cortex

Cortex is the outermost hard layer giving shape, strength and protection from injury. It has a smoother covering layer (periosteal layer) which also gives attachment to muscles, tendons and ligaments. It allows remodelling of the bone throughout the life.

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Medulla

Medulla is the softer inner lining of the bone with a cavity within it (medullary cavity). Medulla is a storehouse of important minerals, calcium and a major seat where the RBCs and WBCs originate.

Microscopic composition of bone

The structural unit of a lamellar bone is Osteon, which consists of a series of concentric laminations surrounding the central longitudinal Haversian canal which contains a nutrient artery supplying blood to the bone.

Bone cells

There are three types of bone cells:

1. Osteoblasts – bone forming cells

2. Osteoclasts – bone resorbing cells

3. Osteocytes – resting cells which can act as both osteoblasts and osteoclasts as per the need

Microscopically, bone is classified as follows:

- Woven – It is an immature bone where the cells and the collagen are arranged in a random pattern. It is found during the initial stage of bone formation after fracture – when the bone is in the process of formation.

- Lamellar – The bone is in a fully matured stage where the cellular distribution is set in an orderly fashion and the collagen fibres are also properly oriented. The dense arrangement of lamellae is present in the cortical bone, whereas the lamellae are arranged loosely in a cancellous bone.

Development and growth of a long bone

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The development and growth of a long bone (except clavicle) begins during the intrauterine period (Fig. 2-2) and continues to the period of skeletal maturity (around the age of 16–18 years).

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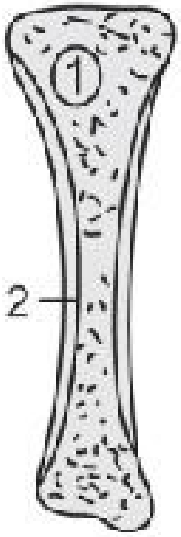

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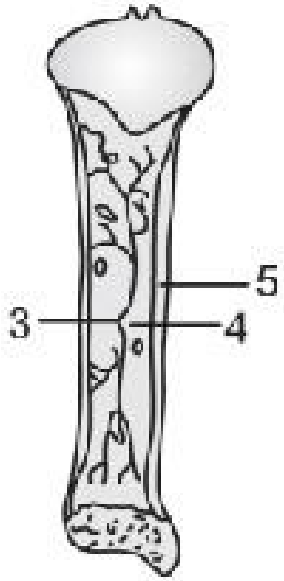

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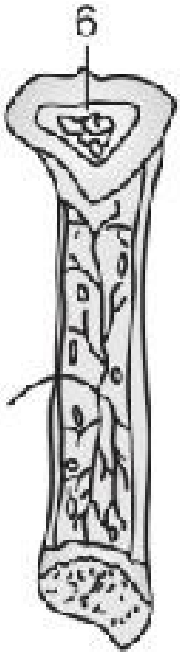

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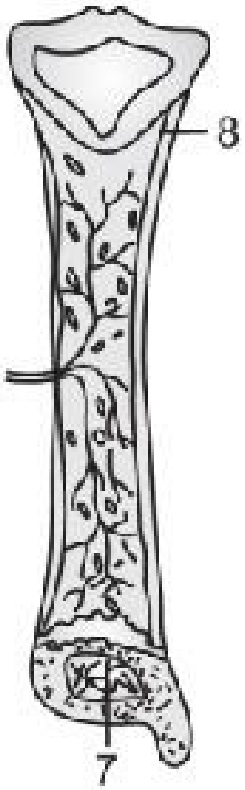

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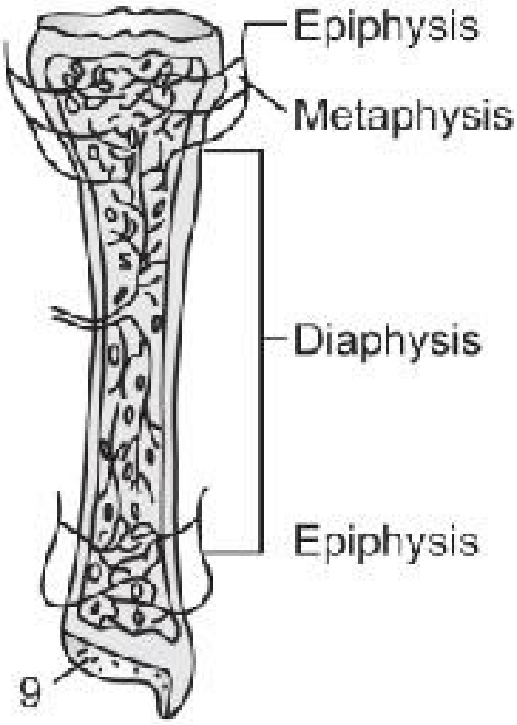

(E)

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FIG. 2-2 Development of a long bone from beginning to maturity. Events in the formation of a long bone: Hyaline cartilage template. (1) Appearance of pericondrium bone collar followed by calcification of the walls. (2) Appearance of capillaries and primary centre of ossification. (3) Nutrient vessel entering the middle of the bone (diaphysis). (4) Perichondrium is converted into periosteum. (5) Appearance of secondary centre of ossification. (6) With osteoid formation and ossification of the shaft, secondary centre of ossification is formed at the distal end. (7) Full ossification of the epiphysis and diaphysis occurs which are separated by epiphyseal plates (cartilage). (8) Finally, the epiphyseal plates are replaced by bone indicating full maturity with articular cartilages and cancellous bone at both proximal and distal ends. (9) A compact bone at the shaft.

Events in the development and growth of a bone

1. Development of the cartilaginous model

2. Ossification of the cartilaginous model to bone

Development of a cartilaginous model

The bone begins to develop during the embryonic life from cartilaginous primordia (enchondral ossification) by the process of condensation of the mesenchyme – as hyaline cartilage surrounded by pericondrium.

Ossification of a cartilaginous model to bone

Around the fifth week of the intrauterine period, the ossification begins by the appearance of the primary centre of ossification (PCO) at the middle of the bone, when it is invaded by capillaries. The pericondrium is converted to periosteum and the osteoid is produced around the shaft. The shaft begins to grow longitudinally by the resorption of the inner surface.

During the late fetal stage or early childhood, two secondary centres of ossification (SCO) appear (the epiphyses). The first SCO appears at the upper epiphysis followed by the second SCO at the lower epiphysis.

Both the SCOs are responsible for the radial growth of a bone. The

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consolidation and thickening of the periosteum occurs by the process of subperiosteal new bone deposition. The SCOs are also called *apophysis* (e.g., apophysis of the greater trochanter).

As the bone approaches adult size, the diaphysis and epiphyses are gradually ossified fully, but are still separated by epiphyseal plates (cartilage).

As the epiphyseal plates cease to grow, the longitudinal growth of a bone stops. At the end of the growth period of a bone, the epiphysis fuses with the diaphysis leaving a definite area of hyaline layer at the articular surface of a bone.

Remodelling of bone

Throughout the lifespan, the bone has an ability for remodelling. A variety of alterations in the size, shape and structure appear in a fully matured healthy bone. This remodelling occurs as a result of its hypertrophy as a response to stress. Bone hypertrophy occurs in the plane of a stress.

Note: The time and the sequence of the appearance, and the fusion of epiphysis have a great clinical relevance:

- In differentiating an epiphyseal plate from a fracture.
- In confirming a true bone-age of a person.

General structure of a long bone (fig. 2-2e)

Epiphysis

In growing children, the long bone consists of two ends known as *epiphysis*. It forms a support for the joint surface. It is susceptible to developmental problems (epiphyseal dysplasia), degenerative changes, injury and avascular necrosis due to ischaemia.

Diaphysis

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A large part of the long bone or shaft constitutes diaphysis. It is made up of strong cortical bone but due to mechanical disadvantage, it always remains susceptible to fracture with angulation. The process of healing is slow as compared to metaphysis. It may develop dysplasias or infection.

Metaphysis

The portion of the bone adjacent to each epiphysis is known as metaphysis. It is made up of cancellous bone where the process of healing is fast. It is susceptible to bone infection, dysplasia and tumours.

Growth plate

There is a thin plate of growth cartilage, one at each end called 'growth plate'. At the time of maturity, this growth plate fuses with metaphysis. The articular surfaces of the epiphyses are covered with an articular cartilage. The rest of the bone is covered with periosteum which provides attachment to tendons, ligaments and muscles. Although mechanically weak, it helps in longitudinal growth of a bone.

It is susceptible to injury or slipping (slipped femoral epiphysis), tumour and osteomyelitis. It is also susceptible to growth arrest as well as deformed growth.

Note: Bone has the ability for remodelling or changing its shape in response to stress.

Blood supply to a long bone

The blood supply to the long bone is derived from four vessels (Fig. 2-3).

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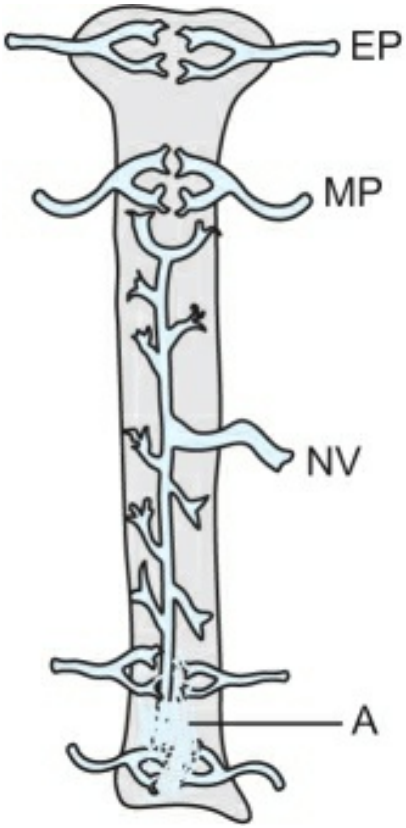

FIG. 2-3 Blood supply to a long bone: EP: epiphyseal vessels. Directly enter and supply epiphysis. MP: metaphyseal vessels – numerous small vessels derived from the anastomosis around the joint. Piercing metaphysis along the line of joint capsule. NV: major vessel entering the bone around its middle-nutrient vessel. The periosteum of a bone also has a rich blood supply through the small vessels supplying the bone cortex. A: anastomosis.

Metaphyseal vessels

Metaphyseal vessels are numerous small vessels derived from the anastomosis at the joint. They enter the metaphysis along the line of attachment of the joint capsule.

Nutrient artery

The major vessel providing nourishment to the long bone enters the bone around the middle of the shaft and immediately bifurcates running in opposite directions towards the proximal and distal end of the bone as medullary vessels. Then each one further divides into a

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number of parallel vessels towards the respective metaphysis.

Epiphyseal vessels

Epiphyseal vessels enter the epiphysis providing independent nutrition to the epiphysis or epiphyseal site.

Periosteal vessels

The periosteum is richly supplied with blood which it receives from a number of small vessels. These directly enter the bone and supply mainly the cortical area of a bone. These vessels play an important role in the process of the healing of the bone following fracture.

Joints

Joints represent the sites where two bones come together. These are designed on the basis of their function.

Functions of the joint

- To protect vital organs from injury (e.g., brain)
- To provide adequate mobility of the body part to facilitate functional activity (e.g., limbs)
- To provide only restricted mobility to facilitate the function of the internal organs and protect them (e.g., lungs)

Broad classification of joints

Mobile Joints (Synovial)	Partially Mobile Joints (Cartilaginous)	Nonmobile or Fixed Joints (Fibrous)
• Uniaxial	• Synchondrosis	• Syndesmosis
• Biaxial	• Symphysis	• Sutures
• Multiaxial		• Gomphosis

Synovial joints

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Synovial joints are so called because the joint space has a special lining membrane called the *synovial membrane* (Fig. 2-4). It secretes a highly thick oily lubricating fluid. Synovial fluid allows freedom of movement to the joint and also provides nourishment to the articular cartilage. They are of three types:

1. ***Uniaxial synovial joints***

These joints permit movement in only one plane and one axis. They could be the following:

- Hinge joints: Movement taking place around the horizontal axis (e.g., elbow, knee – Fig. 2-5A)

- Pivot joints: Movement taking place around the vertical axis (e.g., atlanto-axial joint, superior radio ulnar joint – Fig. 2-5B)

2. ***Biaxial joints***

In these joints, the movement takes place in two planes and two axes which are at right angles to each other. They are as follows:

- Saddle joint: Like a saddle, the articular surface of the proximal bone end is concave in one direction and convex in the other and that of the other bone forming the joint is exactly opposite or convex to ensure the congruity e.g., carpometa carpal joint of thumb (Fig. 2-5C).

- Condyloid joint: In this type, the oval shaped condyle of one bone fits into an elliptical socket of the other bone, e.g., knee joint (Fig. 2-5D).

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3. ***Multiaxial joints***

In these joints, the axes are two or even more and the movement takes place in three or more planes. It has two varieties:

- Ball and socket joint: These joints are unique as they permit joint movement which are multi-axial and multiplane, in widest and free range. The joint is shaped so that one bone has a ball-shaped head and the other a close fitting concave socket, e.g., hip joint (Fig. 2-5E).

- Gliding joints: These joints allow free gliding movements in all the planes; although the movement of lateral glide has a restricted range, (e.g., the joints between the carpal and tarsal bones (Fig. 2-5F).

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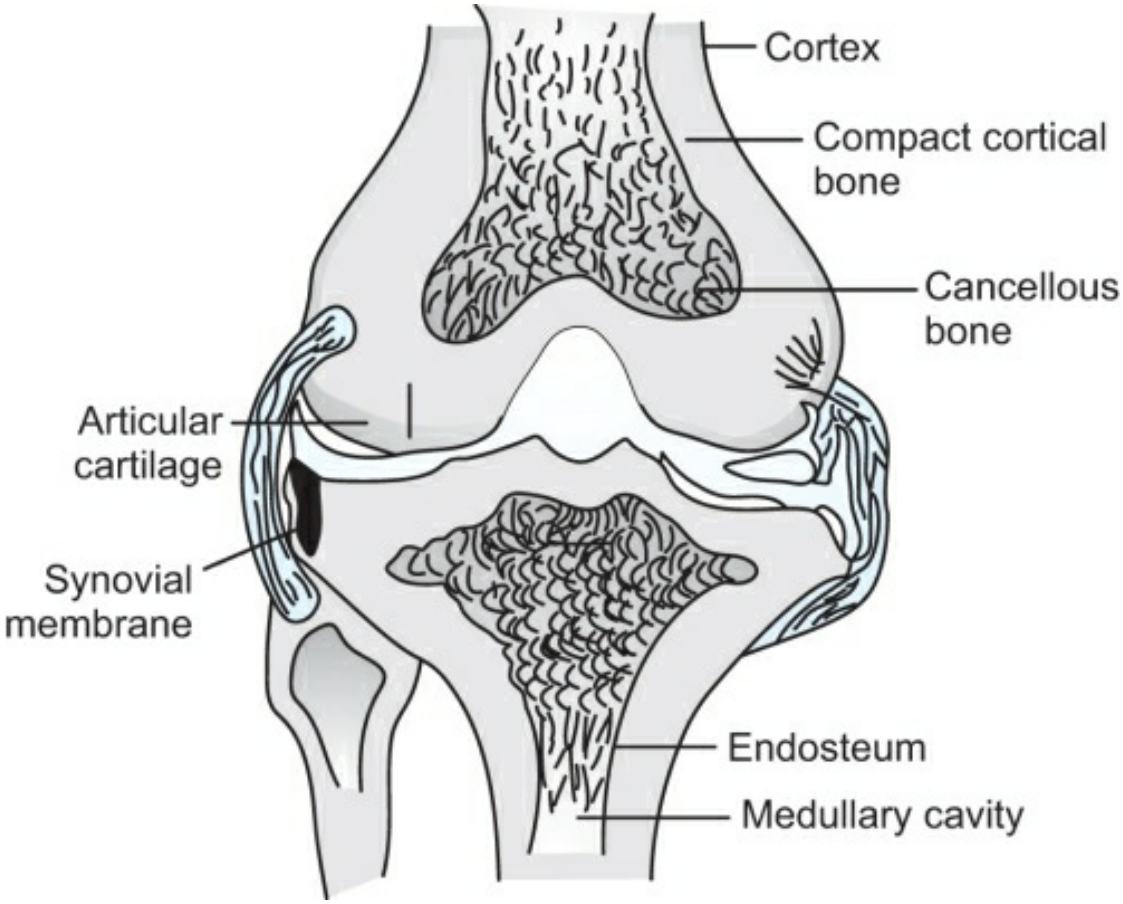

FIG. 2-4 Typical synovial joint (knee).

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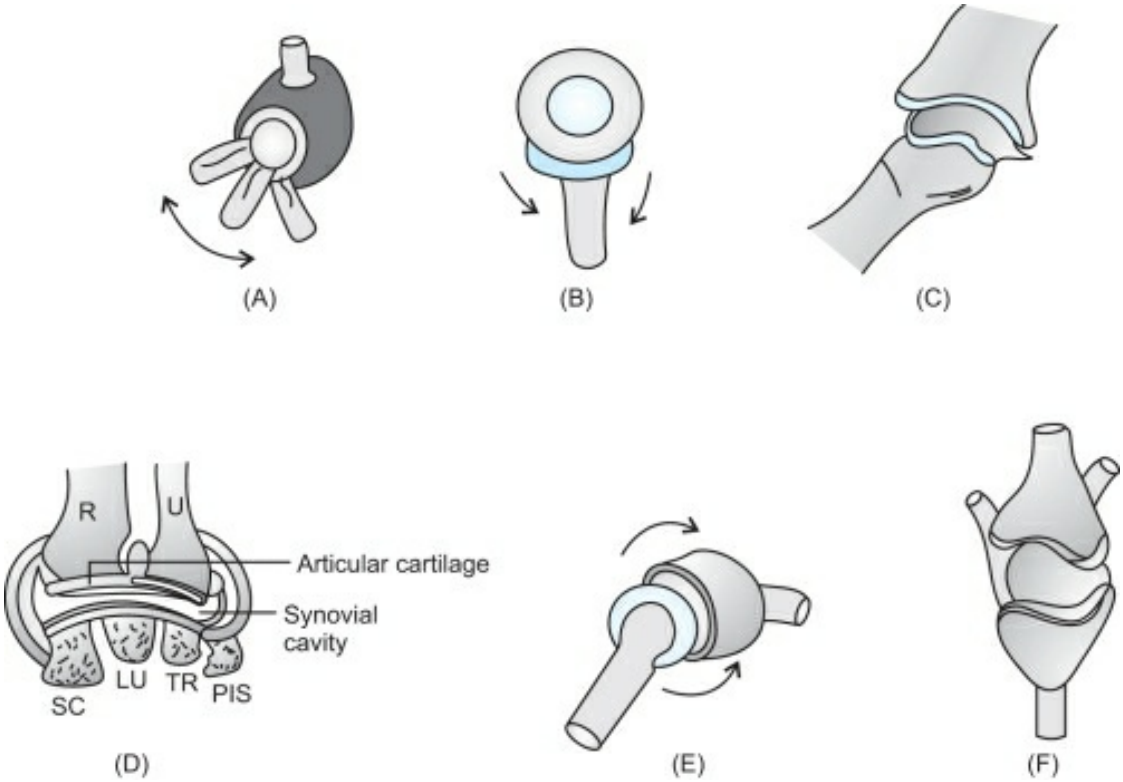

FIG. 2-5 (A–F) Types of synovial joints (diarthrosis). **(A)** Hinge joint (uniaxial – elbow, knee, finger and toe). **(B)** Pivot joint (atlantoaxial joint). **(C)** Saddle joint (carpometacarpal joint of a thumb). **(D)** Condyloid joint (radiocarpal joint of knee). **(E)** Ball and socket joint (hip and shoulder). **(F)** Gliding joint (wrist, ankle and foot).

Cartilaginous joints or amphorthrosis

Cartilaginous joints are partially mobile joints formed by hyaline or fibrocartilage interposed in between the bones forming the joint. These are of two types:

Synchondrosis

In synchondrosis, the hyaline cartilage is interposed between the bones forming the joints, e.g., articulations between rib and sternum.

Symphysis

The fibrocartilage is interposed in between the bones forming the joints, e.g., pubic symphisis at the pelvis.

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Fibrous joints or synarthrosis

Fibrous joints are the joints which are firmly fixed. The articular surfaces of the two bones forming the joint are bound together. These are of three types:

Syndesmosis

The dense fibrous membrane holds tight the articular surfaces of the bones forming the joints, e.g., distal tibiofibular joint.

Sutures

In sutures, the bony margins of the flat bones are firmly fixed to each other, e.g., skull sutures.

Gomphosis

In gomphosis, the conical end of one bone fits and is fixed in the socket of the other, e.g., between the teeth and the sockets of the mandible.

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CHAPTER

3

Inflammation and soft tissue injuries

OUTLINE

- Inflammation
- Soft tissue injury
- Muscle and tendon injury
- Injury to the ligament
- Injury to the synovial membrane
- Injury to the nerve
- Injury to the blood vessel
- Injury to the bursa
- Injuries of the musculotendinous complex
- Rare soft tissue injuries

Inflammation

Inflammation is the reaction of the body tissues to an irritant. The irritant could be traumatic, bacterial, degenerative or even regenerative. During the initial phase, inflammation is very essential as it acts as the chief defence mechanism and promotes healing. Therefore, it often becomes necessary to induce inflammatory reaction to promote the process of repair.

Physiotherapy plays an important role in the treatment of

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inflammation. Properly applied physiotherapy measures facilitate early resolution of inflammation and promote recovery, reducing its ill effects. Therefore, it is necessary to understand the pathology of inflammation, and principles of treatment in the various stages.

The inflammation could be acute, subacute or chronic.The procedures of management vary in all the three stages. The distinguishing features of acute, subacute and chronic inflammation are discussed in the following sections.

Acute inflammation

Signs, symptoms and pathology

The cardinal signs of acute inflammation are listed in Table 3-1.

1. Pain is present over a diffuse area due to pressure on the nerve endings.

2. The pain is present even during rest and is aggravated by activity; it may be referred to other areas from the site of primary inflammation.

3. Skin temperature is raised at the site of the lesion with marked tenderness, effusion, swelling and redness. This occurs due to increased blood flow caused by dilatation of capillaries.

4. There is increased capillary permeability with leakage of protein and plasma. The tissue fluid with high degree of fibrinogen seeps out into the adjacent tissues, giving rise to swelling. Leucocytes migrate from the vessels to the affected tissues to destroy the irritant.

5. Passive range of motion (ROM) may be painful and restricted due to pain and protective spasm in the antagonistic group of muscles. However, there is no real restriction of the ROM.

6. There may be a temporary loss of function of the affected area, depending upon the degree and site of inflammation.

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7. There is usually a history of a recent injury preceding the occurrence of symptoms.

8. There may be a history of earlier episodes of a systemic disease like rheumatoid arthritis.

Table 3-1
Cardinal Signs of Acute Inflammation

• Colour	• Warmth
• Rubor	• Redness
• Tumour	• Swelling
• Dolour	• Pain
• Rigour	• Stiffness
• Functio laesa	• Loss of function

Progress of inflammation

The inflammation thus set in may get completely resolved if the reticuloendothelial cells destroy and ingest the invading organisms. In some infectious diseases, the lymphocytes and plasma proteins may build up antibodies, providing immunity to the patient.

If the organism is virulent or the patient's reticuloendothelial system is poor, the organism may get into the blood stream via the lymphatic system and may precipitate septicaemia.

Repair

Repair may be by the formation of the following:

(a) *Homogenous tissue:* The new tissues are exactly like the original tissues, e.g., bone, fibrous tissue and epidermal structures.

(b) *Scar tissue.* The original tissue is replaced by fibrous tissue during the process of repair, e.g., deep cuts involving the dermis, muscles and nerves. This will naturally result in the reduction of optimal function of that tissue even after repair.

Effects of inflammation on various tissues

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1. *Skin:* Lack of normal blood supply makes the skin dry, papery thin and brittle. It becomes highly prone to infection.

2. *Fibrous tissue:* The fibrous tissue gets thickened and shortened. This results in tightening and contractures ultimately giving rise to deformity.

3. *Muscle tissue:* The lack of oxygen supply and the accumulation of waste products decrease its efficiency, rendering it weak. If the blood supply to the muscle is reduced further, there may be ischaemia or total cessation of blood supply. This may result in fibrosis of the muscle fibres losing their functional properties. The body of a muscle is enclosed in a fibrous tissue. Therefore, inflammation will result in a scar tissue formation which may result in fibrous adhesions. This results in atrophy, restricted activity and weakness.

4. *Nervous tissue:* The nerve fibres may get fibrosed or necrotic directly blocking the muscle activity.

If the inflammatory reaction damages the central nervous system, irreversible degenerative changes occur. This will further complicate the situation as loss of control, coordination, strength and sensations may occur.

5. *Fibrous soft tissues.* The fibrous soft tissue repairs using fibrin. If it is laid in excess, it can also lead to adhesion formation.

6. *Cardiovascular and respiratory systems.* An inflammatory reaction to any of these systems leads to inadequacy of the normal metabolic processes and circulation. This insufficiency can adversely affect any other system and/or the tissues mentioned in Points 1–5.

Management of acute and subacute phase

- Acute stage (first 4–6 days) is also called *a stage of protection.* The main objectives in this stage are:

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1. To protect the inflamed area from further damage

2. To use proper modality to reduce the harmful effects of inflammation

3. To provide guidance and education to the patient on self-care

- Subacute stage (17–21 days) from onset is the stage to educate the patient on the correct methodology on how to initiate controlled mobilization; and also to remain watchful for the signs of progress as well as regress of inflammation.

- The chronic stage of inflammation (21 days onwards) is a stage of the return of full function. It requires properly guided repetitive efforts to achieve preinjury status in all respects, focusing on the deficiencies.

The basic approach of physiotherapy during the acute phase should be a combination of pathology-oriented as well as disability-oriented therapeutic measures.

1. Reduction of the signs and symptoms of inflammation by using the principles of rest, ice, compression and elevation (RICE)

2. Relaxation of the inflamed area as well as the whole body

3. Prevention of further damage and the expected complications

4. Education of a patient on self-care of the injured part; graduated specific exercise programme and transfer or ambulatory activities

5. Maintenance of the ROM and muscle function to the optimal in a pain-free range

6. Guidance to perform safe and gradually progressive functional

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activities

1. **Reduction of signs and symptoms of inflammation:**

(a) *Immobilization*. Selective rest or immobilization of the affected area plays a significant role in the control of inflammation. The period of immobilization has to be just enough to subside inflammation because excessive immobilization is known to produce biochemical, physiological as well as structural changes, resulting in restriction of motion (Saaf, 1950; Ekholm, 1951; Salter and Field, 1960; Enneking and Horowitz, 1972). Reduction of inflammation can be promoted by using certain electrotherapeutic modalities like pulsed electromagnetic field therapy (PEMF), ultrasound sonography, transelelectrical nerve stimulation (TENS) at the acupuncture points and iontophoresis. Limb elevation, isometrics and elastocrepe bandage along with graded speedy isometrics help in reducing swelling. Inflammation in the subacute phase responds very well to superficial heating procedures like infrared, hydrocollator packs and radiant heat, by reflex reciprocal blood flow between the integument and the deeper tissues.

(b) Anti-inflammatory drugs and analgesics are effective in reducing pain and inflammation.

(c) Strong movements to the related joints improve circulation to the inflamed part hastening its resolution.

2. **Relaxation of inflamed area:** This can be achieved by guiding a patient on simple techniques of relaxation by adopting a position of ease of the whole body as well as the affected area (Table 3-2).

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Guidance on diversional activities also induces relaxation.

3. **Prevention of further damage and complications:**

(a) Prevention of further trauma plays an important role in hastening the resolution of inflammation. Any further trauma increases inflammation and may result in complications like joint capsule contracture due to scar tissue formation (Evans, 1980). To avoid this, especially overenthusiastic patients need to be educated on the proper positioning of the affected area during rest, as well as during controlled activity.

(b) Longer immobilization may result in complications like muscle atrophy, partial loss of strength, endurance and flexibility, weakness of the ligaments with reduced tensile strength, loss of elasticity of the collagen fibres and stiffness of the joints.

All these complications can be effectively prevented by early initiation of isometrics as well as guided mobilization. However, selection of appropriate intensity, duration, frequency and the specific technique of exercise is the decisive factor in providing quick relief.

4. **Education of patient on self-care:** Proper guidance on self-assisted activities of daily routine like dressing, taking bath, shaving and combing should be given, which will promote healing as well as avoid any further complications.

5. **Maintenance of muscle function and ROM:** This can be achieved by the following:

(a) Graduated relaxed passive or free active movements

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(b) Continuous passive motion (CPM) equipment

Gentle passive movements not only reduce the inflammation but also are instrumental in providing pain relief (Maitland, 1983; Barak, Rosen & Sofer, 1985).

Isometrics during total immobilization or partial range passive exercises and assisted active movements are effective in improving or maintaining muscle function and ROM. Guidance is necessary to ensure that the joint is moving in its proper groove and the muscle action is optimal in its direction and force.

6. **Guidance to perform functional activities:** ADLs like sitting, transfers, standing, ambulation and work requirements also need guidance to avoid overstrain to the inflamed part.

Table 3-2

Position of Ease of Commonly Involved Joints

Joint	Position of Ease
• Shoulder	• Adduction and internal rotation
• Elbow	• Flexion with forearm in pronation or midprone position
• Wrist	• Flexion
• Fingers	• Flexion
• Hip	• Flexion–abduction with external rotation
• Knee	• Flexion
• Ankle	• Plantar flexion

Chronic inflammation

Chronic inflammation indicates an attempt at repair of the whole process.

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1. Pain is usually absent during rest. The pain may be present over a localized area near the site of the lesion and is aggravated by specific activities which result in the stretching of the inflamed area.

2. There is presence of granulation tissue.

3. The skin temperature is not raised; effusion is absent; tenderness, if at all present, is minimal.

4. Passive ROM is restricted but is not painful.

5. Pain is elicited only when the joint is stretched to the point of its restriction. This restriction of ROM is usually due to tendon shortening, adhesions or capsular fibrosis in the soft tissues.

6. There is a history of long standing problem or recurrence.

Management during chronic phase

Identification of the possible pathology of the dysfunction is essential to plan appropriate therapeutic measures. The possible underlying pathology could be as follows:

1. An abnormal pattern of remodelling of the tissues during the process of healing, e.g., fibrosis, adhesions, scarring, nonunion or malunion of fractures.

2. Tissue may yield under conditions of excessive stresses due to sudden trauma or the summation of the several microtraumas. The tissue breakdown predominates as rate of attrition exceeds the rate of tissue repair. All stressful conditions of bones, muscles, articular cartilages are the result of such situations.

3. Tissue hypertrophy: Tissues with good regeneration capacity, when acting for a longer period, may become stiff and yield under conditions of loading. This may be associated with low-grade inflammation accompanied by pain and tissue hypertrophy.

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4. Psychological trauma: Persistence of pain and dysfunction causes tremendous psychological impact on the patient. Any therapeutic measure cannot be successful by overlooking this aspect in the treatment of chronic conditions.

The extent of the actual damage and the causative factors need to be identified by a thorough physical examination and clinical investigation reports. Correlation of the examination findings with the patient's subjective expression is essential to plan appropriate therapy. On many occasions, there is marked exaggeration of the symptoms due to psychological factors, rather than due to the real pathology. Therefore, handling of chronic dysfunction needs more of a psychologically oriented physiotherapy.

There are a number of procedures and modalities in the armamentarium of a physiotherapist to effectively deal with such a situation. However, the competence of the physiotherapist to choose a suitable modality and to motivate the patient, with all possible encouragement, plays a vital role in the management of chronic dysfunction or disorder. The following points should be kept in mind.

1. Reassure the patient by explaining to him the exact nature of the pathology of dysfunction.

2. Assure relaxation of the body and the area of disorder by applying a relaxing modality like deep thermotherapy.

3. Exercises are instrumental in reducing anxiety and depression (Taylor, Sallis & Needle, 1985).

Exercises should be absolutely specific, avoiding too many in numbers.

1. They should be well planned with gradual loading.

2. They should increase the surface area of loading.

3. Avoid sustained straining by early or prolonged weight bearing.

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4. Detailed instructions should be given on Dos and Don'ts, especially the latter.

5. Simple instructions should be given on exercises to improve strength, endurance, extensibility and neuromuscular coordination, progressing to the resumption of high-stress activities.

6. Systematic graduated procedures of muscle stretching, by accessory movements performed at the limit of the pathologic ROM, may be necessary to relieve soft tissue contractures.

7. The functional use of the part, without causing much discomfort, is to be guided and encouraged as it provides natural exercise.

8. Aerobics like jogging, running, swimming have been proved to be more beneficial as these promote a feeling of well-being, facilitating vigour and better physical fitness. These induce relaxation responses due to the increase in the alpha wave activity (De Vries, 1985).

9. Special treatment techniques like functional electrical stimulation, TENS, biofeedback may be necessary in some chronic disorders.

However, individualized personal attention is the most important aspect.

SUMMARY: INFLAMMATION

Stage of Inflammation	Objective
•Acute stage	• Use of appropriate modality to reduce the signs and symptoms of inflammation (e.g., by RICE) • To provide adequate rigid support to prevent even a minute stress around the site of inflammation • Guidance on relaxed positioning of the limb
• Subacute stage of tissue repair	• To promote correct healing of the injured tissues by educating the patient on mode-degree and safety of the initial movements to be performed • Educate the patient on self-exercising and gentle stretching of the injured tissues
• Chronic stage of the return of function	• Provide guidance on using injured limb as an assisting limb while performing light activities of daily living (ADLs) with the normal limb • Prevention of developing tightness or contractures • The progression of the vigorousity of all exercise in graduate steps to achieve maximally strong and mobile limbs • Special exercise session to increase the efficiency of performing ADLs as

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	well as work-related activities to reach the preinjury level

Remember

Inflammation is an essential process of early healing.

MANAGEMENT GUIDELINES DURING THE ACUTE OR PROTECTIVE STAGE OF INFLAMMATION (DURING 4–6 DAYS POSTINFLAMMATION)

Expected Problems

- Continuation of the symptoms and signs of acute inflammation
- Impaired movement and function
- Reduced or limited use of the associated parts of the body

Objective	Management
• To reduce the acute signs and symptoms of inflammation	• Application of the principles of RICE • Provide complete rest to the injured part in a relaxed position by proper supportive means (e.g., cast, splint or bandage) • Educate the patient to avoid any stress to the affected area • Apply suitable modality to reduce oedema, pain or spasm
• To maintain the integrity of the soft tissue and the joint	• Initiate *mild* and *small-range* isometrics to the encased part of the unaffected limb • Full-range resistive movement to the rest of the joints and muscles, which are not immobilized
• To maintain integrity and function of the associated areas	• Full use of the unaffected parts for activities of daily living • Educate the patient to use the affected parts totally or largely assisted by the normal contra lateral limb

Contraindications: 'No' to stretching, repetitive movements or any type of resistive movement to the injured area.

Note: Carefully keep watch to ensure the definite reduction in the

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signs and symptoms of inflammation.

MANAGEMENT GUIDELINES DURING THE SUBACUTE STAGE OF CONTROLLED MOBILIZATION (17–21 DAYS FROM THE ONSET)

Expected Problems

- Pain near the end of the available ROM
- Initial stage of the development of tightness in the soft tissues, muscles and joint
- Slow process of developing muscle weakness (atrophy in the encased part)
- Decreased ability or inability to use the affected part for activities of daily living

• Guidance and education of the patient	• On progressive modes of correct exercises from passive self-assisted ROM to self-resistive exercises and applying the self-stretch–hold technique intermittently • Check the performance of each mode to ensure the correctness of the relative mode • Warn the patient against pain while performing the self-stretch–hold technique
• Promote healing and controlled lengthening of the inflamed tissues	• Momentarily discard the protective or assistive devices and achieve maximum ROM • Use the technique of multiple isometrics to enhance strength a • Increase repetitions of isotonic exercises
• Improve neuromuscular coordination and control, muscular strength as well as endurance of the involved related muscle	• Introduce low intensity (weight) and short duration functional movements. Encourage full joint ROM as well as stretching manoeuvres

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groups	
• Progress towards near-normal functional activities	• Ensure progress in each type of exercise procedures

[a]Importance of early initiation of isometrics: It places the contracting muscle in a shortened relaxed position so that the newly forming scar is not unduly stretched. Always keep or control the intensity of contraction below the level of perception of pain and discomfort.

Caution

During this stage of healing, carefully watch for recurrence of the signs and symptoms of acute inflammation; if suspected momentarily, return to the necessary rest.

MANAGEMENT GUIDELINES DURING THE STAGE OF RETURN OF FUNCTION (WEEK 3 ONWARDS) EXPECTED PROBLEMS

- Formation of adhesions and development of tightness, or soft tissue contractures
- Subnormal muscular functions of strength and endurance
- Decreased functional performance of the involved part
- Plan and organize exercise training programme to be focused on the existing deficiency, e.g., repetitive self-stretch–hold to improve ROM in the instance of tightness, contracture or adhesion formations.
- Educate on graduated progressive resistance exercises (PREs) to the full passive joint range of motion (JROM) in the instance of below normal muscle functions.
- Teach safe-body mechanics and ergonomic counselling ease

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functional performance in patients who lack confidence in performing ADLs.

- Organize special training sessions of work-related activities to facilitate back to the preinjury job or house-hold work in patients who are hesitant to begin work on their own.
- Conduct re-evaluation sessions to assess the progress and plan programme to pinpoint specific needs.
- Use simple to complex motions, to control proximal stability, superimpose distal motion and sessions of speeds coordination training if and when neuromuscular control, muscular strength and endurance is lacking.

Note: Increase the vigorousity of all the exercise procedures to return the patient to the preinjury status as early as possible.

Soft tissue injury

Soft tissues which form protective cover to the bone are the first targets to face the ravages of direct or indirect trauma. Besides, each soft tissue plays a vital role in functional tasks (Table 3-3).

Table 3-3

Distinguishing Characteristic of Major Soft Tissue Injuries and Their Comprehensive Management

Injury to the Muscle (Strain)	Injury to the Ligament (Strain)	Injury to the Blood Vessel	Injury to the Synovium	Injury to Peripheral Nerve	Injury to Bursa
Grade I (contusion) • Blunt injury • Intact muscle and fascia • Haematoma – patchy and localized at the site of injury *Grade II (partial*	*Grade I (minor sprain)* • Twisting injury • Positive stretch test *Grade II (partial*	*Grade I (contusion/haematoma)* • Blunt injury patchy • Collection of blood and exudate *Grade II rupture (partial)* • Associated with	*Acute synovitis* • Common site: knee joint • Trauma, infective	*Grade I (neuropraxia)* • Sustained compression • Intact axis cylinder •	*Irritative bursitis (adventitio* • Excessive repetitive pressure, friction or trauma

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rupture) • Isometrics elicit sharp pain • Some muscle fibres may tear, intact fascia *Grade III (complete rupture)* • Loss of continuity in the muscle belly with palpable gap • Complete loss of voluntary movement • Complete division of muscle and fascia *Healing* • Abundant blood supply so healing is fast • If smooth interface is available, muscle fibres grow at the rate of 1.0–1 mm per day • If smooth interface is not available, fibroblasts secrete procollagen and then regeneration occurs with a scar tissue which can cause shortening or contracture	*rupture)* • Gradually appearing swelling • Joint involved is unable to take pressure (e.g., weight bearing in lower limb injuries) *Grade III (complete rupture)* • Rapid onset of effusion • Marked instability in the joint • Due to poor blood supply, they take long time to heal *Healing* • If not displaced, immobilization with a POP cast for 6–8 weeks • If displaced, needs surgical repair and immobilization in POP for 6–8 weeks	injury to the bone (e.g. fracture, dislocation) • Pulselessness or doubtful peripheral circulation • Cramp-like pain, pallor, paraesthesia paralysis *Grade III (complete rupture or total blocking of blood flow)* • Flexor muscle fibrositis • Uncontrolled bleeding • Pulselessness • Blocking of the blood flow may result in serious consequences like MI, internal thrombosis, neuromuscular necrosis or gangrene	or inflammatory joint disease, arthritis, etc. • Slowly developing red hot, soft and localized, fluctuating swelling • Positive Homans sign • Pain and heaviness in performing active movements *Chronic synovitis* • Negligible pain • Effusion turns into a hard mass • Atrophy of muscle close to the involved joint • Joint instability when ligament is also involved • Tenosynovitis • Inflammation of the synovial lining of a tendon sheath • Pain and	Reversible neuronal signs and symptoms • Intact nerve conduction *Grade II (axonotmesis)* • Endoneurium intact • Axonal breakdown • Wallerian degeneration sets in; good recovery but may not be complete *Grade III (complete section of the nerve)* • Blocking of nerve conduction • Both proximal and distal degeneration • No recovery *Healing* • Rate of axonal growth: 1 mm per day • Muscle proximal to the site of injury recover first (motor march) • Damage to the endoneural tube may result in	• Pain • Tender red and hot localized swelling *Infective bursitis* • Infective, inflammat or metabolic disorders • Antibacter drugs *Chronic bursitis* • Excision drainage local infiltration modified foot-ware *Adventitio bursae* • Medial side of great toe • Ischial tuberosity *True bursae* • Subacrom bursaBurs in knee and heels

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			crepitus on palpation over the tendon *Tenovaginitis* • Fibrous sheath of a tendon is affected • No crepitus • Tendency for progressive contracture of tendon (e.g., De Quervain)	neuroma	

Causes of soft tissue injury

1. Direct, blunt or lacerative trauma – due to fall, road traffic accident, assault, etc.

2. Indirect trauma – due to a sudden violent muscle pull when one is not aware of it. It may result in ligament sprain at the impacting joint (e.g., ankle sprain), or avulsion injuries.

Commonly injured soft tissues

- Muscle and tendons
- Ligaments
- Peripheral nerves
- Blood vessels
- Synovium
- Joint capsule

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- Bursae
- Fascia and subcutaneous connective tissue
- Skin

Of these, injuries to the muscles, tendons, ligaments, blood vessels and nerves demand special attention due to their major role as the functional units of the body.

Role and objectives of physiotherapy

With physiotherapy being a major discipline employed to restore function, the physiotherapist must have adequate knowledge and skill of the following:

- Early detection and correct diagnosis through critical evaluation
- Planning patient-oriented correct methods of management
- Conducting planned therapy and educating the patient on exercise and self-care
- Re-evaluation at regular intervals to ensure progress
- Postrecovery dos and don'ts and guidance on preventing recurrence

Note: Early initiation of active movements within the *pain-free* range provides ideal background for recovery.

Examination and evaluation

Subjective

Overall impression of a patient about the disorder and the main subjective difficulty may not always correlate with the findings of the clinician's evaluation.

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Objective

Considering the nature of injury, soft tissues must be examined first to assess the site and the extent of damage to the respective soft tissues. Scientific and critical evaluation of the neuromusculoskeletal system by physical examination using established tests and ordinal scales are used to describe each test (e.g., muscle power, ROM, pain) should be done.

Functional: Careful evaluation of the effect of injury on routine functions and ADLs is a must. Although it is of great importance, it is usually neglected in the routine evaluation done by the physiotherapist. At the same time, it is equally necessary to curb certain attitudes and activities of overenthusiastic patients which may prove detrimental to their recovery, e.g., antigravity shoulder abduction in the presence of a rotator cuff injury.

Interpretation: The findings of the aforementioned data should be properly interpreted in relation to the clinician's evaluation data and the records of the investigations so that an optimally effective therapeutic programme can be formulated.

Response: Response of a patient to treatment needs to be evaluated carefully and critically at regular intervals. The treatment programme may need some modifications and alterations from time to time.

Functions and objectives of physiotherapy

These fall into two categories:

1. Immediate restorative measures

2. Late restorative measures

1. ***Immediate restorative measures***

(a) Control bleeding

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(b) Reduce swelling

(c) Minimize pain and inflammation

(d) Prevention of further damage

(e) Prevention of stiffness of joints and soft tissues

(f) Maintenance of muscle functions

2. ***Late restorative measures***

(a) Re-education of movement

(b) Increase strength, power, endurance and flexibility of the affected muscles in particular and the whole body in general

(c) Increase optimally the mobility of the affected joint and soft tissues

(d) Restoration of kinaesthetic/proprioceptive mechanisms

(e) Restore confidence and provide all necessary encouragement

(f) Correct guidance in patient-oriented self-exercise training programmes

(g) Intensive programme to facilitate ADLs

(h) Training in specific home treatment programme

(i) Guidance to prevent recurrence

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(j) Emphasis on regular check-up and follow-up advice.

Clinically, the major soft tissue injuries are divided into six categories:

1. Muscle and tendon injury

2. Injury to the ligament

3. Injury to the synovial membrane

4. Injury to the nerve

5. Injury to the blood vessel

6. Injury to the bursa

7. Injuries to the musculoskeletal complex

Muscle and tendon injury

Muscle and tendon injury (strain) (box 3-1)

Injury to the muscle is classified into four categories on the basis of damage to the muscle tissue:

1. Grade I strain: Superficial contusion

2. Grade II strain: Deep and widely spread contusion

3. Grade III strain: Partial rupture of the muscle or tendon

4. Grade IV strain: Complex rupture of the muscle or tendon

Box 3-1

STRAIN (INJURY TO MUSCLE)

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- Grade I (contusion)
- Blunt injury
- Intact muscle and fascia
- Haematoma – patchy and localized at the site of injury
- Grade II (partial rupture)
- Isometrics elicit sharp pain
- Some muscle fibres may tear, intact fascia
- Grade III (complete rupture)
- Loss of continuity in the muscle belly with palpable gap
- Complete loss of voluntary movement
- Complete division of muscle and fascia

Healing: Abundant blood supply so healing is fast.
If smooth interface is available, muscle fibres grow at the rate of 0.1 mm per day.
If smooth interface is not available, fibroblasts secrete procollagen and then regeneration occurs with scar tissue that can cause shortening or contracture.

Grade I strain or contusion

This injury results mostly from a blunt injury.

Pathology

1. Intact fascia

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2. Minimal intramuscular bleeding causing patchy localized haematoma

Clinical features

1. Localized pain and tenderness

2. Reflex muscular spasm

3. Limitation of movements close to the injury

4. Typical signs of inflammation may be present

Healing

Being abundantly vascularized, the process of healing is speedy and complete. However, original muscular tissue is replaced by fibrous tissue resulting in a decrease in the efficiency of contraction.

Management

- Treatment by applying the principles of RICE
- Cryotherapy in the form of ice application for the first 24 h is very effective (three to four sittings of cryotherapy each for 20 min)

Beneficial effects of cryotherapy

- Reduces tissue oedema (Mc Master and Liddle, 1980; Masten, Questad & Masten, 1975)
- Slows down localized blood flow (Abramson, Tuck, Lee, Richardson & Chu Luke, 1966; Knight and Londerce, 1980)
- Lowers intraarticular and intramuscular temperature and reduces pain (Cobbold and Lewis, 1956; Wakim, Porter & Krusen, 1951;

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Johnson, Moore, Moore & Oliver, 1979; Chambers, 1969; Lane, 1971; Rocks, 1979)

- Reduces metabolic function and brings about vasoconstriction (Clarke, Mellon & Lind, 1958; Janssen and Waaler, 1967)
- Reduces sensory and motor nerve conduction velocities (Fox, 1961; Lee, Warren, & Mason, 1978)
- Produces analgesia by increasing the threshold of stimulation of pain nerve fibres (Stangel, 1975)
- Increases neuromuscular function
- There may be an increase in the muscle strength after the treatment

Caution

Excessive cooling beyond 15°C is contraindicated. At this temperature, vasodilation occurs as a protective tissue response to prevent necrosis (Lewis, 1941).

It is contraindicated in collagenous diseases where there is possibility of increasing pain and stiffness (Backlund and Tiselius, 1967).

It is also contraindicated in Raynaud disease, as it produces excessive digital arterial spasm and ischaemic tissue necrosis (Goldberg and Pittman, 1959).

It is also contraindicated in some people who have an allergy to cold. It may produce cold erythema and cold hypersensitivity syndrome (Shelley and Caro, 1962).

Note

- Grade I or superficial contusion – it settles quickly just by RICE.
- Grade II or deeper contusion takes more time for the dispersal of haematoma.

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- Grade III or deep and widespread contusion not only requires longer time to settle, but, if it is close to the joints like elbow or hip, the patient is also susceptible to develop *myositis ossificance* – a joint stiffening complication. In such a situation, application of heat, massage or forced passive movements to improve passive joint range of motion (JROM) are totally contraindicated.

Grade II strain (deep and wide contusion) – possibly due to more violent blunt trauma

Pathology: wide and deep haematoma

- Intact fascia
- Greater number of muscle fibres are traumatized
- More internal bleeding
- More than one muscle group may be involved

Symptoms

- More severe localized pain and tenderness
- Severe reflex muscle spasm
- Fascia may remain intact or may be torn
- Loss of voluntary active movement
- Attempted isometrics elicit sharp pain
- Both intra- and intermuscular bleeding may occur

Grade III strain (partial rupture)

- There is tearing of greater number of muscle fibres.

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- It may involve more than one muscle groups.
- Fascia may be partially torn.
- Widespread intra- and intermuscular bleeding may occur.

Cause

Grade III strain is caused by incoordinated sudden violent muscle pull when the muscle is not prepared for it (e.g., sudden violent stretching of the muscle in a contracted state, as in sports). Although the torn muscle fibres are replaced by fibrous tissue (scar), adequate function of the injured muscle can be regained if it is kept supple by relaxed early mobilization and controlled stretching manoeuvre.

Management of grade II and III strains

During the first 24 h:

- Immediate application of RICE principles
- Immobilization of the limb in a splint or a pressure isometric bandage
- Begin with pain-free isometrics both in speedy and sustained mode against pressure bandage with the limb elevated
- Vigorous active exercises to the uninvolved joints

From 48 to 72 h:

- Pressure bandage is removed and pain-free relaxed rhythmic movements are begun in a small pain-free range.

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- Carefully controlled gentle stretching is introduced.
- Soothing thermotherapy modality followed by progressive mode of exercise is initiated.
- Light ADLs, may be assisted with the normal limb (self-assisted), are introduced and non–weight-bearing (NWB) crutch walking is started.

During 48–72 h:

- Vigorousity and the duration of exercises are progressed.
- Ultrasonic exposures are ideal to reduce pain as well as haematoma, if present.
- Light functional activities are continued with NWB crutch walking.

After 72 h:

- Usually the pressure bandage is off by now, unless swelling persists.
- Gradual introduction of *self-resistive exercises* incorporating exercise patterns of proprioceptive neuromuscular facilitation (PNF) is included if feasible and pain free.
- Systematic introduction of the DeLorme technique of repeated maximum strength (RMS) is tried.
- Allow carrying or lifting heavier weights and all FWB in ambulation in a graduated manner.
- Preinjury functional status should be restored within 3–6 weeks.
- Advise against overuse or recurrence.

Grade IV strain (a complete rupture)

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Causes

Causes can be severe lacerative trauma or a violent stretching of a muscle during active contraction. It may occur through the tendon or close to the point of its attachment to the bone. It results in a piece of bone getting avulsed along with the tendon (Fig. 3-1). Avulsion may occur due to attrition of the tendon or roughening of the bony groove in which it lies or as a result of sharp and violent laceration. It is associated with the rupture of a blood vessel with haematoma developing in the gap between the ruptured fragments. It is replaced by vascular fibrous tissue. This vascular fibrous tissue eventually organizes as scar tissue prone to developing shortening or contracture.

FIG. 3-1 A CT scan-3-dimentional reconstruction image.

Test

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There will be loss of the primary function of the involved muscle, e.g., in the rupture of the tendoachilles, active toe raising test will be POSITIVE, even though the patient may be able to perform weaker plantar flexion by using peronei and the long toe flexors. The sequential steps of healing of the ruptured muscle and tendon are presented in Fig. 3-2.

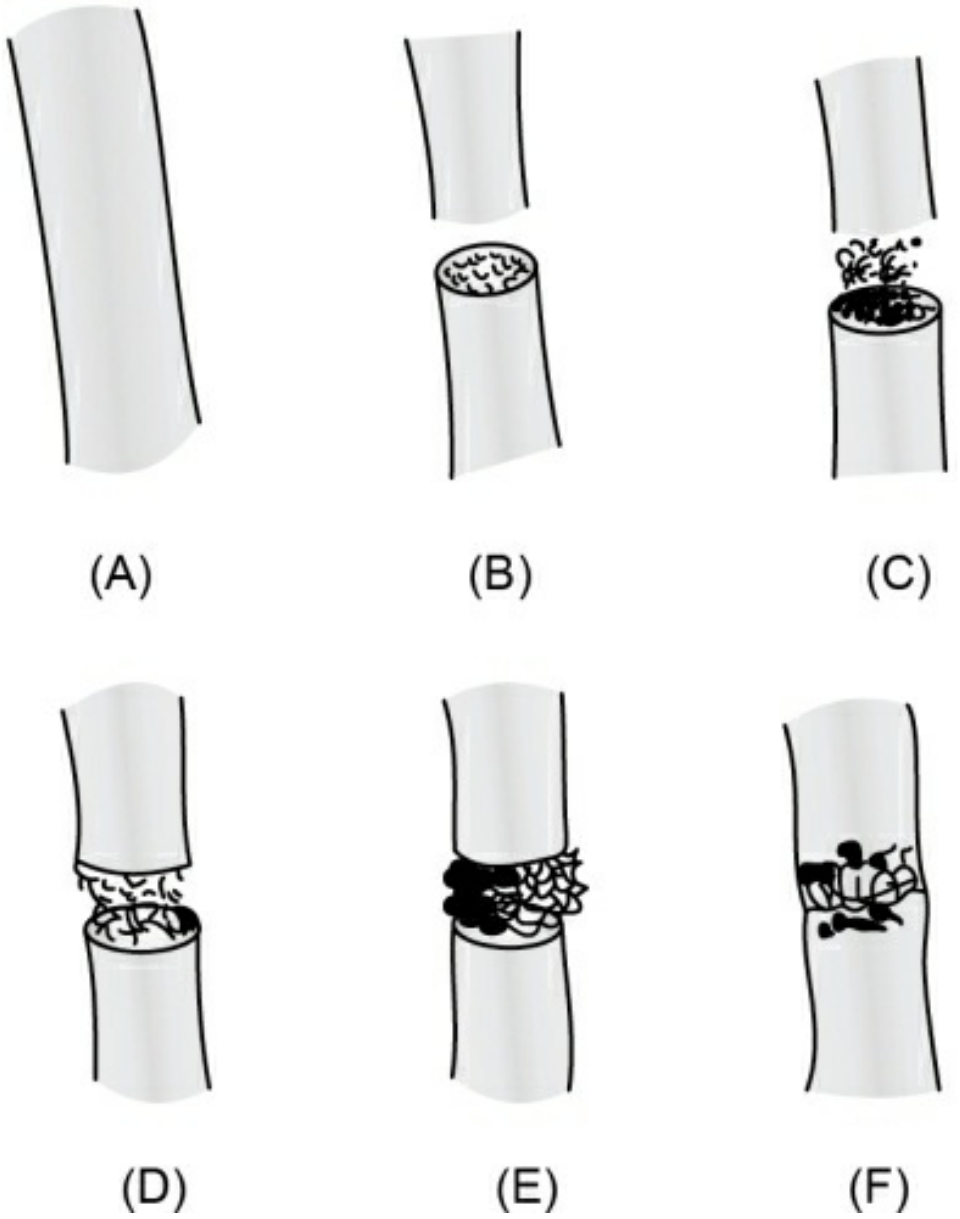

FIG. 3-2 Sequential healing of the muscle and tendon injury. **(A)** Intact

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tendon with longitudinally placed collagen fibres. **(B)** Cut tendon with both the cut ends in correct alignment. **(C)** Formation of fibrin clot (early repair process). **(D)** Within 3–5 days fibroblasts proliferate and begin production of collagen fibres. **(E)** By 2 weeks, the collagen scar begins to remodel (an important period to apply graduated longitudinal stretch. **(F)** Remodelled or properly aligned collagen.

Pathology

- A palpable gap may be felt at the point of a complete rupture
- Tearing of the fascia
- Considerable intra and intermuscular bleeding
- Gross swelling over the site of rupture and its periphery

Clinical features

- Severe localized pain and tenderness
- A snapping sound may be heard by the patient
- A total loss of muscular contraction
- Severe reflex muscular spasm
- A visible gap in the continuity of a muscle at the site of rupture

Treatment

- There is no alternative to surgical repair.
- Opening the ruptured site, haematoma is evacuated and suturing of the fascial sheath is performed. Direct muscle repair is avoided.
- Compression bandage is applied.
- Limb is immobilized (in elevation) for 2–3 weeks.

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- Light, pain-free, speedy or slow-speed isometrics are performed at the earliest.

- Faradic stimulation over the repaired muscle will be useful in maintaining and influencing fast as well as slow twitch muscle fibres, in the distribution of motor units and the fusiomotor systems (Pette 1980).

- Superficial thermotherapy could be altered to deep heating thermotherapy to improve circulation, to reduce pain, to increase metabolism; selective action on different tissues and generalized and localized relaxation (Griffin and Karselis, 1978).

The therapeutic mode should be progressed on the same lines as described for grade II and III strains.

Note: Exercise to augment specificity: the process of recovery for muscle and tendon.

For muscle injury:

1. Progressive tensile loading at various speeds recruits different motor units.

2. Low-load exercises to the point of a muscle fatigue promote metabolic adaptations.

For tendon injury:

1. Progressive tensile loading

2. Strength training exercises

3. Exposure to tensile loads over a longer period increases size concentration and collagen crosslinking

Compression bandage: Compression bandage is applied with

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moderate even pressure without a gap to control the oedema. Intermittent pneumatic compressive therapy has been proved to be very effective (Airaksinen, 1989). The technique of combination of intermittent compressive system and ice as described by Murphy (1988) should also provide an effective measure to reduce pain and oedema.

Positioning and movements: Elevation of the affected part and active movements of the distal body segment, and isometrics further increase the efficiency of compression bandage in reducing swelling and oedema. The patient should be educated to prevent further trauma by proper, controlled positioning and transfers.

- Active relaxed rhythmic movements are initiated to the distal-most segment (e.g., toes) supported in elevation.
- Low-dose insonation is an extremely effective means of reducing haematoma.
- Soothing effleurage helps in the dispersal of swelling and haematoma.
- Movements are to be progressed depending upon the discomfort; ideally initiated following soothing superficial thermotherapy.
- Isometrics and self-resistive modes of exercises play a vital role in the recovery.
- Light functional activities are safe.
- Period of full recovery is 8–10 days.

Management of a ruptured tendon (fig. 3-2)

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A ruptured tendon is usually sutured and immobilized for 2–9 weeks. The period of immobilization actually depends upon various factors like the method and type of suture, and the expected degree of stress on the tendon. For example, a large tendon bearing excessive stresses, like tendoachilles, needs 9–10 weeks of postop immobilization. The treatment follows the same routine as described for grade IV muscle rupture, except the following:

- Extra emphasis should be put on low-load stress on the sutured tendon.
- Careful progressive application of tensile loading is required.
- Strength training exercises with deep friction massage and ultrasonics play an important role in the maintenance of the tendon length.
- Thorough guidance should be provided on the correct application of sustained self-stretching.
- Slow-stress activities can be started by 10–12 weeks.
- Competitive sports can be allowed after 16–18 weeks with several practice sessions.

Injury to the ligament (table 3-4)

Injury to the ligaments are also addressed as *sprain.* Ligaments are major stabilization forces of a joint and in turn the whole body during our most important static as well as dynamic activities.

Table 3-4

Classification of the Extent of Injuries to the Ligaments

Characteristics	Mild (Grade I)	Moderate (Grade II)	Severe (Grade III)
Pain	Minimal (+)	Moderate	Complete tear
Tenderness	(+)	(++)	(+++)

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Instability	Nil	Minimal	Marked (+++)
Localized oedema	Negligible	(+)	(++)
Passive stress test	Increased pain	Extreme pain	Excruciating pain
Joint separation	Up to 5 mm	Between 5 and 10 mm	>10 mm

According to the degree of damage, ligament injuries are classified into three grades: I–III.

Functional anatomy

The ligaments are made up of longitudinally arranged fibres to ensure adequate and safe excursion of a joint during high-stretching activities of the body.

They are compact fibrous tissues, which reinforce the joint capsule.

As they have no tone like a muscle tissue, they are inadequate to offer sole defence to the joint. To cover this inadequacy, they are always reinforced and supported by muscles. This combined action of muscles and ligaments is further facilitated by receiving the same neural innervations as its paired muscle, totally handling the excessive stretch by increasing its tone (e.g., if there is excessive strain on the medial collateral ligament, the supporting vastus medialis muscle will be activated to reduce stress on the medial collateral ligament and the medical compartment of the knee joint).

Main functions of the ligaments

- To provide support by reinforcing the joint capsule
- Joint stability: To provide major support to hold together the bony ends forming the joint
- Protection: Being tough and pliable, they have the ability to withstand excessive stress over the joint
- Efficiency of movement: To provide great mechanical advantage to the joint movement with reduced load and stress on the prime mover muscle group

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Problems in healing of the ligaments

- Poor vascularity results in undue delay in the process of healing following an injury.
- Repair always takes place by scar tissue, as they do not have specialized cells to mimic the original tissue.
- As and when the ligaments are not protected from stress for a longer duration, the process of repair takes place with excessive fibrous tissue. This results in the lengthening of the healing ligament, which results in its laxity giving rise to permanent laxity or loosening of the joint (hyper laxity).
- Continuous pull on the injured ligament during the early sessions of passive JROM exercises may give rise to periosteal irritation and serofibrinous exudates – leading to organization of fibrous adhesions and finally resulting in painful stiffness of the related joint.

Therefore, while initiating early passive ROM exercises or stretches, one must not cross the boundary of pain and discomfort.

Caution

While applying stretch on a healing ligament, it should be INTERMITTENT and controlled carefully to achieve the objective of strong ligament.

Ligamentous injury is classified into three grades (Box 3-2; Fig. 3-3):

Grade I: Minor sprain

Grade II: Moderate sprain

Grade III: Complete rupture

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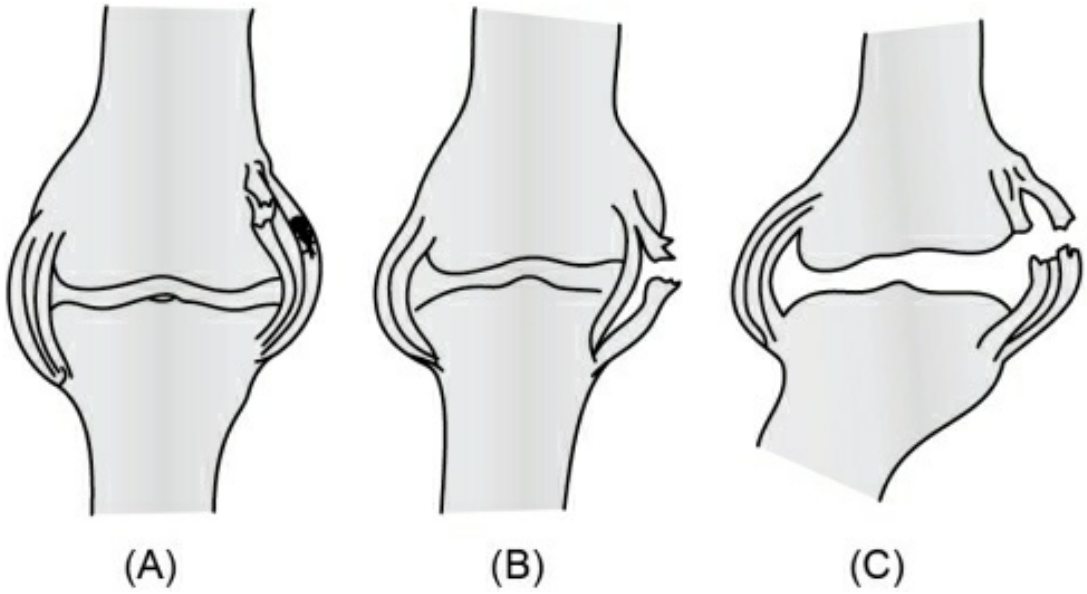

FIG. 3-3 Grades of ligament injury. **(A)** Grade I – sprain. **(B)** Grade II – partial rupture. **(C)** Grade III – complete rupture.

Box 3-2

SPRAIN (INJURY TO THE LIGAMENT)

- Grade I (minor sprain)
- Twisting injury
- Positive stretch test
- Grade II (partial rupture)
- Gradually appearing swelling
- Joint involved is unable to take pressure (e.g., weight bearing in lower limb injuries)
- Grade III (complete rupture)
- Rapid onset of effusion

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- Marked instability in the joint

Due to poor blood supply, they take long time to heal.

Healing

- If not displaced, immobilization with a POP cast is needed for 6–8 weeks.
- If displaced needs surgical repair and immobilization in POP for 6–8 weeks.

Grade I injury

Grade I injury is easy to deal with and instant application of all the four principles of RICE with analgesic and anti-inflammatory medication are adequate.

Clinical features

- Localized pain and tenderness
- Slight swelling may be present

Test

- Passive stress test is the diagnostic sign; it will be positive when sprain has occurred.
- Separation of the joint surfaces up to 5 mm may sometimes be present.
- Partial loss of function may be present due to pain.

Treatment

First day

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- With limb in elevation, active movements are to be encouraged to the distal-most joints.
- Pain-free light isometrics are guided.
- Functional activities should be encouraged, depending upon the area of involvement.

Second day

- Replace cryotherapy with superficial thermotherapy.
- Increase vigourosity of isometrics, emphasizing repetitive performance.
- Educate on safe and appropriately grooved active self-assisted to active movements.
- Rapidly progress exercise mode to self-resistance or progressive resistance exercise (PRE), if possible.
- Allow functional activities gradually if no discomfort.
- Full recovery is expected within a week or 10 days.

Grade II injury (moderate sprain)

Here the ligament is either partially torn or detached from its bone of attachment.

Clinical features

Moderate localized pain and tenderness

Test

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- Passive stress test is extremely painful with joint separation varying between 5 and 10 mm.
- This type of injury being common at the knee, walking or weight bearing is painful and associated with a limp.

Treatment

- RICE methodology is used with cryotherapy for the first 24 h.
- For compact immobilization, cast (long) is applied for 3–6 weeks.
- Early isometrics within the pain-free range are encouraged and guided as early as possible.

After removal of the cast

- Stiff and painful movements are expected, especially in the terminal JROM – need early and immediate attention.
- Begin with a small range of rhythmic relaxed active free movements, progressing to self-assisted mode.
- Wherever possible, introduce correct education to perform self-resistance movements.
- Rapidly progress to PRE, passive stretching, PRE or CPM, if feasible.
- Progress to PWB ambulation to FWB with gait training sessions.

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- Full recovery is expected within 3 weeks.

Grade III injury (a complete rupture)

It is a severe injury putting the injured muscle totally out of action, due to sudden violent injury.

Clinical feature

- Profuse swelling with marked localized tenderness
- Unremitting pain and discomfort to the whole limb

Test

- Passive stress test is impossible
- Marked joint instability
- Impossible to bear body weight on the injured limb
- Joint separation of >10 mm

Treatment for undisplaced ligament injury

- Usually treated by a conservation approach of immobilization in a long leg cast for 6–8 weeks.
- Limb is maintained in elevation.
- Initiate vigorous, repetitive full ROM movements to the distal joints.
- Initiate early isometrics to the encased muscles.
- Diapulse, which can be given with the cast on, is ideal if available.
- NWB crutch walking is progressed to PWB first with crutches and

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with cane by 4–6 weeks.

After removal of the cast

- Kneecap or a crepe bandage is applied.
- Isometrics are intensified.
- Superficial thermotherapy, followed by rhythmic, relaxed, free, active knee mobilization, is emphasized.
- The patient is well educated and guided on the techniques of self-assisted and self-stretched modes for knee flexion emphasizing sustaining and holding.
- Repetitive quadriceps exercises are performed against gravity.
- Active self-resistance exercises are important at this stage along with strong isometrics to the quadriceps.
- The **best method** of strengthening, increasing muscle power and endurance along with JROM is to teach and guide patients on self-resistance and self-stretching modes of exercise.
- By 10–12 weeks, the patient should reach a stage of preinjury status.

Treatment for displaced or completely torn ligament

It may be a surgical emergency.

The usual surgical procedures employed are as follows (Fig. 3-4):

- Suturing
- Reattachment

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- Advancement
- Replacement

The complete rupture of the following ligaments is commonly seen in a knee joint: MCL, LCL and ACL. The treatment consists of reconstructing the torn ligament by an appropriate tendon graft; which is usually undertaken as follows:

- *MCL (medical collateral ligament)* is replaced by either semitendinosus or hamstring.
- *LCL (lateral collateral ligament)* is replaced by the muscle biceps femoris or TFL (tens- or fascia lata).
- ACL (anterior collateral ligament) is replaced by iliotibial band.

After the surgical repair the limb is encased in a long POP cast to avoid stress to the operated area.

Physiotherapy during immobilization

- Perform limb elevation.
- Provide active movements to the free joints and the distal joints (toes or fingers).
- Carry out regular activities with the sound limb.
- Gradually use the injured limb assisted by the sound limb to perform light ADLs.

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- No weight bearing is allowed at this stage.

After removal of the cast, the physiotherapy regimen follows the same line of treatment as discussed for displaced ligamentous injury.

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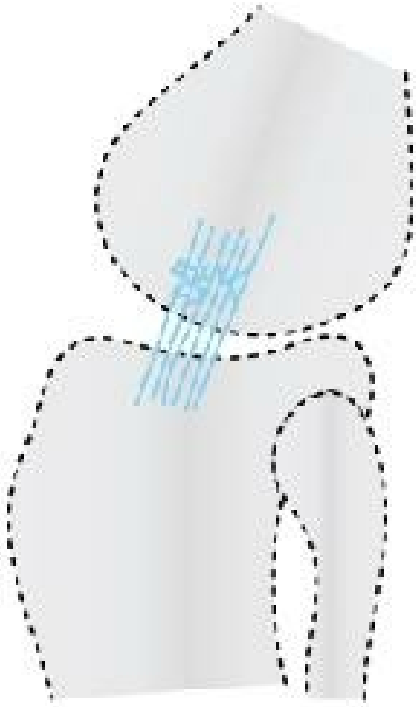

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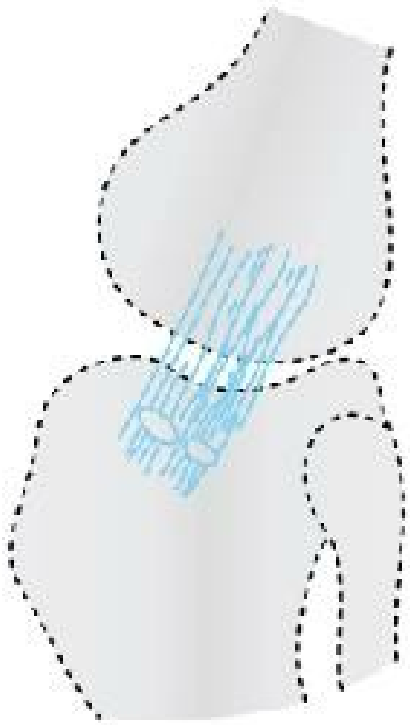

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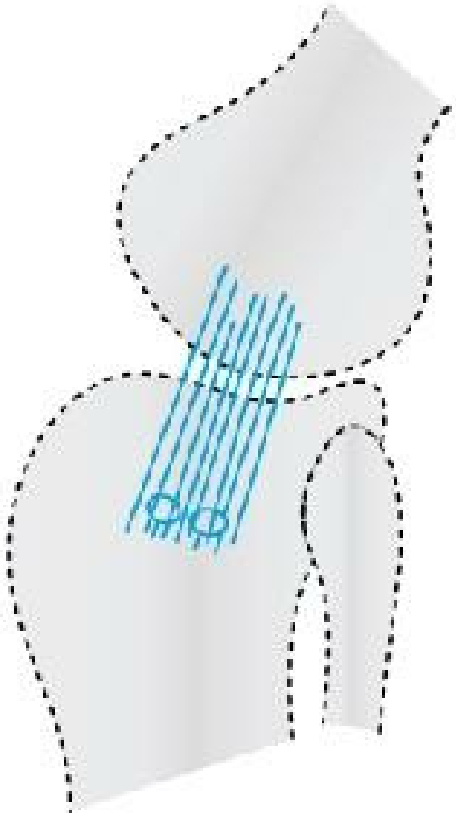

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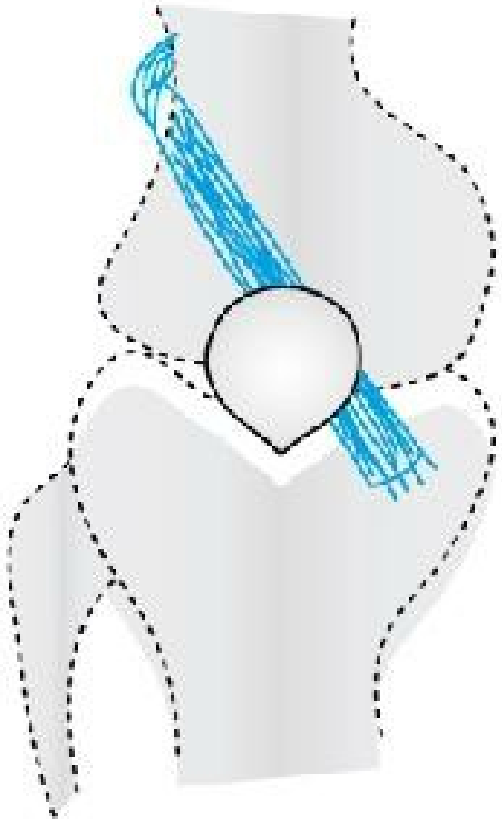

(D)

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FIG. 3-4 Surgical repair of ligament injury: **(A)** Repair. Minor grade I tear can be managed by simple repair (suturing) of the partially ruptured ligament. **(B)** Reattacment. When there is detachment of the ligament from the bone of insertion, procedure of re-attachment is advisable. **(C)** Advancement of attachment. A procedure of advancement becomes necessary to impart better stability to the joint over which the ligament passes. **(D)** Replacement with tendon. Replacement of the total ligament is indicated when it is totally destroyed and cannot be repaired. Replacement is performed either with tendon or by a prosthesis.

Note: One must be extra careful while applying stretch to the replaced muscle; imbalanced application may lead to a limitation when the applied stretch is inadequate to a lax joint when there is overstretching, giving rise to instability to the related joint (especially the weight-bearing joint).

Injury to the synovial membrane (synovium) (box 3-3)

Synovium is a lining covering important tissues like joints, capsules, tendon sheaths and articular surfaces of joints. It is richly supplied with blood vessels, lymph vessels with abundant nerve endings.

Box 3-3

INJURY TO THE SYNOVIUM

Acute synovitis

- Common site – knee joint
- Trauma, infective or inflammatory joint disease, arthritis, etc.
- Slowly developing red hot, soft and localized, fluctuating swelling
- Positive Homans sign
- Pain and heaviness in performing active movements

Chronic synovitis

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- Negligible pain
- Effusion turns into a hard mass
- Atrophy of muscle close to the involved joint
- Joint instability, when ligament is also involved

Tenosynovitis

- Inflammation of the synovial lining of a tendon sheath
- Pain and crepitus on palpation over the tendon

Tenovaginitis

- Fibrous sheath of tendon is affected – no crepitus
- Tendency for progressive contracture of the tendon (De Quervain)

Functions

It has the following three most important functions:

- It secretes smooth viscous synovial fluid, minimizing joint wear and tear due to repetitive movements in various directions.
- It provides nourishment to the joint cartilage preventing early degeneration.
- It also promotes interchanges of substances between the blood and the joint structures.

Prone to inflammation

Synovium is prone to developing inflammation (synovitis) as a result of infection, injury to the joint, rheumatoid arthritis (like RA),

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haemophilia, chondromalacia, etc.

Types of synovitis

Acute: Commonly occurs as a result of injury or trauma

Chronic: Due to diseases like tuberculosis, rheumatoid arthritis or even as a result of old injury

Acute synovitis

Clinical features

- Swelling develops slowly within 2–4 h.
- Cardinal signs of acute inflammation like warmth, redness, swelling, pain, joint stiffness and loss of function appear.
- The involved joint adapts flexion attitude as a natural position of ease.
- Joint is swollen due to the accommodation of excess fluid; unremitting pain is present even at rest during the acute stage of inflammation.
- Muscle atrophy quickly appears, particularly in the quadriceps, when synovitis affects the knee joint, which is a common site for synovitis.

Management

First 24–48 h

- Application of the principles of RICE (ice application during the first 24 h completely encasing the knee)
- Gentle but speedy isometrics to the quadriceps with the

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limb elevated

- Vigorous active movement to the toes, slow repetitive movements to the ankle (when pain-free)
- Diapulse, insonation or superficial thermotherapy advantageously applied to reduce pain

After 48 h

- The joint may be aspirated if the swelling persists.
- Speedy isometrics to reduce swelling and sustained isometrics to strengthen quadriceps are initiated to prevent atrophy.
- Small-range active movements are initiated as rhythmic, relaxed free movements.
- Carefully monitored, sustained passive stretching may be applied to improve JROM.
- Dynamic knee orthosis is given to maintain the knee in full or near-full extension. It may also help minimize limp in the future.
- Training for graduated weight transfers is important. Ambulation, whenever feasible, could begin with NWB, progressed to PWB and then to independent walking.
- Safety, guidance and education of the patient on self-performance of exercise can be instrumental in preventing knee flexion contracture and quadriceps atrophy.

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How to identify the progression of synovitis and synovial rupture?

Progression

The synovial effusion, which is fluctuating initially, gradually assumes firm character turning to thick firm and nonfluctuating with simultaneous reduction in the intensity of pain.

Synovial rupture

- The patient notices shooting pain at the posterior aspect of the knee while getting up from a stool or chair.
- Getting down steps with the unaffected leg down develops tremendous tension in the affected knee on the upper step bearing the total body weight.
- The swelling may spread to calf resulting in a positive Homans sign.

Chronic synovitis

Chronic synovitis is easily distinguishable on the basis of the following signs and symptoms:

- Marked reduction in the intensity of pain
- Appearance of visual atrophy in the quadriceps especially on the anterior aspect of thigh just above the knee (upper pole of patella)
- Firm swelling over the joint (synovial effusion) with typical shapes at various sites

The sites and the shapes of the synovial effusion:

- At knee, it is horseshoe shaped.

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- At the prepatellar bursa, it is egg shaped.
- At the tendon sheath, it is sausage shaped.
- There is considerable stiffness in the joint.
- Setting in of laxity in the ligament results in joint instability.

Treatment

As the main hindering factor to exercise is minimized, liberty should be taken in rapid exercise progressions as follows:

- Strong, self-resisted isometrics to the quadriceps (Fig. 3-5)
- Monitored PRE to the quadriceps, hamstrings and hip joint muscles
- Sustained passive stretching of the knee to improve JROM; may be in combination with hot packs
- Graded stretching or intermittent or sustained traction to ease organized joint contractures
- If residual flexion contracture persists, a knee stretching orthosis may be given, which can serve both the purposes of continued stretching as well as easing ambulation
- Encourage self-monitored exercise training procedures to its maximum

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FIG. 3-5 SLR assistance is provided by physiotherapist posteriorly just proximal to the ankle joint by one hand and below knee by the other.

Injury to the nerve

Occasionally, there may be injury or entrapment of the peripheral nerve as a result of soft tissue injury (Box 3-4).

Box 3-4

INJURY TO THE PERIPHERAL NERVE

- Grade I (neuropraxia)
- Sustained compression
- Intact axis cylinder
- Reversible neuronal signs and symptoms

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- Intact nerve conduction
- Grade II (axonotmesis)
- Endoneurium intact
- Axonal breakdown
- Wallerian degeneration sets in
- Good recovery but may not be complete
- Grade III (complete section of the nerve)
- Blocking of nerve conduction
- Both proximal and distal degeneration
- No recovery

Healing

- Rate of axonal growth: 1 mm per day
- Muscle proximal to the site of injury recovers first (motor march)
- Damage to the endoneural tube may result in neuroma

Nerve entrapment syndrome

Some extrinsic source may put pressure on the nerve at the point of its exit from the intervertebral foramina or a peripheral nerve may get compressed by a muscle belly or a tight fascia, e.g., median nerve in the carpal tunnel.

Pressure alters conduction along the largest fibres and along the

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smallest. The subjective and objective manifestation should be detected by clinical examination as well as by sophisticated electrodiagnostic tests.

Symptoms

1. Paraesthesia (pins and needles)

2. Dysaesthesia (altered sensation)

3. Pain

Pain is common in cases when the pressure is at the nerve root level. Pins and needles or paraesthesia are common in cases where the pressure is on the periphery of the nerve, e.g., thoracic outlet syndrome, ulnar nerve palsy and carpal tunnel syndrome.

The nature of pain is usually sharp, shooting and dermatomic. This pattern may change to a dull aching sclerotomic type when the large fibres cease to conduct and the small unmyelinated fibres are stimulated. This indicates that the pressure has progressed further.

The peculiarity of paraesthesia is that it may occur with the onset of pressure, or when the pressure is released, or both.

The earliest evidence of decreased conduction appears in the functions mediated by the largest myelinated fibres, which are most sensitive to pressure. Therefore, reduced vibration sense is the earliest clinical sign. If the pressure continues, there will be reduction or absence of deep tendon reflexes followed by muscular weakness. Finally, sensation will be reduced first to light touch and then to noxious stimulation. Because of the presence of multisegmental innervation to the muscles, skin and the overlapping dermatomes and myotomes, even completely severed nerve root may cause only minor sensory deficit.

Management

Once the diagnosis and the extent of injury to the nerve are established, the following appropriate therapeutic procedures should

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be initiated:

1. In case of sensory deficits, measures should be taken to avoid damage due to sensory loss.

2. Adequate static or dynamic splints may be necessary to avoid overstretching of the paralysed muscles and the concerned joint.

3. Immobilization, whenever given, should be critically checked to avoid undue pressure hindering the circulation. Also ensure that free passive ROM at the nonimmobilized joints is not blocked.

4. Re-education of muscles, affected by the nerve injury, should be started following nerve conduction test. Re-education may be done using various techniques like biofeedback, stimulation and PNF technique.

5. Passive ROM movements and methodology of self-active movements with a visual feedback should be taught to the patient to avoid joint stiffness.

6. The progress of the nerve should be assessed by electrophysiological tests. If the progress is not satisfactory, necessary action should be taken.

The management of common soft tissue injuries and disorders is enlisted in Box 3-5 on p. 44 and discussed in the chapter under respective heads. The common soft tissue involvements marked are discussed in this chapter.

Box 3-5

REGIONWISE LIST OF COMMON SOFT TISSUE INVOLVEMENTS AND INJURIES

Note: Individually they are as follows:

- Spine

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- Wry neck
- Low back ache
- Shoulder and shoulder girdle
- Adhesive capsulitis (periarthritis or frozen shoulder)
- Supraspinatus tendinitis or tear
- Rotator cuff tendinitis or tear
- Infraspinatus tendinitis
- Subscapularis tendinitis
- Long head of biceps tendinitis
- Subdeltoid bursitis
- Elbow
- Tennis elbow
- Golfer's elbow
- Olecranon bursitis (minor's elbow)
- Ruptured biceps tendon
- Wrist and hand
- Wrist sprain

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- Ganglion
- Carpal tunnel syndrome
- Dupuytren contracture
- De Quervain disease (tenosynovitis tenovaginitis)
- Trigger finger
- Mallet finger

- Pelvis and hip
- Iliotibial tract syndrome
- Piriformis syndrome

- Knee
- Ligament and meniscal injuries
- Quadriceps apparatus injury
- Quadriceps strain
- Hamstring strain
- Calf strain
- Patellar tendinitis
- Prepatellar bursitis

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- Plica syndrome
- Ankle and foot
- Ankle sprain
- Plantar fasciitis and calcaneal spur
- Tarsal tunnel syndrome
- Injuries to tendoachilles
- Metatarsalgia
- Morton neuralgia

Note: These injuries have been discussed in the respective regional chapters.

Injury to the blood vessel (box 3-6)

Blood vessels and the peripheral nerves usually run in close proximity to each other, and at certain sites, these are very close to the bones. Therefore, they always remain susceptible to injury, fractures or dislocations at these sites (Table 3-5).

Table 3-5
Possible Sites of Injury to the Blood Vessel and Peripheral Nerve

Injury and Site	Susceptible Blood Vessel	Susceptible Nerve
Fractures		
• Clavicle	Subclavian vessels	Brachial plexus
• Proximal humerus	Axillary vessels	Axillary nerve
• Shaft humerus	–	Radial nerve
• Supracondylar humerus	Brachial vessels	Median nerve
• Both bones of forearm	Anterior interosseous	–
• Monteggia	–	Posterior interosseous nerve
	–	

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• Hook of hamate • Wrist • Supracondylar femur • Proximal tibia • Both bones of legs • Ankle injuries • Neck fibula	– Popliteal vessels Posterior tibial vessels Posterior tibial vessels Posterior tibial vessels –	Ulnar nerve – deep branch Median nerve – Posterior tibial nerve – Posterior tibial nerve
Dislocations • Posterior dislocation of elbow • Hip joint (anterior) (posterior) • Knee	Brachial vessels Femoral vessels – Popliteal vessels	Lateral popliteal Median nerve Femoral nerve Sciatic nerve Common peroneal

Box 3-6

INJURY TO THE BLOOD VESSEL

- Grade I (contusion/haematoma)
- Blunt injury
- Patchy collection of blood and exudates
- Grade II rupture (partial)
- Associated with injury to the bone (e.g., fracture, dislocation)
- Pulselessness or doubtful peripheral circulation
- Cramp-like pain, pallor, paraesthesia, paralysis
- Grade III (complete rupture or total blocking of blood flow)
- Ischaemia to the muscles
- Uncontrolled bleeding
- Pulselessness

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- Blocking of the blood flow may result in serious consequences like MI internal thrombosis, neuromuscular necrosis, gangrene

Causes of vascular injury

■ Direct blunt injury

■ Compression by fractured bony fragment, tight bandage or haematoma

■ Reflex vasospasm

■ Incomplete or partial tear

■ Complete tear

■ Blockage due to callus, scar, internal thrombus or atherosclerotic plaque

Clinical features

Depending upon the type of injury, the clinical signs could be as follows:

■ Ecchymosis contusion and haematoma

■ Localized cramp-like pain, rapidly increasing swelling

■ Pulselessness

■ Paraesthesias

■ Paralysis

■ Pallor, cold extremities, muscle ischaemia (e.g., Volkmann

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ischaemic contracture – VIC) – grossly insufficient blood supply may lead to necrosis

Contusion: A blunt injury of mild intensity causes damage to the capillaries with extravasation of blood in the subcutaneous tissues. Normal flow of blood is affected because of the occlusion of capillaries and pressure of the swelling.

Ice massage, cold compresses and pressure bandages provide relief from pain and gradual reduction of the swelling.

Ultrasonic therapy is also very useful, its effect adjunct, lasting for 24–48 h.

Haematoma: Organization of haematoma occurs as a result of blockage in the blood and lymph vessels due to spasm, pain and compression of veins by congestion and is aggravated further by the lack of muscular action in the muscle facial pump.

A greater intensity blunt trauma may cause damage to the blood vessels within the intact muscle sheath (intramuscular haematoma).

If the muscle sheath is torn, the extravasated blood may seep in between muscles in a facial plane (intermuscular haematoma).

In intermuscular haematoma, bleeding continues for a longer period and the haematoma is diffuse. The extravasated blood shows discolouration beneath the skin.

Local pain, tenderness and impaired function due to pain are the presenting features.

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Treatment: Same as for contusion, takes longer for resolution, 48–72 h or more.

Diagnosis

Injury or obstruction to the blood vessel is confirmed by angiography or Doppler test.

Treatment

■ **Contusion**

■ Cold compression

■ Pressure bandage with limb elevation in a splint

■ Ultrasonic therapy

■ The tendency of acute flexion at the adjacent joints of the injured limb to be corrected

■ **Haematoma**

■ For subcutaneous intra- or intermuscular haematoma, the treatment is same as for contusion.

■ **Deeper trauma –** where the smooth flow of blood through the peripheral circulation is doubtful, but continuity of the vessel is maintained:

■ Exploration of the vessel

■ Release of vasospasm by sympathectomy, papaverine or xylocaine injection

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- Thrombectomy or segmental excision and anastomosis

- **Complete rupture of the vessel**

- End-to-end repair

- Grafting by using a vein or synthetic graft

- Graduated relaxed passive movements or active free movements progressing to full-range resistive movement are ideal

- Progressive functional training in a graded manner to avoid stresses on the end-to-end repair

Caution

- Watch for the return of pulse within an hour.
- Carefully observe for the return of the peripheral circulation. Cold extremities herald the onset of gangrene.
- Joint movements close to the site of injury must be conducted and progressed, with utmost care during the initiation of mobilization.
- Pain-free gentle isometrics performed often are important.
- Discomfort, which begins just before the pain, is an alarming signal to limit the ROM while conducting exercise training.

Injury to the bursa (box 3-7)

A bursa is a thin membranous pouch or a sac lined with synovial membrane. Its function is to prevent friction where two structures like tendons or bones are exposed to repetitive friction, a common cause of

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overuse injury.

Box 3-7

INJURY TO BURSA

Irritative bursitis (adventitious)

- Excessive repetitive pressure friction or trauma
- Pain
- Tender red and hot localized swelling

Infective bursitis

- Infective, inflammatory or metabolic disorders
- Antibacterial drugs

Chronic bursitis

- Excision
- Drainage
- Local infiltration, modified footwear

Adventitious bursae

- Medial side of great toe
- Ischial tuberocity

True bursae

- Subacromial
- Elbow

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- Knee
- Heel

Functions

- To protect tissues from undue pressures, trauma and their wear and tear
- To protect common expected repetitive frictional sites like acromion, elbow, knee and heel

Besides these true bursae, false bursa or so-called adventitious bursa appears due to external trauma or excessive one-point pressure where inflammation sets in causing the typical signs of acute inflammation.

Cause of bursitis

- Trauma – may be a single blow or a repetitive one
- Infection – acute or chronic (TB)
- Metabolic disorders like gout
- Abnormal external pressures – ischial tuberosity of hip
- Inflammatory disorders – classical example is that of rheumatoid arthritis
- Unaccustomed activity – ill-fitting foot wear causing excessive tightness at certain points where the bone is close to the skin, e.g., olecranon bursitis

Injuries of the musculotendinous complex

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The musculotendinous complex may be injured at the following sites:

(a) Musculoperiosteal junction

(b) Musculotendinous junction

(c) Tendoperiosteal junction

(d) Tendon itself

In a majority of injuries, the common cause is indirect injury where continuity is maintained. These injuries are treated conservatively. Rarely, the continuity of a tendon may be disrupted due to a cut injury.

Clinical features

Localized pain, tenderness, swelling and functional impairment are the usual presenting features. Attempted movements are extremely painful, and the degree of loss of function depends upon the severity of injury.

Treatment

Tendon repair is indicated in the instances of cut injuries.

Tendency for adhesion formation after repair restricts tendon excursion because of the following:

- Proliferation of fibroblast and vascular elements damaged at the time of injury.
- Transformation of the resting tenocytes into tendoblasts within the cut ends of a tendon.

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This requires specialized splinting and therapeutic approach of controlled movements to restore normal excursion of the repaired tendon (see Chapter 34).

Note: Resistive movements in the antagonistic direction, assisted active movements in the agonistic direction and performance of maximal relaxed stretches in both agonistic and the antagonistic directions provide ideal environment for early and complete recovery of the musculotendoskeletal injuries. If painful, emphasize pain-free isometrics.

Rare soft tissue injuries

- Fibromyalgia
- Fibrositis
- Haematoma

Fibromyalgia

Fibromyalgia is a common rheumatological disorder, which can easily be distinguished because of its symptoms. It is present with multiple tender and painful points all over the body without any fibrous nodules.

Incidence

- Overall 2.5%
- About 8–10 times more common in women than in men

Causes

- Any condition that lowers the endurance of a muscle
- Irritable bowel syndrome

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- Dysmenorrhoea
- Psychological disturbances
- Hypo- or hyperthyroidism
- Trauma
- Infection
- Connective tissue disorders

Clinical symptoms

- Stress due to widespread painful tender points
- Early fatigue and discomfort
- Restricted movements at the joints
- Chest and abdominal pains

Diagnostic criteria

- Widespread extraordinarily sensitive and tender trigger points
- Lack of sustained muscular activities
- Longer lasting widely distributed tender points lasting even for several months
- Tenderness in the joints
- Family history of fibromyalgia symptoms, rheumatoid arthritis and lupus
- Develops a typical vicious circle of pain cycle. Pain reduces activity – weakens muscles, require extra efforts to perform ADLs, which

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results in pain

- Past history of several unsuccessful therapeutic interventions.

Treatment

Essentially multidisciplinary approach is required.

Initially, the following should be performed:

- Physiotherapy in the form of thermotherapy by soothing superficial procedures alternated with deep and penetrative modes like SWD, insonation, TENS over the acutely painful points
- Soothing massage, followed by active, relaxed, free exercises to be initiated and progressed as the pain eases out
- Encourage and assist the patient in performing low-grade functional activities

Multidisciplinary approach

- Psychotherapy: To reduce stress
- Injection therapy
- Dry needling over the tender points
- Injecting normal saline
- Local anaesthetic injections
- Steroid injections may be helpful in reducing pain and

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tenderness

- Diet therapy: Rich protein diet, with amino acids and minerals
- Yoga therapy: To reduce stress
- Acupressure: Over specific tender points, to reduce pain, is safe
- Hypnosis

Fibrositis

Some muscles have a tendency to develop localized small but firm and tender fibrous nodules. It is a nonspecific entity of unknown aetiology.

Characteristics of nodules

They are palpable and intramuscular, small sized, immovable but painful nodules developed in the belly of certain muscles.

They are nonspecific and develop in certain muscles like trapezius, lower lumbar area and around the posterior iliac spines (commonly present in patients with low back ache).

They are harmless and do not present any functional impairment.

Treatment

- These nodules respond very well to hydrocollator packs, ultrasonics, localized friction massage and SWD.
- Rarely, localized steroid infiltration may become necessary.

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Haematomas

Collection of blood in the body of the muscle itself or in between the muscles is termed as haematoma.

Intramuscular haematoma

- The blood gets organized within the muscle bound by an intact muscle sheath.
- Bleeding takes places within 2 h of injury and stops, giving rise to localized haematoma.
- There may be a localized swelling.

Intermuscular haematoma

- The tears in the muscle sheath result in extravasations of blood between the planes of muscle and fascia.
- The haematoma is deep and more diffused causing discoloration beneath the skin.
- There is moderate pain and tenderness over the haematoma.
- The discoloration takes place within first 48 h of trauma, confirming the diagnosis of intermuscular haematoma.
- Swelling may be present over the localized site of injury or else due to gravity, sometimes. It may track down and present away from the site of injury.
- Generally, there is no loss of function if it follows grade I strain, but in muscle injury, if it follows grade II and III strains, there is possibility of loss of function.

Treatment

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- The first objective is to control any further bleed
- Give rest to the part
- Apply the principles of RICE with appropriate orthosis, if necessary

Musculoskeletal disorders

In musculoskeletal disorders, the aim is to provide optimal functional independence within the limits of the disability and the disease. The physiotherapist has to use various methods of assessment to reach the diagnosis and then plan the education of the patient on self-performance of simple but specific exercises. The patient performance has to be supervised and initially, the therapeutic programme has to be personally conducted. The therapeutic regime is reviewed at regular intervals to make necessary alterations to suit each patient.

This involves the following:

1. Assessing the exact nature and extent of the lesion

2. Recording of qualitative and quantitative data by a thorough examination to diagnose the cause, extent and effects of the dysfunction

3. Accurately assessing the extent of the disability and its impact on the functional activities of occupation, house tasks and hobbies

4. Planning of the therapeutic programme on an individual basis by methodical interpretation of the data of examination

5. Carrying out the planned therapy and making suitable alterations, whenever necessary

6. Objective recording of the patient's progress at regular intervals and also the subjective response of the therapy is important to decide and plan the future course of management

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7. Discharging advice with education and guidance to avoid recurrence

8. Regular follow-up reassessment and advice

Physiotherapeutic management should not only be disability oriented but has to be pathology oriented also to resolve both the factors for an optimal recovery.

Pathology of dysfunction

A homeostatic mechanism is responsible to maintain a perfect balance between the processes of tissue breakdown and repair. The body tissues suffer breakdown due to stresses, whereas repair occurs through the formation of new tissue. The body continuously tries to maintain perfect balance between these two processes which occur as a result of normal daily use. Any imbalance results in musculoskeletal dysfunction or disorder. This imbalance could be as follows:

1. Increased rate of tissue breakdown

2. Decreased rate of tissue breakdown

3. Increased rate of tissue production

4. Decreased rate of tissue production

1. ***Increased rate of tissue breakdown***

When the rate of tissue breakdown exceeds the rate of tissue repair, excessive stress level leads to hypertrophy of the tissues, e.g., repetitive loading results in hypertrophy of muscle. Similarly, a well vascularized bone will hypertrophy; however, excessive stress on the bone may lead to a stress fracture.

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The articular cartilage, which is poorly vascularized and has a lower metabolic rate, tends to break and degenerate under the conditions of stress.

Therefore, when excessive tissue is of the same nature as the original, the function improves (e.g., muscle hypertrophy following regular sessions of PRE). However, if the repair is replaced by a different type of tissue, it will result in deficiency in a regular function (e.g., formation of excessive collagen will lead to lack of extensibility resulting in partial fibrosis of the joint capsule).

The therapeutic programme needs to be planned in such a way that it is sufficient to promote the process of repair. It should neither be too aggressive to disturb the repair, nor too inadequate to facilitate the process of repair by tissues other than the original one.

As circulation plays a predominant role in the process of tissue repair, dysfunction at the sites where the tissue is poorly vascularized or has a low metabolic rate needs to be handled before further breakdown takes place. Circulation is augmented by limb elevation, deep heating procedures or resistive exercises to the adjacent muscle groups, but at the same time early stress on loading exercises is contraindicated.

A classical example of this is supraspinatus tendinitis. The rate of breakdown at the insertion of this tendon exceeds due to fatigue and reduced vascularity. The body compensates its inability to produce new tendon by causing calcification. When exercise or activities causing

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extra stress, like shoulder abduction against gravity, are performed, partial rupture may progress to complete rupture.

2. ***Decreased rate of tissue breakdown***

Immobilization always brings about a decrease in the rate of tissue breakdown due to decrease in stress. This sets in the disuse atrophy of muscles, ligaments, joint capsules as well as the bones.

The approach of physiotherapy should be to impart some stress on the immobilized tissues. Proper training of isometric exercises, vigorous exercises to the joints adjacent to the immobilized joints and early initiation of whole body movements, e.g., transfers, protected standing and early initiation of functional activities, are required.

3. ***Increased rate of tissue production***

The process of repair following inflammation may lead to the excessive proliferation of collagen tissue. The new collagen tissues may be laid in abnormal patterns resulting in interfibre crosslinks. This increased rate of collagen formation in the immobilized joint results in loss of extensibility leading to painful and/or stiff joints. Asymmetrical collagen with interfibre crosslinking may result in the loss of the normal groove and also the character of movement.

4. ***Decreased rate of tissue production***

Here the process of tissue repair is prolonged due to a

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decrease in the rate of tissue production. Change in the metabolic status is the basic factor. The tissue equilibrium is destroyed due to abnormal hormonal levels, nutritional deficiencies or reduced vascularity. These types of imbalances are complex in nature and cannot be improved greatly by physiotherapy. However, general toning of all the body systems through safer limits of exercises could be contributory. Advice on the measures to protect the tissue from further damage is also necessary.

Postmenopausal osteoporosis in the cancellous bones is an example of alteration in the hormonal level. Repetitive stress on the osteoporotic bones could be harmful. Strong repetitive trunk flexion exercises to relieve back pain have been shown to produce compression fractures in the spine of women with postmenopausal osteoporosis (Sinaki, 1982; Sinaki and Millkclsen, 1984).

Examination of musculoskeletal dysfunction

Accurate, subjective, as well as objective critical examination of a patient is important to the diagnosis and hence is key to successful management. The process of examination falls into four stages:

1. Subjective examination

2. Objective examination

3. Functional examination

4. Psychological and vocation-oriented assessment

1. ***Subjective examination***

The subjective examination is basically history taking. The

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clinician aims at collecting data from the patient which are relevant to the dysfunction.

(a) Patient's own assessment of the dysfunction and the major problem (self-perceived)

(b) When and how did the dysfunction start?

(c) Site, time, quality and behaviour of pain

(d) Previous history of such dysfunction and how it was controlled

(e) Factors aggravating and relieving the symptoms

(f) Any associated symptoms or the history of associated disease

(g) General health of the patient

(h) Influence and the extent of disability on the patient's functional activity

Assimilation of the subjective data is important to interpret and arrive at the diagnosis and the intensity of the patient's problem. Also, it is vital to plan the exact therapy and judgement of the patient's response to therapy.

Symptom-provoking or -relieving diagnosis and therapy-oriented selective tension test

Selective tension test to localize the focus of a lesion:

■ Selective passive tension is applied carefully with

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adequate stabilization – provokes or recreates the patient's symptoms or may help in alleviating or providing relief to the symptoms.

- It helps in detecting whether the lesion is present within the inert joint structures like bone, joint capsule, ligaments and fasciae, or whether it is localized to the contractile unit.

Besides, it is extremely beneficial in formulating the suitable therapeutic prescription.

Observation

As the patient walks in, critical observation related to his/her overall problem should be done. This will give the first impression of his/her posture, ambulation and major impact of the dysfunction, along with most conspicuous skeletal deformities.

2. ***Objective examination***

Objective examination is a test of the knowledge and skill of the physiotherapist. It needs correct methodology and knowledge of the following:

(a) Surface anatomy of the human body bony landmarks (Table 3-6)

(b) Anatomical configuration, alignments of bones and joints

(c) Range and anatomical limitations, the patterns of restriction of movements and end feel of a joint

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(d) Biomechanics of movements

(e) Correct evaluation of the tone, strength, power, endurance and flexibility of the required muscle groups; degree of neuromusculoskeletal coordination can also be assessed

(f) Active as well as passive JROM

(g) Diagnostic procedures and tests and their appropriate interpretation related to the objective evaluation

(h) Components and neuromusculoskeletal demands of the functional activities

(i) The knowledge of pathology, physiology, anatomy, kinesiology, clinical course and the prognosis of a disorder is a must

Table 3-6

Key Bony Landmarks

Spinous process	Iliac crests
Scapular border	Anterior and posterior
Mastoid process	Iliac spines
Clavicle	Ischial tuberosities
Acromial process	Greater trochanters
Greater tubercle	Adductor tubercles
Olecranon	Patellar borders
Humeral epicondyles	Tibial heads
Radio ulnar styloid process	Malleoli
Lister tuberosities	Talar heads
Carpal bones	Navicular tubercles

Objective examination includes analysis of the following:

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1. Inspection and palpation
2. Evaluation of movements:
   (a) Active
   (b) Passive
   (c) Resistive
3. Neuromuscular tests

1. **Inspection and palpation**

   (a) Examination of the bones and their structural alignment is done to detect any malalignment, tenderness or enlargement.

   (b) When suspected, measurement of the limb length disparity is done.

   (c) Girth measurement or volumetric measurements are done at specific locations from the bony prominences to assess any muscular hypertrophy, atrophy, oedema or effusion.

   (d) Subcutaneous soft tissues are palpated for generalized or localized oedema or effusion, tenderness, articular effusion, hypertrophy or atrophy. It is necessary to examine for the presence of cyst, nodule or ganglion.

   (e) Muscle joints, ligaments, tendon sheaths are examined for tenderness, malalignment, synovial hypertrophy, sensory impairment, crepitus, etc.

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(f) The skin and nails are examined for the presence of temperature alterations, vascular changes like erythema, cyanosis, pallor, moisture or dryness, atrophy, scaling, scars, ulcers and infection. If skin lesion is present, it should be documented by size, location and the stage of healing.

(g) Loss of tissue continuity, if present, should be documented.

(h) Examine resting pulse rate, pulse rhythm and the cardinal signs of any inflammation.

2. **Evaluation of movements (selective tissue tension tests):** Active, passive and resisted movement tests are the specific means of detecting the nature and extent of pathology.

Active movement tests are as follows:

- Accurate assessment of the active ROM as well as the strength of related muscle groups is objectively recorded by goniometry and muscle testing (MMT) procedures.

- The presence of pain, crepitus or any other symptom is noted.

- The degree of pain is evaluated by using visual analogue scale; although it is more or less subjective. It is useful to know the progress in the absence of any objective pain index test.

- The presence of fine crepitus indicates early wearing of the articular cartilage or a tendinous problem. More coarse

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crepitus indicates considerable degeneration of the cartilage.

- Painful arc or sudden weakness in the portion of the arc will indicate tendinitis (as in supraspinatus tendon).

- Gentle overpressure may be applied to assess the effect of stretch at the terminal range of the movement.

- Active movements are also tested to evaluate the strength, endurance, flexibility, coordination, speed and agility.

- Manual muscle testing (MMT) is an important test to evaluate the muscle strength.

Passive movement test – pattern of restriction:

- Passive movement is tested in its full or available range in all the planes and axes of a joint. The patient should be relaxed to the maximum and proper stabilization to the bone adjacent to the joint to be tested must be assured.

- When properly done, it can provide an important clue to the nature and extent of the disorder. Passive ROM, could be normal or in excess (indicating hypermobility), or restricted. When restricted at the end of passive ROM, gentle overpressure is given to assess the end feel.

- The restriction of passive (JROM) could be (a) capsular or (b) noncapsular.

  (a) ***Capsular restriction***: It indicates the loss of mobility of the entire joint capsule. In the capsular pattern of

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restriction, only certain movements are restricted. This provides guidance to detect the capsular pattern of restriction. The capsular pattern of restriction of the major joints of upper and lower extremity is illustrated in Table 3-7.

The capsular restriction may follow acute trauma inflammation or effusion to the joint. It may be present following long immobilization, arthritis or degenerative joint disease.

(b) ***Noncapsular restriction:*** There is abrupt restriction of ROM due to intraarticular mechanical blocking, or extra-articular lesion. The limitation of movement may be present in only one direction.

Capsular adhesions or even adherence of an isolated ligament during healing (following injury) may cause noncapsular restrictions (e.g., anterior capsular tightness resulting in loss of external rotation following anterior dislocation at the shoulder, or limitation of knee flexion due to the adherence of medial collateral ligament to the medial femoral condyle following knee sprain).

Mechanical blockage may be due to the torn meniscus or a loose body which may get displaced into the joint, blocking joint movement (e.g., locking of the movement of knee extension with free flexion following bucket handle tear of medial meniscus).

Extra-articular soft tissue tightness may result in reduction of the JROM from fibrosis or myositis.

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Extra-articular effusion or inflammation accompanying bursitis may also give rise to noncapsular restriction.

End feel: End feel is a test carried out at the point of restriction of the passive ROM of a joint. It is done by applying gentle overpressure at the end of the passive JROM. The end feel may be normal or pathologic.

Types of end feel

- ***Soft tissue approximation end feel:*** The end feel is soft and rubbery as there is approximation of the normal muscular tissues providing resistance to further JROM. When there is significant muscular hypertrophy, this end feel is felt earliest in the JROM; this apparently reduces the normal ROM. Therefore, it is customary to compare ROM on contralateral joints.

- ***Capsular end feel:*** A firm and leathery feeling without any effusion or inflammation indicates the presence of capsular fibrosis.

- ***Bony end feel:*** An abrupt end feel which fails to yield further ROM, locking the joint totally, is typical of bony end feel. It may be present following malunited fracture or in hypertrophic bony changes following degenerative joint changes.

- ***Pathologic end feel (muscular spasm end feel):*** Abrupt resistance with rebound to the passive range may be encountered in its arc due to reflex contractions in the muscle. However, further ROM is possible with little extra

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pressure. When it is present with a capsular pattern of restriction, synovial inflammation of part of joint capsule may be suspected.

- ***Boggy end feel:*** It is a soft and mushy end feel associated with joint effusion. It may be accompanied frequently by the capsular pattern of restriction.

- ***Internal derangement end feel:*** Loose body in the joint or displaced meniscus results in a mechanical block to the passive ROM. This offers marked springy rebound at the terminal point of ROM. The pattern of restriction is invariably noncapsular.

- ***Empty end feel:*** The movement is suddenly stopped, not due to restriction but because of severe pain. It is noticed in painful extra-articular lesions (e.g., bursitis, neoplasm).

Pain and mobility: The presence or absence of pain and the extent of mobility provide useful guidance in detecting the lesions of the articular capsule and the major ligaments of a joint.

Pain at the extreme ROM: Pain is elicited as a result of stretching of the painful structure itself. The lesion may be either musculotendinous or capsuloligamentous in origin. However, the movement, when resisted, will be painful in musculotendinous lesion, whereas it would be pain-free in a capsulotendinous lesion.

Painful arc: Pain is felt only during a certain small part of the arc of ROM. This occurs when a painful structure is

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temporarily squeezed at a particular part of ROM in extra-articular lesion. Pain disappears instantaneously as soon as the movement is progressed further, when more pressure on the painful structures is relieved.

Passive joint play: Systematically performed passive joint play movement test produces stress on capsuloligamentous complex. Positive passive joint play (eliciting pain) test indicates the presence of lesion of the major ligaments or the joint capsule.

Mobility of a joint: The passive mobility of a joint may be affected either way. It may be in excess of the normal ROM (hypermobility), or less than the normal ROM (hypomobility).

Hypermobility is present when there is loss of continuity, e.g., partial or a complete rupture of muscle, tendon or a joint ligament.

Hypomobility indicates fibrosis. Fibrosis may occur due to adhesions, low-grade inflammation in the adjacent tissues, due to excessive collagen formation, localized protective muscular spasm following acute inflammation or chronic stress.

Interrelationship between pain and mobility can provide useful information on the probable cause and the type of dysfunction (Table 3-8).

Presence of crepitus: Crepitus may be felt on passive ROM of the joints of cervical spine, shoulder and knee

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(patellofemoral). This indicates the presence of degenerative joint changes.

Resisted movement tests: Interrelationship between pain and strength of a joint movement can provide guidance to detect the expected nature of the dysfunction.

The maximum resistance to the movement (isometric) is tested in the strongest part of the arc of ROM (outer part of middle range). It provides information about the optimal strength and efficiency of a particular muscle or muscle group. The degree of pain can give a clue to the nature of lesion including the neurological status (Table 3-9).

3. **Neuromuscular tests:** The detection of the site, nature and extent of neuromuscular deficit is done by using appropriate manual and neurophysiological tests. This includes the following:

(a) Test for strength, endurance, tone and flexibility of muscle groups and its objective documentation

(b) Test for the sensory status and its documentation on the body chart

(c) Diagnostic electrophysiological testing like EMG and nerve conduction tests to evaluate the neuromuscular status – EMG provides an excellent means of early detection of degenerative lower motor neuron lesion and also the first sign of reinnervation of a muscle

(d) Tests for the deep tendon reflexes

(e) Test for neuromuscular coordination, including fine and

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speedy coordination, is done for the upper extremity particularly in relation to hand function; in the lower extremity, the testing can be done by slow walking, fast walking and spot running

(f) Character of pain – Initially the pain is shooting, sharp, burning and dermatomic in nature; this pain may change to a dull aching sclerotomic type when the large fibres cease to conduct and the small unmyelinated C fibres are stimulated; this indicates an increase in pressure

(g) Testing balance; equilibrium – standing and balancing on an alternate leg

3. ***Functional examination***

This is done to assess the functional status of the patient. The functional efficiency is tested by recording the dexterity, speed and the overall functional capacity of the affected limb and the patient as a whole. The movement combination involved in the performance of the daily activities is critically analysed and recorded. Synchronized coordination and strength of all the four major components (shoulder, elbow, wrist and hand) and fine speedy coordination of hand along with the degree of trunk stabilization needs is assessed for the upper extremity. Gait, balance and various parameters of ambulation and the efficiency of adopting floor squatting and cross-leg sittings are evaluated in the lower extremities in relation to the patient's work requirements and daily routine. It will facilitate appropriate planning of therapeutic measures.

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4. ***Psychological and vocational assessment***

During the course of subjective and objective examination, it is extremely important to understand the general psychological getup of a patient. Information on the patient's state of mind, impact of disorder, understanding capacity and the will to get well are important. Similarly, vocational status and physical requirements of the job are necessary for the planning of the therapeutic programme. For the physiotherapy to be successful, it needs proper coordination of the body and the mind. It is a self-effort-oriented therapy basically involving physical exercise and the patient's voluntary efforts. Therefore, unless the patient is motivated enough, no physiotherapeutic procedure can be successful.

Table 3-7

Capsular Pattern of Restriction of Major Joints

Joint	Maximum Restriction	Moderate Restriction	Mild/No Restriction
Neck	Extension	Rotation, Lat flexion	Flexion
Shoulder	External rotation	Abduction	Flexion and internal rotation
Elbow	Flexion	Flexion	Extension
Forearm (distal radio ulnar joint)	–	–	Supination and pronation
Wrist		Flexion and extension	(equal limitation of ROM)
Thumb (trapeziometacarpal joint)	–	Abduction	Flexion
Metacarpophalangeal	–	Flexion	Extension
Interphalangeal	–	Extension	Flexion
Hip	Internal rotation, abduction	Flexion-extension	External rotation
Knee	Flexion	–	Extension
Ankle	–	Plantar flexion	Dorsiflexion
Subtalar joint	Inversion (varus)	–	Eversion (valgus)
Digits			

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MCP (great toe)	–	Extension	Flexion
MCP (toes II to V)	–	–	Flexion
IP joints	–	–	Extension

Table 3-8

Pain Mobility and Possible Lesion

Pain and Mobility	Possible Lesion
Pain-free, normal mobility	NAD
Normal mobility with pain	Minor sprain
Painless hypomobility	Contracture or adhesion of the involved structure being tested
Painful hypomobility	Painful guarding, it may be due to acute inflammation, sprain, tear or rupture
Painless hypermobility	Complete rupture of the structure with severance of pain conducting fibres
Painful hypermobility	Partial tear which exerts stress on some intact fibres

Table 3-9

Resisted Movement Test and the Possible Lesion

Pain and Strength of Resisted Movement	Possible Lesion
Strong and pain-free	No musculotendinous lesion orneurologic deficit
Strong but painful	Minor lesion of musculotendinousorigin
Weak and pain-free	(a) Complete rupture of the tested muscle (b) Some interruption of nerve supply to the muscle tested
Weak and painful	(a) Partial rupture of the muscle or tendon (b) Painful inhibition due to fracture or acute inflammation (c) Serious pathology like neoplasia may also be suspected

Diagnosis

Identification of the involved tissues can be determined by methodical analysis and interpretation of the subjective, objective as well as functional examination data. However, adequate knowledge of anatomy, kinesiology, biomechanics, physiology and pathology is necessary. At the same time, knowledge of aetiology, symptoms, clinical course and limitation of the disorder is absolutely essential to arrive at the possible diagnosis (Table 3-10). Records of clinical

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investigations and physical examination should provide further guidance to arrive at the final diagnosis.

Table 3-10

Characteristic Features of Clinical Examination and Probable Diagnosis

	Characteristic Features	Probable Diagnosis
1.	Structural deformity, joint play with passive movement at the site; acute inflammation and pain	Fracture, dislocation
2.	Boggy end feel with limitation of movement in capsular pattern	Synovitis
3.	End feel is empty and painful; local tenderness with limitation of joint movement in capsular pattern	Bursitis
4.	Painful but normal amplitude joint range with localized tenderness and mild effusion	Mild ligamentous sprain
5.	Joint play with pain and hypermobility	Severe ligamentous sprain
6.	Passive stretch or compression results in the joint giving way with hypermobility; pain may or may not be present	Complete ligamentous rupture
7.	Pain and early fatigue with strong resisted test to the involved musculotendinous structures	Minor lesion of tendon (tendinitis)
8.	Marked weakness; pain may or may not be present	Complete rupture of a tendon (e.g., tendoachilles rupture)
9.	Local tenderness, full passive stretching and resisted test to the muscle are positive with localized tenderness	Muscular strain
10.	Resisted test of strength is positive but pain-free; a gap in the continuity of a muscle may be visible with loss of function	Complete rupture of a muscle
11.	***Articular cartilage***: Presence of crepitus, broken cartilage present as a loose body, locking of the joint	• Degenerative articular changes • Late stage of degenerative joint disease • Tear of medial meniscus or entrapment of loose body in the joint
12.	***lntra-articular fibrocartilage:*** Clicking of the joint	Minor displacement of fibrocartilage (e.g., bucket handle tear)

General plan of physical examination and evaluation

The patient should be examined with minimum inconvenience. The examination should be organized in such a manner that all the possible tests in a particular body posture are done at the same time.

From the data of the basic subjective and objective examination, the physiotherapist should be able to identify the major areas of emphasis. The general plan of examination is detailed to provide the

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necessary guidance.

A general plan of physical examination in various fundamental body positions is as follows:

A. ***Standing***

1. *General observation:* The posture is observed from the front, behind and the side for any conspicuous structural deviation from the normal:

(a) Shoulder levels

(b) Spine

(c) Pelvic level

(d) Alignment of hip, knee and ankle joints

2. *Observation of the gait pattern:* The gait should be observed from the front, back and sides for any deviations in the average speed, cadence and the pattern.

3. *Observation of the ROM:* Wherever possible, overall range of active movements can be judged in some of the major joints by observation.

4. *Muscle power*: Generalized evaluation of the strength of important muscle groups can be assessed by observing simple movements.

5. *Functional test*: Functional test checks the ability to adopt floor squatting and cross-leg sitting. Double-leg balancing, single-leg balancing, spot marching or double ups and hopping should be tested to assess the efficiency

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or the level of neuromusculoskeletal control and coordination.

Gait analysis is discussed in a separate chapter.

B. ***In sitting position***

1. *Evaluation of ROM*: The neck, upper extremity, back and the lower extremity joints to be tested for ROM and strength

2. *Dural mobility*: Knee extension, ankle dorsiflexion, with neck flexion (slump test)

3. *Reflexes*: Knee jerk and ankle jerk

4. *Evaluation of strength*: The degree of resistance can be tested for movements of the neck, upper extremities, trunk, hip flexors, knee extensors (L3, L4 myotomes), resisted ankle dorsiflexion (L4 myotome), resisted dorsiflexion eversion (L4, L5 myotomes) and resisted great toe extension (L5 myotome)

C. ***Supine lying***

1. *ROM*: Evaluation of passive ROM for all the joints except hip and spinal extension

2. *Dural mobility*: SLR, with neck flexion

3. *Muscle strength*: Neck flexors, shoulder flexors, external and internal rotators, elbow flexors, abdominals

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4. *Reflexes*: Biceps, triceps, pronator–supinator and abdominal

5. Testing the sensory status over the anterior aspect of the body and limbs

6. Extensibility of the hip flexors, abductors, adductors, hamstrings and the gastrosoleus

D. ***Side lying***

1. *Muscular strength* of hip abductors on the same side and adductors of the opposite hip

2. *Extensibility* of the iliotibial band

E. ***Prone lying***

1. ROM of spinal extension, shoulder and elbow extension, hip extension and knee flexion

2. Strength of spinal extensors, hip extensors, hamstrings (S1, S2 myotomes) and soleus

3. Sensory status over the posterior aspects of the body

On the basis of the findings of examination and their critical evaluation, the therapeutic programme is planned to provide optimal functional efficiency to a patient.

The major parameters of evaluation and treatment planning are elaborated under each heading.

The general plan of treatment goals and strategies to be adopted for musculoskeletal disorders is summarized in Table 3-11.

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Table 3-11

Treatment Goals and Strategies for Musculoskeletal Disorders

	Goals	Strategies
Resolve	Acute symptoms; promote correct alignment and healing	Correct positioning, appropriate modality, immobilization, controlled movements, drugs and surgical procedure
Prevent	Soft tissue, joint contractures and recurrence	• Early guided movements • Education on conditioning exercise, guidance on body mechanics and dos and don'ts
Restore	• Muscle functions • Joint alignment and mobility • Muscular balances and movement control • Maximal functional independence	• Objective progressive exercise procedures to improve strength, endurance and flexibility of muscles • Surgical procedures, corrective exercise, orthotic or ambulatory aids • Specialized exercise techniques, education of patients on correct and controlled exercise training • Maximal physical independence through progressive exercise, ambulatory and other aids

Test to assess functional self-sufficiency: After arranging a general plan of physical examination in each fundamental position, a patient is guided and directed to perform each functional activity independently, e.g., assuming steady standing posture with both the legs placed wide, progressing to close-leg standing, momentary standing and balancing on an alternate leg. The skill and speedy coordination activities like spot-jogging and running are also tested.

The same pattern of graded exercises should be planned for other fundamental positions followed by tests. Specially planned exercise programmes should be arranged and undertaken for other activities.

Systematic musculoskeletal examination at a glance

- Demographic data: Age, sex, height, weight
- Social history: Family and support system at home and at the place of work
- Occupation
- Current
- Physical activity level involved in profession or

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occupation

- History: Onset of the present episode
- If the onset is traumatic, mechanism of trauma
- If the onset is nontraumatic, past history of onset, course of the disease and treatment
- Final outcome in both traumatic and nontraumatic incidences
- Residual or present physical problems

Examination by

- Inspection and palpation
- Skin, subcutaneous tissue for temperature, texture, oedema, continuity, scars and lumps
- Muscles, for tone, tenderness, trigger points, swelling and continuity
- Joints, for alignment and bones, tenderness, bursae, nodules
- Detailed examination of musculoskeletal parameters
- Tests of provocation
- Active ROM
- Passive ROM

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- Resistive ROM
- Special tests for the joints and muscle performance
- Neurological tests
- Key muscles
- Motor ability
- Sensory perception
- Nerve mobility, conductivity and control
- Functional performance test
- Functional efficiency of affected part and whole body
- Gait – stability, pattern, other ambulatory activities
- Body mechanics and related activities
- Upper limb functional performance
- Coordination, movement control, agility and skill
- Additional tests and investigation reports to ensure adequacy of exercise tolerance

Physiotherapist's skill in educating and guiding self-efforts and dependency

Soft tissue injuries in fractures

Fractures, whether closed or open, are associated with an injury to the

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soft tissues close to its site. The classification of soft tissue injuries in closed and open fractures is depicted in Table 3-12 as an important guideline to eliminate complications as a result of soft tissue injuries like:

- Risk of infection
- Delay in healing
- Compartment syndromes
- Contractures
- Nonunion
- Amputations

Table 3-12
Classification of Soft Tissue Injuries in Closed and Open Fractures

Tschernés Classification of Closed Fracture ST Injuries	Gastilo–Anderson Classification of Open Fractures ST Injuries
Grade I • No soft tissue damage • Indirect forces resulting in torsion fractures **Grade II** • Fracture fragment pressure from within may cause only superficial contusion or abrasion • Fracture may be of mild to moderate severity **Grade III** • A direct hit results in deep, contaminated abrasion with localized muscular or skin contusion • May have comminuted or segmental injury **Grade IV** • Extensive contusion of the skin with muscle • Associated with severe skin or muscle damage **Compartment syndrome is a common complication** • Crush injury may occur in muscles by direct injury or may have contusion	**Type I** • Wound of <1 cm • Minimal soft tissue damage, e.g., simple transverse or short oblique fractures with comminution **Type II** • Wound of >1 cm • Extensive soft tissue damage **Type III** • Extensive soft tissue damage and soft tissue • Unstable fractures with comminution • Associated with neurovascular injuries besides skin and muscles **Type III A** • Highly comminuted or segmental fractures due to high energy trauma; do not require free flaps **Type III B** • Extensive soft tissue injury with periosteal stripping exposing the concerned bone • Need debridement and irrigation; exposed bone requires local or free flap **Type III C** • Arterial injury needing urgent repair • Have high rate of amputation (25–90%)

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Chapter 4

Fractures (general)

Outline

■ Types of fractures

■ Diagnosis of fractures

■ Healing of fractures

■ Treatment of fractures

■ Complications of fractures

A fracture is defined as a break in the continuity of a bone. It is usually due to direct or indirect trauma. A fracture can be simple or compound, as described in the following sections. When it occurs in a diseased bone following a trivial trauma, it is termed as *pathological fracture*, e.g., fracture through a bone cyst or a metastatic lesion.

Types of fractures

A fracture can be of two types:

1. Simple or closed

2. Compound or open

Simple or closed fracture

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In this type, the fracture does not communicate with the exterior as there is no wound directly over the fracture.

Compound or open fracture

In this type, the fracture communicates with the exterior through a wound over the fracture. The management of compound fracture may pose problems of skin and soft tissue loss and subsequent infection, etc.

The following terms are used to describe a fracture (Fig. 4-1):

1. *Transverse fracture*: The fracture line is transversely placed. It results from a direct injury to the bone.

2. *Oblique fracture*: The fracture line is obliquely placed. An indirect injury causes this type of fracture, which is usually unstable and may need internal fixation.

3. *Spiral fracture*: It results from a twisting (rotational) force to the bone. The fracture line is spirally placed. Union in a minimally displaced or undisplaced fracture is faster since there is a large surface area of the fractured bone.

4. *Impacted fracture*: The fractured bone ends are driven into each other maintaining close approximation.

5. *Comminuted fracture*: The fractured bone is broken into more than two pieces. It occurs due to a direct injury.

6. *Segmental fracture* (double fracture): A bone is fractured at two different levels with a large segment of bone between

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the two fracture lines. The middle segment of bone may lose its blood supply resulting in nonunion at one of the fracture sites.

7. *Incomplete fracture*: Only one cortex of a bone is fractured without any change in the alignment of the bone.

8. *Greenstick fracture*: It is a variety of incomplete fracture seen in children. In this type, one or both cortices of a bone are broken, but since a periosteal hinge remains intact, the bone may be bent but there is no discontinuity.

9. *Compression fracture*: It is produced as a result of compressive forces on the bone. The bony mass gets compressed within itself. It is common in cancellous bones (e.g., vertebral body).

10. *Avulsion fracture*: Sudden contraction of a muscle, when it is not fully prepared to take it, may result in fracture, e.g., fracture patella due to sudden contraction of quadriceps femoris or contraction of the triceps resulting in fracture of the olecranon.

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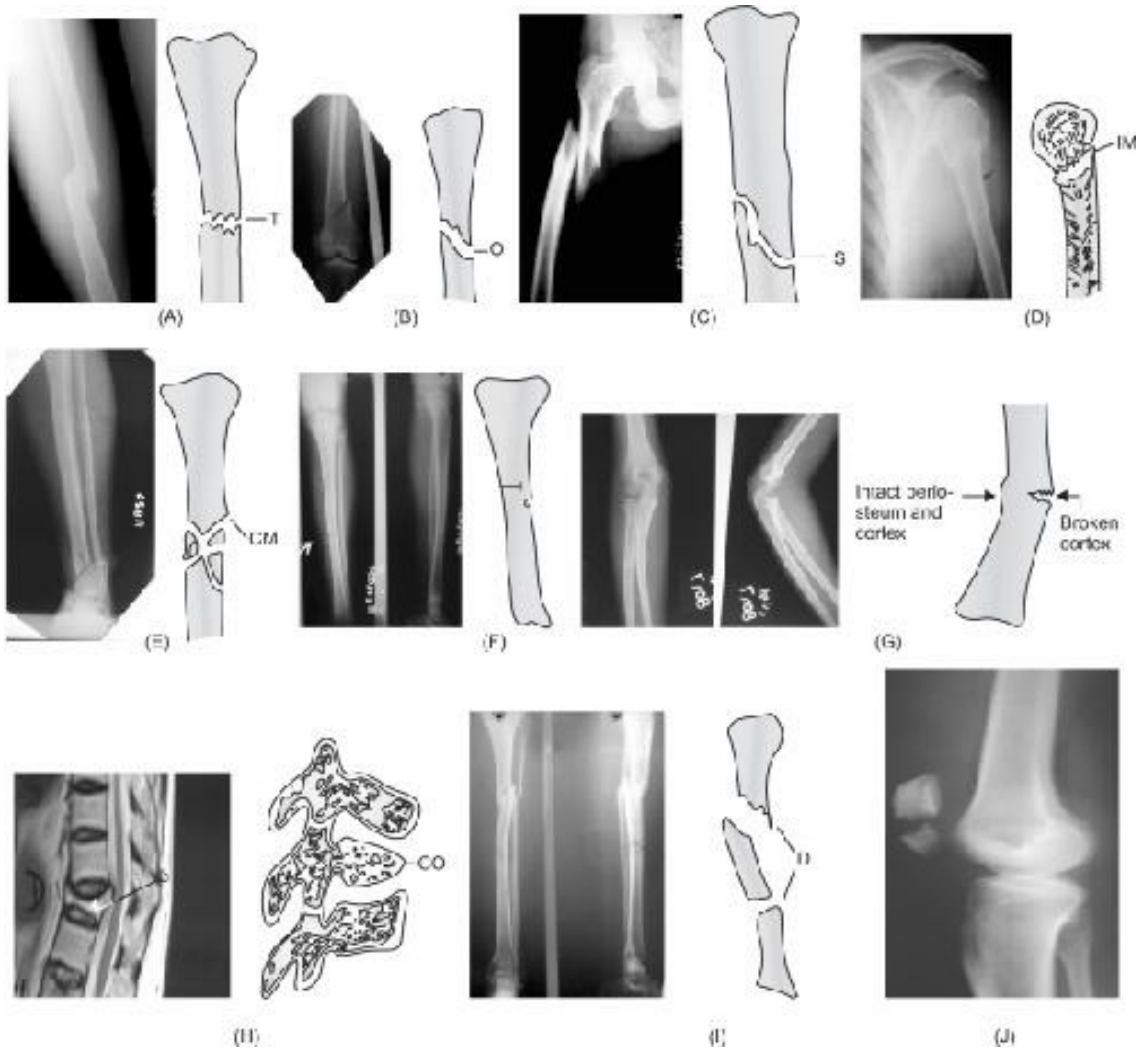

FIG. 4-1The common patterns of fracture: **(A)** T: Transverse, **(B)** O: Oblique fracture of radius and ulna, **(C)** S: Spiral, **(D)** IM: Impacted, **(E)** CM: Comminuted, **(F)** I: Incomplete, **(G)** G: Greenstick with broken cortex on one side, **(H)** CO: Compression vertebral fracture, **(I)** D: Double or segmental fracture of tibia, **(J)** AV: Avulsion fracture of patella.

Displacements

After a fracture, the bone ends may get displaced from its

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original position either due to a sudden pull of the attached muscle or due to gravity. The displacements are as follows (Fig. 4-2):

(a) Lateral, where the fragments of the fractured bone are displaced laterally

(b) Angular, where fragments of the bone may form an angle with each other

(c) Overriding, where the fractured ends overlap each other

(d) Rotational, where the fragments of the bone may be rotated in relation to each other

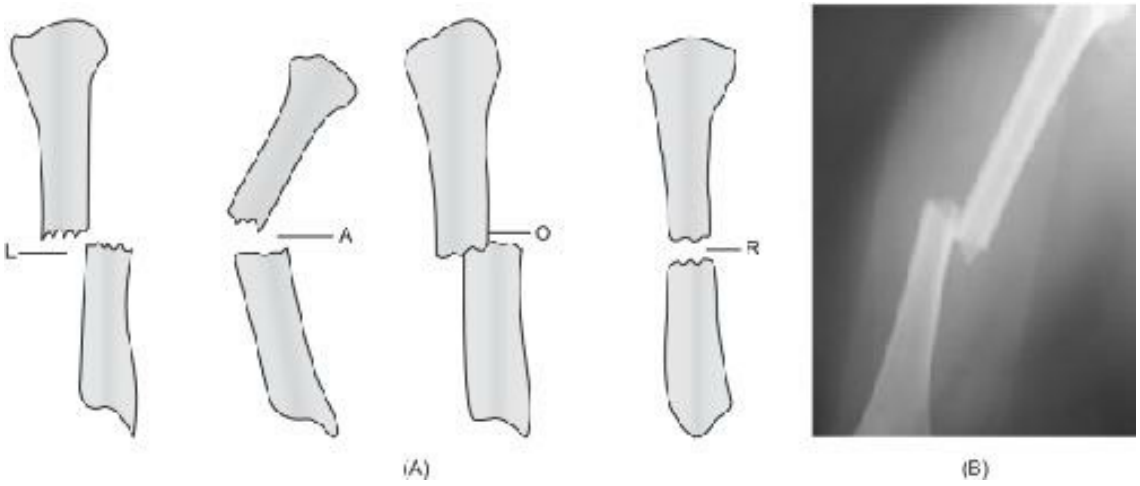

FIG. 4-2**(A)** Common displacements in a fracture: L: Lateral, A: Angular, O: Overlapping, R: Rotational. **(B)** Radiograph showing overriding, lateral displacement and angulation in a fracture shaft of femur.

Diagnosis of fractures

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The diagnosis can be arrived at from the following:

1. *History of sudden trauma* (except in pathological fractures), localized pain and bony tenderness are the definite features of a fracture.

2. *Symptoms*

(a) *Pain* is the most consistent symptom present in every fracture.

(b) *Localized swelling* occurs due to (i) haemorrhage from the fracture ends and injury to the surrounding soft tissues and (ii) inflammation within an hour of injury.

(c) *Deformity:* A deformity occurs in a displaced fracture or in a dislocation. Sometimes, the deformity is masked in the presence of profuse oedema.

(d) *Loss of movement*: In dislocation, no movement is possible at that joint. The function is also impaired in the joint or the extremity, itself.

(e) *Inability to use or bear weight*: In fractures or dislocations of the upper extremity, the patient is not able to use the extremity, whereas in the injuries of the lower extremity, the patient is not able to bear weight on the affected extremity.

3. *Signs*

(a) *Muscle spasm and tenderness:* Reflex muscular spasm appears in the muscle groups close to the site of fracture.

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(b) *Oedema*: The soft tissue injury accompanying fracture often results in haematoma, and oedema over the fracture site. The process of repair begins with inflammation.

(c) *Warmth*: There may be a rise in the local temperature due to increased vascularity to the area of injury.

(d) *Crepitus*: Passive movements over the fracture site produce grating between the broken ends which is called crepitus. It is, however, painful and therefore should be avoided.

(e) *Deformity:* Deformity is obvious in a displaced fracture. However, it may be missed in the presence of profuse oedema.

(f) *Abnormal mobility*: The diagnosis of a fracture is obvious when abnormal mobility is seen in the limb at the fracture site or swelling is present over the fracture site.

(g) *Ecchymosis:* This is commonly seen in the skin due to soft-tissue injuries around the site of the fracture. A common example is fractures of the proximal humerus, where ecchymosis is seen in the arm, axilla and even the chest wall.

4. *Investigations*

(a) *Radiography*: It is an important tool in the diagnosis of a fracture. Plain AP (anteroposterior) and lateral view radiographs are routinely done in every case. Sometimes, oblique views or special views are required in the diagnosis of difficult fractures.

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(b) *Computerized tomography (CT) scan*: CT scan is not routinely required in the diagnosis of a fracture. However, it is useful in the diagnosis of fractures of small bones (such as carpal bones) (Fig. 4-3A) and spine (Fig. 4-3B). 3-D (three dimensional) reconstruction of CT images helps in better evaluation of fractures (Fig. 4-4). CT scan also helps in deciding the treatment of a fracture since it gives minute details of the fracture fragments.

(c) *Magnetic resonance imaging (MRI) scan*: MRI scan gives a better delineation of the soft tissue, ligaments and bones. It is useful in showing changes in the soft tissue such as oedema, effusion and haematoma after trauma (Fig. 4-5). MRI of the spine shows status of the spinal cord and the surrounding soft tissue (Fig. 4-6).

(d) *Radioisotope scan or bone scan.* This is useful in the diagnosis and differentiation of various traumatic and nontraumatic conditions (Fig. 4-7).

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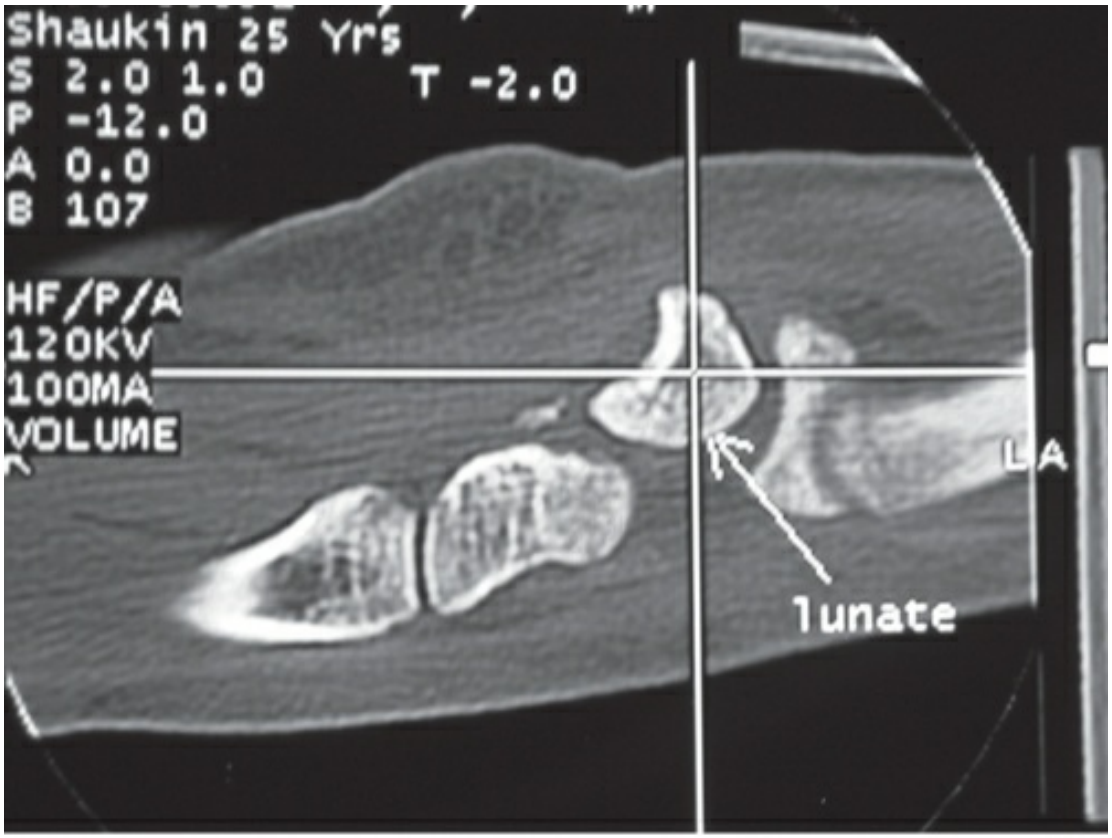
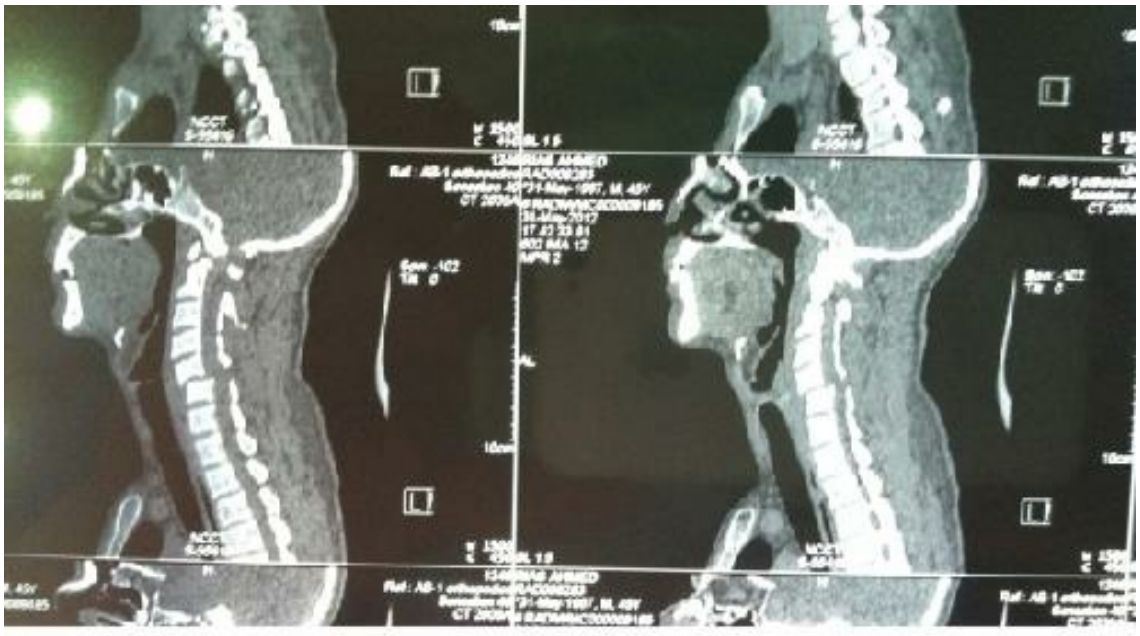


(A)



(B)

FIG. 4-3**(A)** CT scan showing disruption in the

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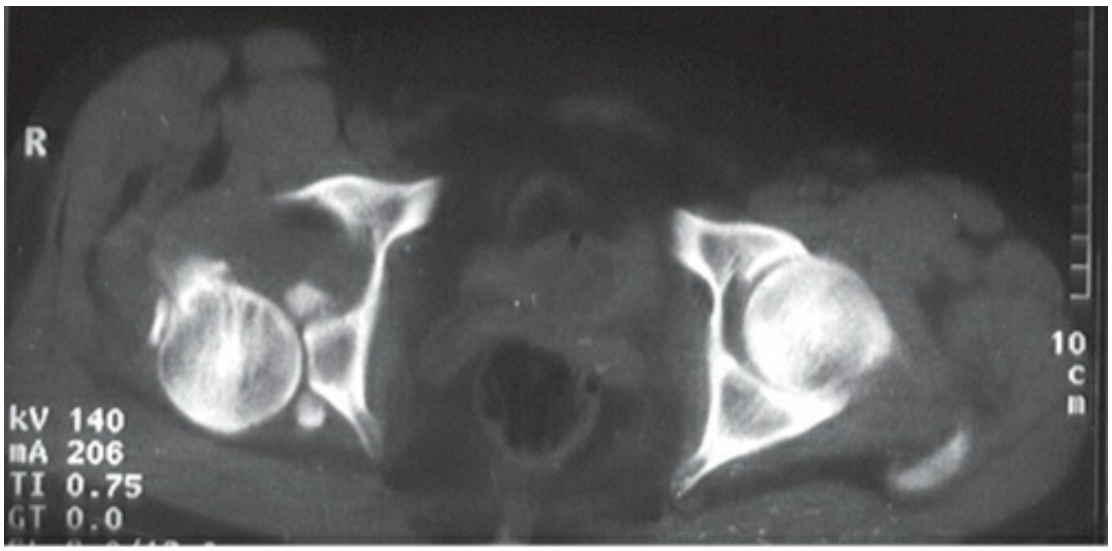
alignment of lunate and capitate resulting in perilunate dislocation. **(B)** CT scan of the cervical spine showing subluxation of C5 over C6 vertebrae.



(A)

(B)

FIG. 4-4**(A)** CT scan showing posterior dislocation of the right hip joint. Note the fracture of the posterior lip of acetabulum. **(B)** CT scan with 3-D reconstruction shows posterior dislocation of the femoral head.

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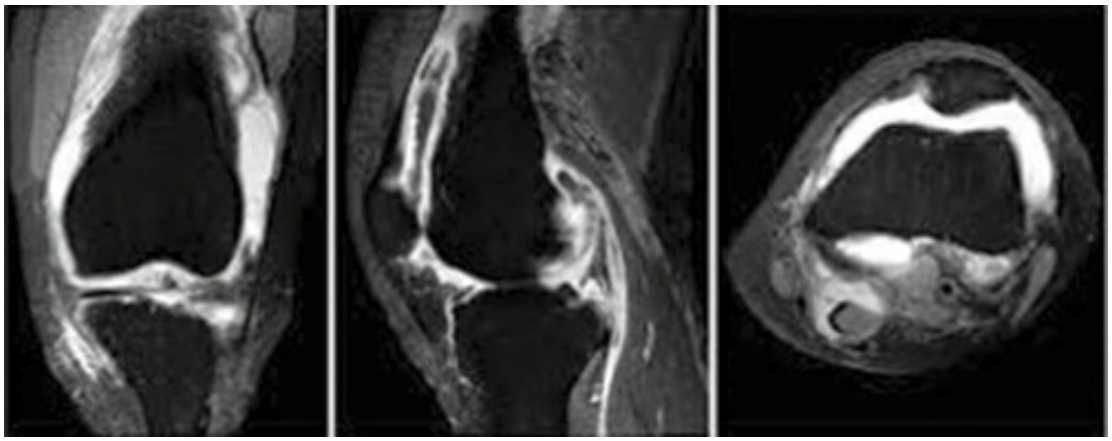

FIG. 4-5The various images of the MRI of knee joint showing gross effusion (seen as white).

FIG. 4-6MRI scan of a patient showing fracture dislocation of D8-9 vertebrae with compression of the spinal cord.

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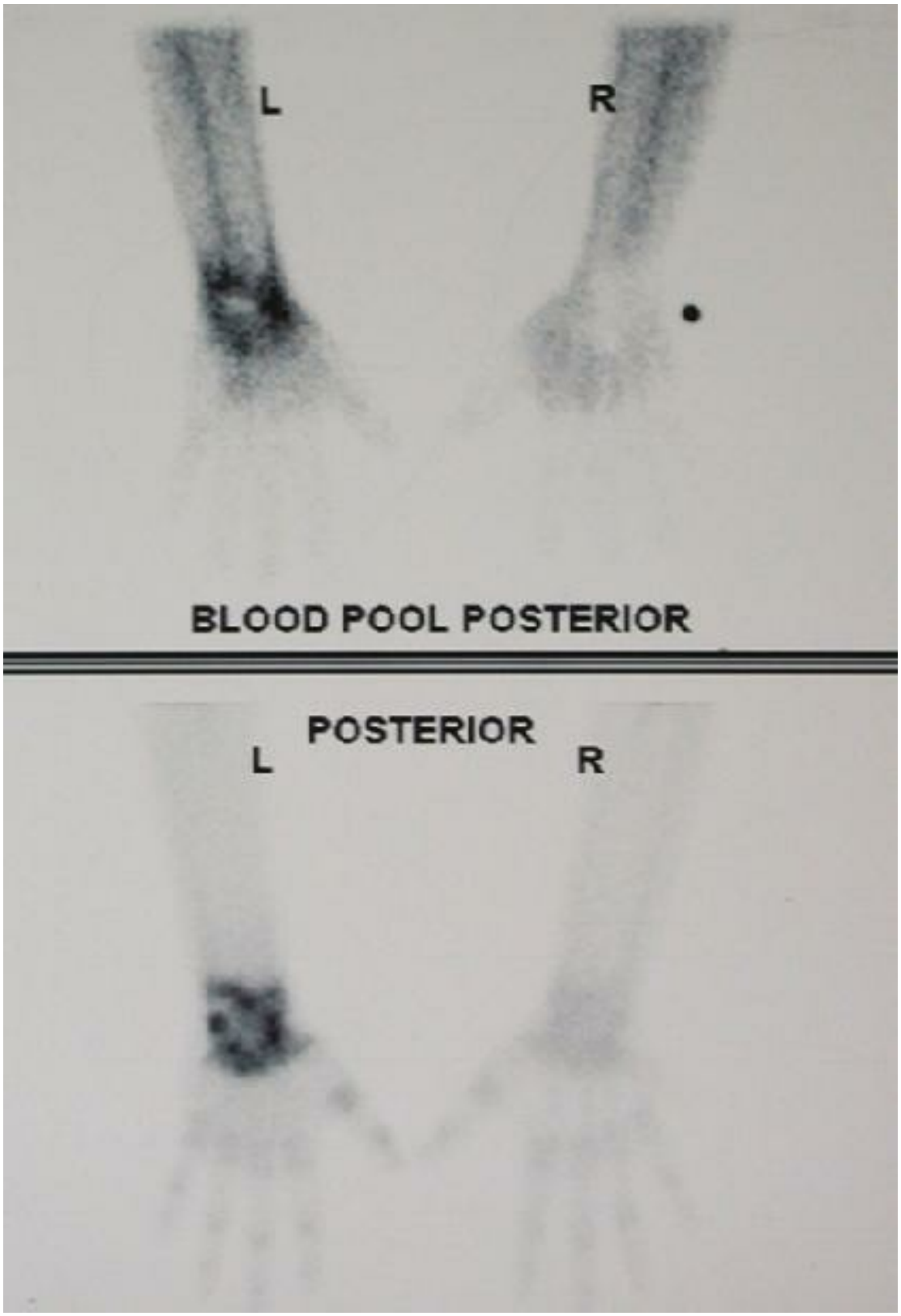

FIG. 4-7Bone scan showing increased uptake in the left

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wrist following trauma.

Caution

Epiphyseal lines in children and the adolescents, vascular markings, accessory bones may mimic the presence of a fracture or subluxation in a radiograph.

Healing of fractures

The healing of fractured bone occurs in three phases (Fig. 4-8):

1. Inflammatory phase

2. Cellular proliferation phase

3. Remodelling phase

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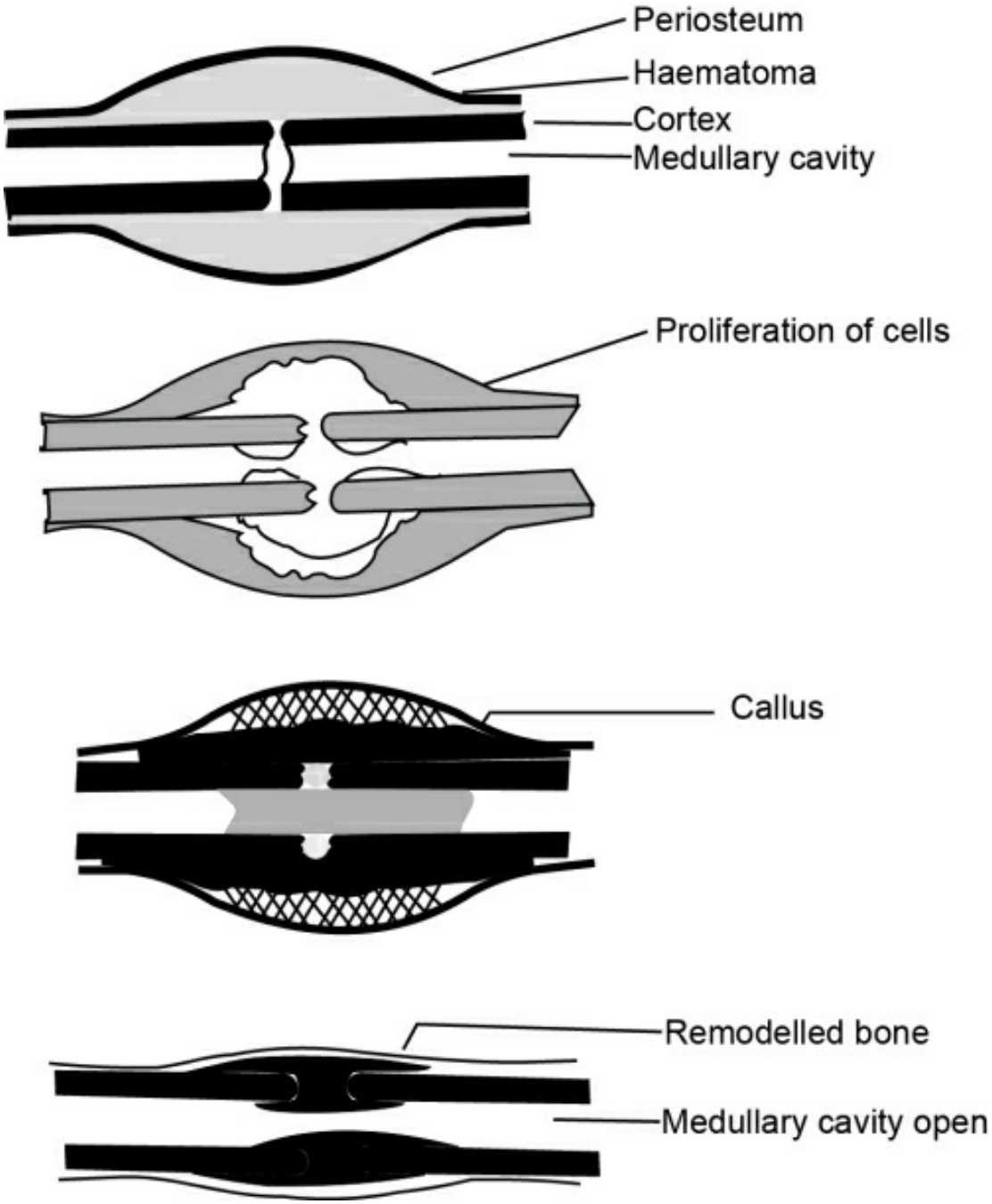

FIG. 4-8Stages of healing of the fracture.

Inflammatory phase

Haematoma (a clot) is formed between and around the broken bone ends. It follows vasodilation, release of protein

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and blood cells in this area. Histocytes, mast cells and polymorphonuclear leucocytes invade the toxic bacteria and clear the debris. New granulation tissue is formed due to cell proliferation between the bone ends.

Cellular proliferation phase

The granulation tissue thus formed between the bone ends bridges the gap between the fractured bone ends. The bone ends become rarified and calcium is laid down in the granulation tissue as callus. Similar activity goes on in the medullary cavity also. The external and the medullary callus may meet and unite the fracture. At this stage, the fracture is said to be united clinically, but it is not strong enough to be exposed to stress.

Remodelling phase

This is the phase of remodelling of the callus towards normal ossification. The soft callus gets consolidated by the deposition of bone salts. This is carried out by osteoblasts. The multinucleate osteoclasts then come into action and properly control the density of the new bone. The medullary cavity is reproduced and the marrow cells reappear. The process of remodelling ends by reconstruction of new bone similar to the one before injury.

The bone tissue always heals by forming new bone which has all the characteristics of a normal bone. Healing never occurs by scar formation like other body tissues.

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Union of fractures

The union of a fracture depends upon various factors; the important ones are as follows:

1. Type of bone and its thickness

2. Type of fracture

3. Extent of blood supply to the site of fracture

4. Position of the bony ends at the site of fracture

5. Age of the patient

1. ***Type of bone***

The cancellous bone has a wider surface area and abundant blood supply. Therefore, healing is quick. In the cortical bone (shaft of a long bone), the blood supply may be precarious in some areas; here the healing process may be slow.

2. ***Type of fracture***

Spiral or oblique fractures unite faster compared to transverse fractures (Table 4-1). Transverse fractures take nearly twice the time for union compared to spiral or oblique fractures. Upper extremity fractures heal faster than the fractures in the lower extremity.

3. ***Extent of blood supply to the site of fracture***

As the whole process of healing is the result of various

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events primarily occurring due to blood, healing directly depends upon the extent of blood supply to the site of fracture and the bone.

4. ***Position of the bony ends at the site of fracture***

For the union to be optimal and faster, proper alignment of the fractured bone ends is vital. Improper alignment results in delayed union, malunion, nonunion and their complications.

5. ***Age of the patient***

Age also plays an important role in the union of fractures. Fractures unite faster in children than in adults and may take longer in elderly patients. In children, there is a great potential to correct fracture displacement and even angulation to a certain extent by remodelling. Rotational malalignment, however, does not get corrected. In adults, on the other hand, it is essential to obtain a good reduction of fracture, as major displacements may not get corrected by remodelling.

Table 4-1

Approximate Time of Consolidation in Spiral and Transverse Fractures in the Upper and Lower Limbs

Type of Fracture	Upper Limb	Lower Limb
Spiral	6 weeks	12 weeks
Transverse	12 weeks	24 weeks

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Source: Perkins (1980).

Treatment of fractures

Newer techniques of treatment are added every now and then. However, the basic principles are as follows:

1. To achieve anatomical alignment of the fractured bone ends (reduction)

2. To ensure correct immobilization (maintenance of reduction), till the fracture unites

3. To reduce inflammation and pain

4. To provide necessary compressive forces to the embryonic callus and, at the same time, discourage stretching situations to this raw callus

5. To restore maximum possible functional independence to the patient as a whole and the fractured limb in particular

Fundamental stages of the management of fracture are (i) reduction, (ii) immobilization, and (iii) mobilization and rehabilitation (Table 4-2).

Table 4-2

Fundamental Stages of the Treatment of Fractures

Stage	Purpose	Methodology
Stage I	• To secure closest	• Manipulative

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Reduction of the fractured bones	apposition of fractured bony ends in the perfect anatomical alignment – at the earliest (at least within 48 h)	reduction under general or local anaesthesia • Open reduction and internal fixation (ORIF) in displaced or unstable fractures
Stage II Immobilization of a reduced fracture	• Ensures union of the fracture in perfect anatomical alignment • Reduces pain • Allows functional freedom to the fractured limb	• POP cast • Skin or skeletal traction • Open reduction and internal fixation (ORIF) • External fixation by applying external fixator
Stage III Mobilization of the fractured joint and the limb	• To restore maximum possible functional self-sufficiency to the patient by various physiotherapeutic measures	• Restoring normal ROM to the joint affected following immobilization • Achieve minimal possible required functional ROM

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		when a fracture involves a joint • Restore to the maximum all the functions of the muscles affected by fracture and immobilization • Training to use assistive aids for functional self-sufficiency • Use of specialized exercise techniques

Reduction

The aim of reduction is to achieve perfect anatomical alignment and length of bone. Reduction of a fracture could be (i) closed, where the alignment of fractured bony ends is achieved by manipulation, and (ii) open, where alignment is achieved by surgery.

Immobilization

Maintaining or holding the fracture reduction is important

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and can be achieved by immobilization. The methods of immobilization are as follows:

1. Traction

2. Plaster of Paris cast

3. Functional cast bracing

4. Internal fixation

5. External fixation

Traction

It exerts an axial pull while the countertraction localizes the effect of traction. The external traction force is provided by gravity, part of the body weight and pulley system. The internal force is generated by voluntary isometric muscle contractions or muscular spasm. Countertraction is provided by gravity or splint (Thomas splint – Fig. 4-9).

FIG. 4-9Thomas splint.

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Types of traction

Skin traction: Provides generalized pull to the whole limb (Fig. 4-10A). An adhesive bandage or foam is applied on the medial; a lateral aspects of the limb, and held in position by a tight bandage; a weight is suspended at the distal end through a spreader and rope. It is a noninvasive procedure and can be used where light traction is required, since it can take only up to 5 kg of weight.

(A)

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(B)

FIG. 4-10**(A)** Skin traction with spreader and weight. **(B)** Skeletal traction with Thomas splint.

Skin traction cannot be used in very elderly patients where the skin is papery thin and may be peeled off easily, and also in patients allergic to the adhesive bandage.

Skeletal traction: This traction exerts effective pull on the bone (Fig. 4-10B). A Steinmann pin or a Kirschner wire (also called K-wire) is passed through the bone (commonly through the upper tibia and lower tibia). A stirrup is applied over the pin/wire and the weight is suspended through a rope and pulley. Skeletal traction is used for giving heavy traction (up to 10–15 kg). It can be used in elderly patients. It is however an invasive procedure and can have the problems of pin traction infection, cut through the bone, or fracture. The common sites of skeletal traction are as follows:

■ Upper and lower tibia

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■ Lower femur

■ Calcaneum

■ Skull traction in cervical spine injuries (Fig. 4-11): The pins of the Crutchfield tongs are passed into the outer table of the skull in the parietal bone as shown in the figure. Weight is then suspended through a rope and pulley.

FIG. 4-11Skull traction by Crutchfield tongs.

Gallows traction: For the treatment of fracture shaft of femur shaft in children below 2 years of age, bilateral above or below knee skin traction is applied and the limbs are suspended vertically upwards. The buttocks of the child are kept off the bed so that the body weight acts as countertraction (Fig. 4-12). It also helps in toileting, etc.

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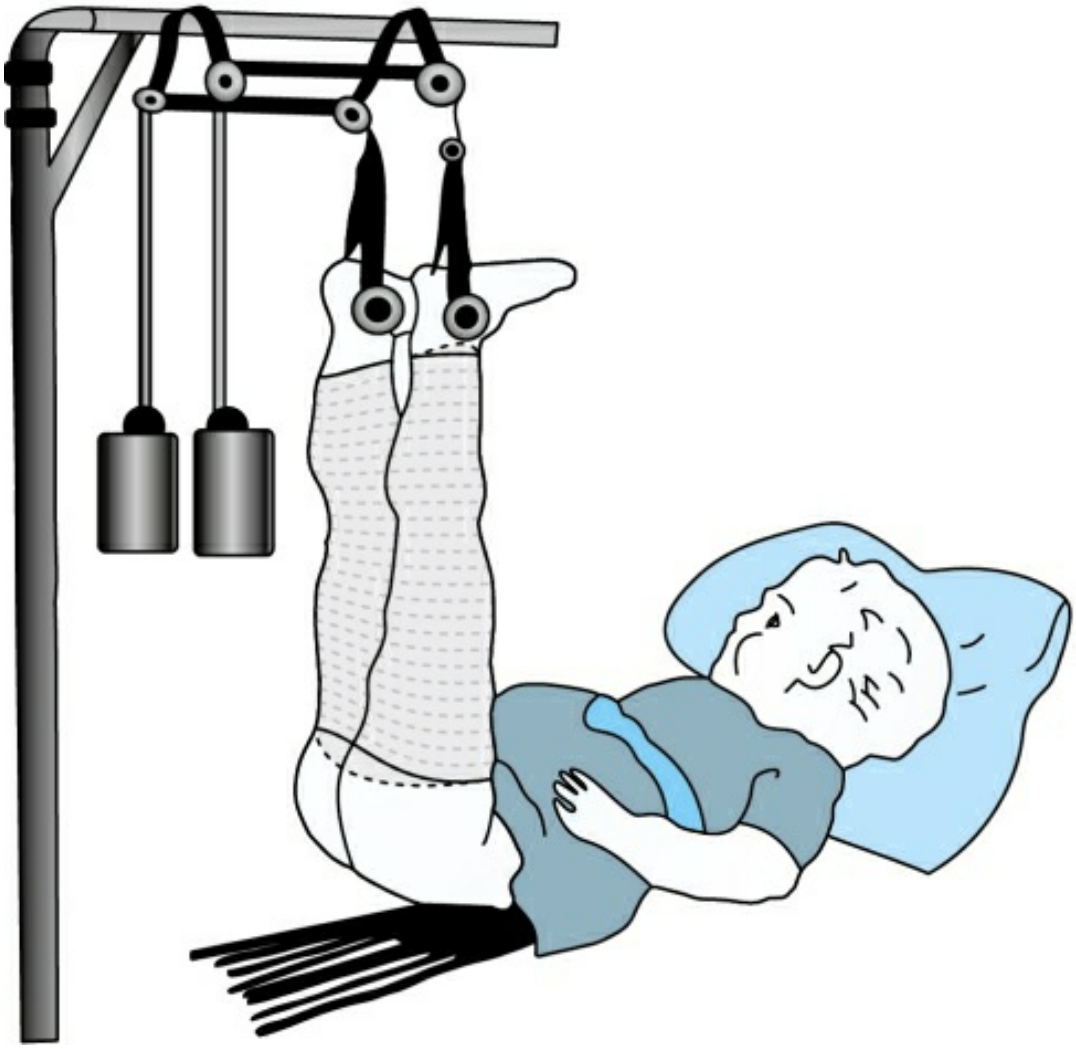

FIG. 4-12Gallows traction.

Perkins traction: It allows early mobilization of the knee (Fig. 4-13) while the limb is in traction. Note that the buttock is off the bed.

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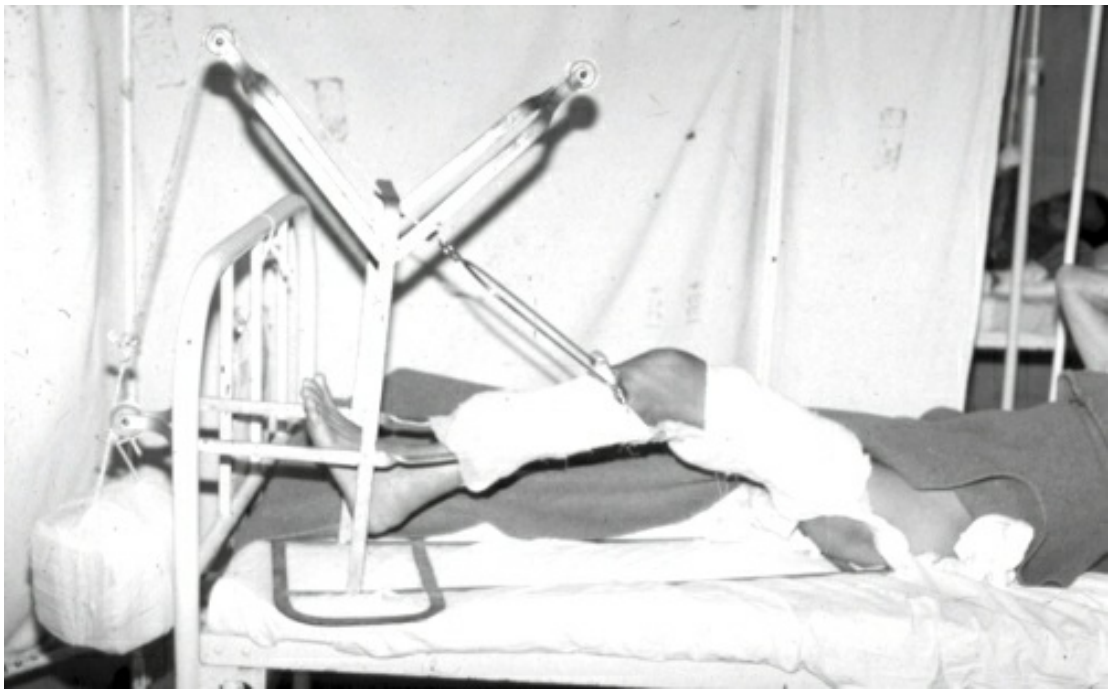

FIG. 4-13Perkins traction.

Halopelvic traction: It is used for the correction of spinal deformity. In this method, pins are passed into the outer table of the skull bones and also into the pelvic bone. These pins are attached to an outer metal ring around the skull and the pelvis. Distraction is then given by attaching threaded rods to these rings, as shown in Figure 4-14.

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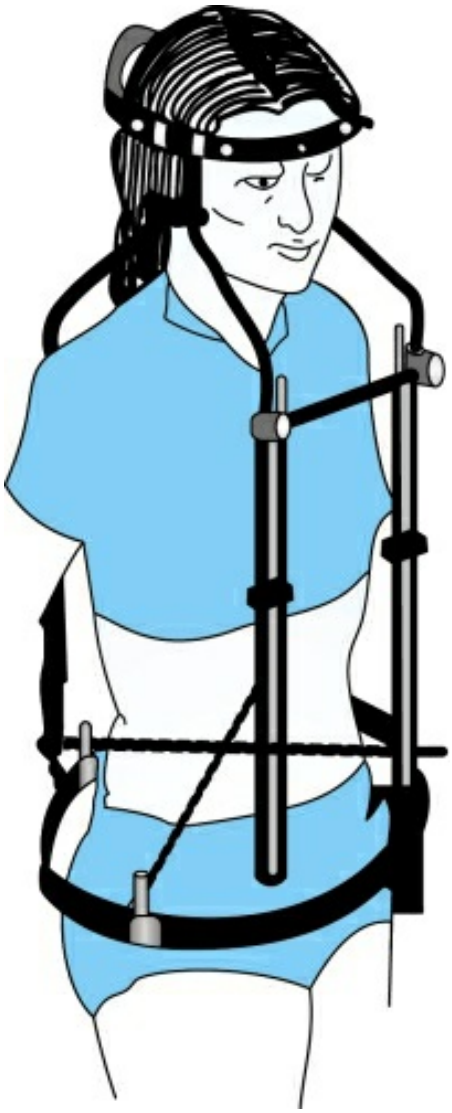

FIG. 4-14Halopelvic traction.

Plaster of paris cast

Plaster of Paris cast is a standard method of immobilization of fractures. The plaster cast incorporates one joint above and one below the fractured long bone. However, stiffness of joints and slow dissipation of oedema in the limb are the main disadvantages of this method, particularly in case of prolonged immobilization.

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Functional cast bracing

The functional cast bracing allows movement of the joint thereby facilitating correct collagen remodelling of the tissues during healing along with required immobilization. This is applied after an initial period of traction or plaster for 2–3 weeks (Fig. 4-15).

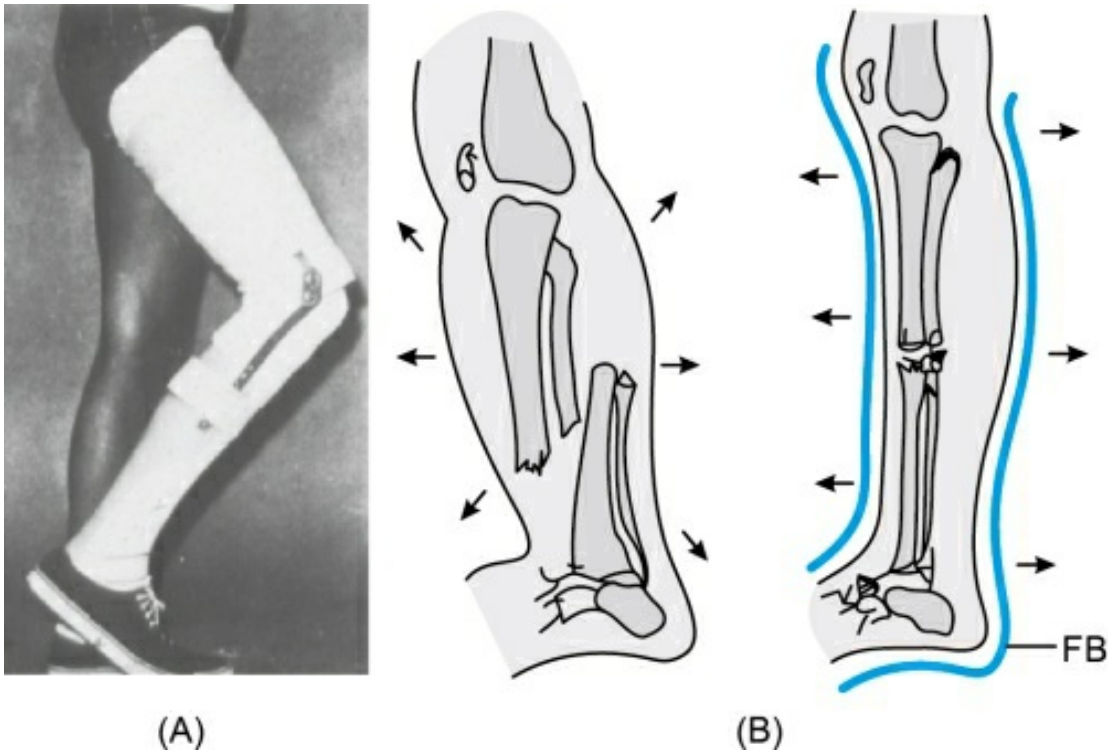

FIG. 4-15**(A)** Functional cast brace, applied in the treatment of fracture shaft of femur. POP cast is applied over the thigh and upper third of leg with a hinge joint at the knee. **(B)** Functional brace: Immobilization – the brace confines the soft tissues in a tight compartment developing hydraulic pressure within the braced compartment. Healing – axial compression due to weight bearing promotes healing. Functional freedom – provides the joy of early

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ambulation.

Internal fixation

Internal fixation is done by various types of implants such as screws, plates and nails (Fig. 4-16). Internal fixation is indicated in the following:

FIG. 4-16Internal fixation devices: **(A)** Plate and screw: pre- and postoperative X-rays of fracture shaft of humerus treated by plating. **(B)** Interlocking nail. **(C)** Intramedullary nail. (D and E) Trochanteric fracture, treated by dynamic hip screw fixation, dynamic hip screw. **(F)** Malleolar screw; plate and screw. **(G)** Compression screw with washer. **(H)** Transverse fracture of patella treated by tension band wiring.

Fresh fractures

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■ Grossly displaced fractures where closed reduction has failed

■ Fractures where the fragments are pulled apart by muscular action, e.g., fracture of patella and olecranon

■ Fractures where prolonged immobilization (in the form of traction or plaster cast) is contraindicated, e.g., fractures in elderly patients

■ Multiple fractures

■ Fractures associated with vascular injury

■ Pathological fractures

Internal fixation is performed along with cancellous bone grafting in case of delayed union or nonunion.

External fixation

External fixation is an excellent method of treating an open or compound fracture with severe soft tissue damage. It stabilizes the fractured bone; it allows easy wound care, and permits surgical procedures like skin grafts and bone grafting. The external fixator can be a tubular fixator where Schanz pins are passed into the bone and connected to a tubular rod (Fig. 4-17), or a ring fixator where wires are passed into the bone under tension and connected to a half or full circle ring (Fig. 4-18). However, the external fixator occasionally poses the problems of pin tract infection and loosening of pins.

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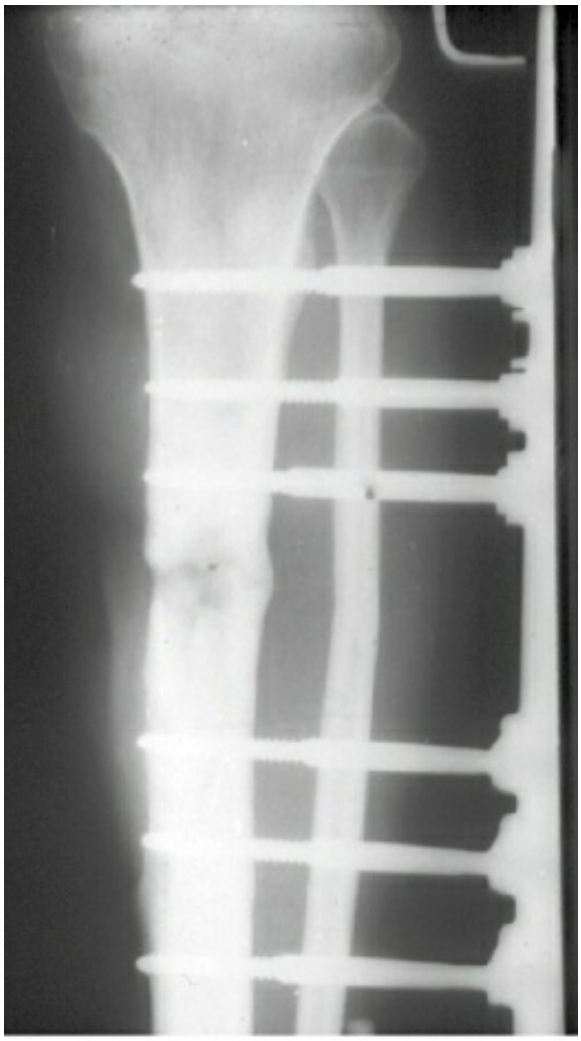

(A)

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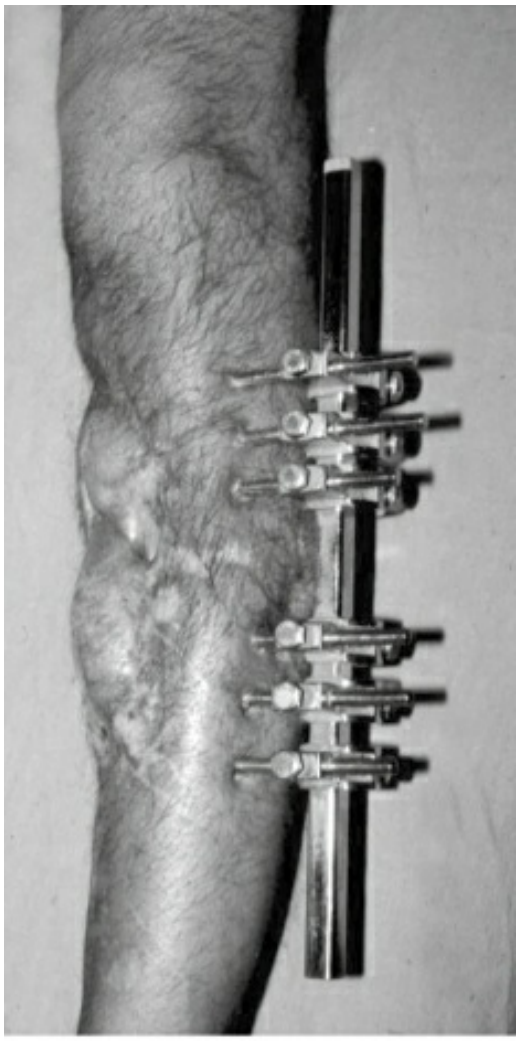

(B)

FIG. 4-17Uniplanar biaxial fixator **(A)** Radiograph. **(B)** Clinical photograph.

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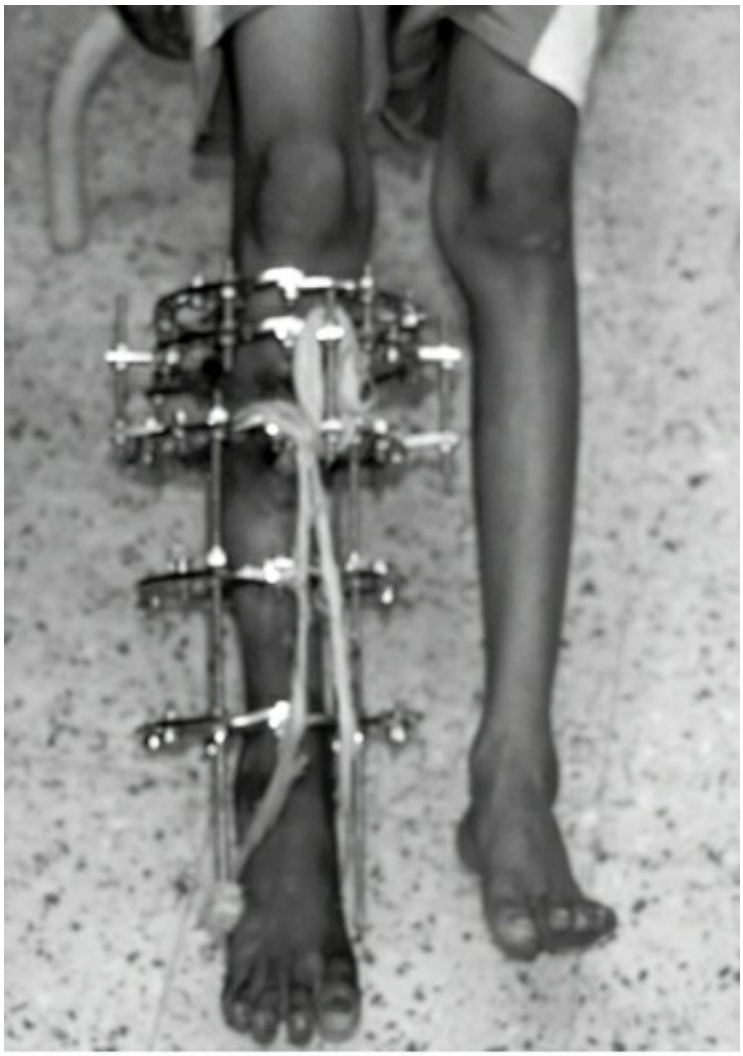

(A)

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(B)

FIG. 4-18Ring fixator (also called Ilizarov fixator) applied in the treatment of fracture of both bones of leg. **(A)** Clinical photograph. **(B)** As seen on radiograph.

Mobilization and rehabilitation

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It is the final stage of fracture treatment. The objective is to restore near-normal mobility to the fractured limb and make the patient physically independent. It is in fact the total responsibility of the physiotherapist.

Role and functions of physiotherapy

Role and Responsibility: The role of physiotherapy in fracture management is so valuable that none can boast of a 100% recovery without the attention and care by a physiotherapist.

Irrespective of the method of management of a fracture, whether conservative or surgical, the physiotherapist should take all the possible measures to achieve quick and complete or at least optimally functional recovery.

The quantum of recovery, besides physiotherapist's knowledge, largely depends upon his or her skill to educate, guide and supervise patient's performance. Responsibility of total treatment should be of the nature of self-management, fully guiding a patient on every aspect of the poststabilization period.

Objective of physiotherapy

The objective is to restore to the maximum the function and the efficiency of the injured musculoskeletal complex along with other adjacent joints of the affected limb and to maintain or improve the functional capacity of the unaffected parts of the body.

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Any bone fracture or joint dislocation goes through the following two main stages:

(1) **Immobilization:**

(a) Reduction of the fracture either by conservative or surgical approach

(b) Retention of the reduction

(2) **Mobilization**: It is required when the joints adjacent to the fractured bone get stiff and painful because of prolonged immobilization.

Physiotherapeutic management of fractures

Return of normal to near-normal function following correct and timely management of a fracture is possible by simple methods of physiotherapy. But the physiotherapist faces a challenge in regaining the functional independence in a patient with complicated multiple fractures, mismanaged fractures, nonunions and fractures where surgery is contraindicated.

The role of physiotherapy remains unaltered but the approach varies with the individual situations.

1. **Management of a fracture:** It could be surgical or conservative

2. **Site of involvement:** The body segment, e.g., upper extremity, lower extremity, trunk and their sub segments

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3. **Type of fracture:** Simple, compound, comminuted

4. **Associated problems:** A fracture may be associated with joint complications, and injuries to the soft tissues like muscles, tendons, ligaments and nerves.

A physiotherapist has not only to use professional skill but also has to modify the procedures of physiotherapy to suit each stage of healing of the fracture (Table 4-3). To achieve early success one has to consider the patient's physical status, age, level of cooperation, ability to understand and above all the occupational demands. The ability to motivate the patient to actively perform the movements is vital. All these procedures demand an individualized approach to the problem.

Table 4-3

Scheme of Progressive Exercise during Various Stages of the Healing of Fracture

Mode	Purpose	Stage of Healing
Passive full ROM and functional ROM (PROM) or normal limb	• To educate the patient on correct groove of the movement	Preoperative
(1) Isometrics a voluntary inbuilt of muscular	• Localized strengthening of a muscle group	• Following reduction of a fracture and

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contractions	• To improve the stability of the joint • To promote fracture healing through localized increase in the circulation	immobilization (as soon as the pain allows)
(2) Isotonic (dynamic)	• Relaxed free active exercises (to improve ROM) • Active resistive exercise • To strengthen the muscle group and its endurance • Small intensity sustained passive stretch to further improve the ROM	• Immediately after the removal of immobilization • As soon as the pain is reduced • As early as possible with emphasis on self-resistance and several repetitions
(3) Isokinetic Full ROM active joint movements performed maximum at a	• Strengthen muscle action through the maximum arc of the ROM • Improves joint control	• As soon as the joint is fairly mobile • Excellent mode to

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constant speed with automatic strength variation full ROM	and movement coordination	improve muscular strength
(4) High-performance exercises (a) Closed kinetic chain exercise (CKC) (b) Open kinetic chain exercise (OKC) – Fig. 4-19 (c) Polymetric exercise	• A multijoint resistive exercise with fixed distal segment (e.g., floor squats) of the exercising limb. Strengths all important muscle groups of a whole limb • Linking together the force and the speed of the movement (explosive reactive movement (e.g., PNF pattern following quick stretch reflex)	• Late stage of healing when the fracture union is confirmed • To prepare for sports • Before joining sports during the end stage of healing

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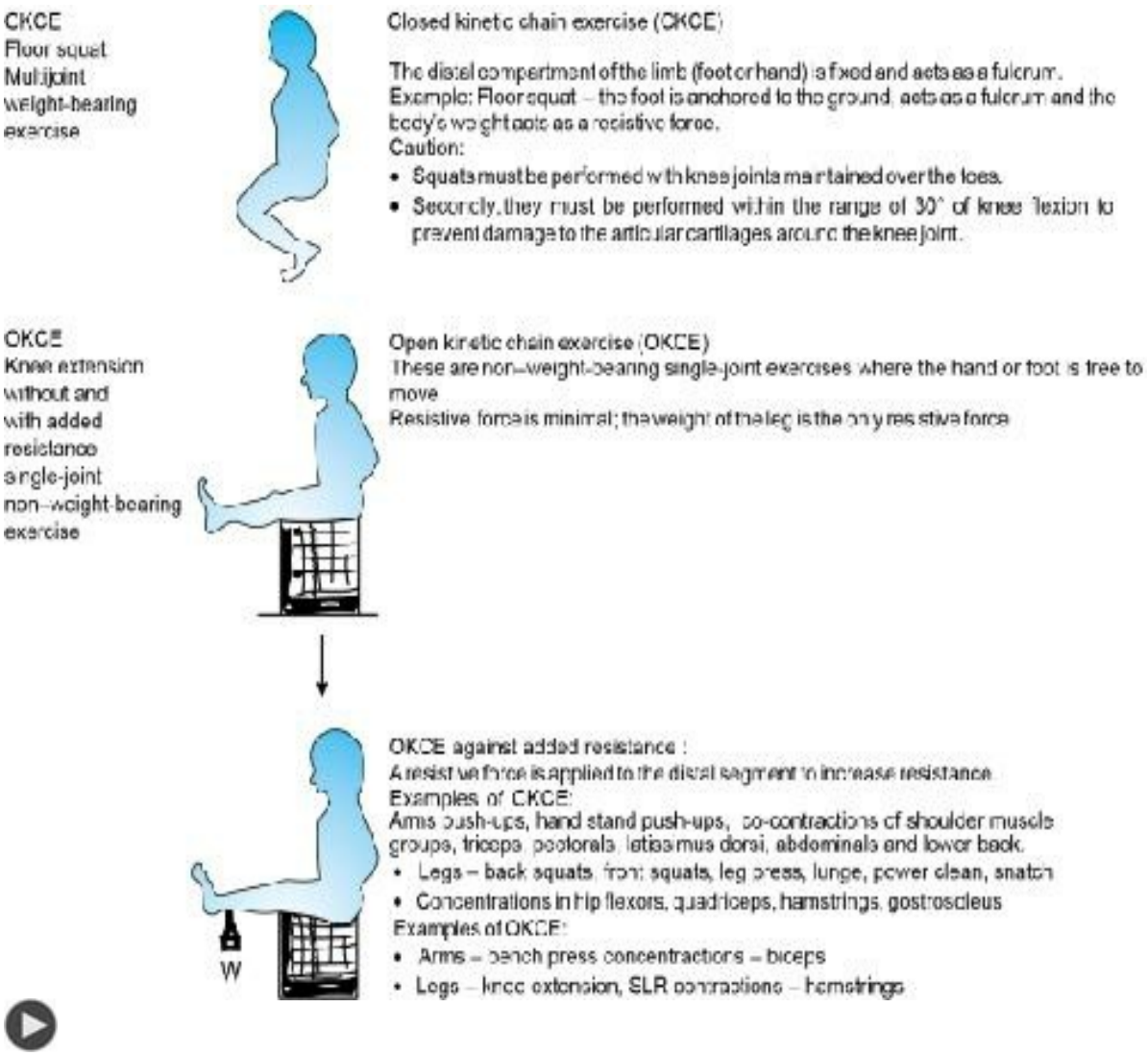

FIG. 4-19Closed and open kinetic exercise (CKCE and OKCE).

Principal functions of a physiotherapist

1. *Identification of the nature of injury:* If a fracture is suspected, refer to the consultant, and if it is only a soft tissue injury treat by appropriate measures.

2. *Physical assessment:* This should be done systematically to

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assess the nature and extent of the disability. Identify the possible complications to the joint, muscle, tendon and nerves. Other complications like adult respiratory distress syndrome (ARDS), venous thrombosis, soft tissue and bone infections and pressure sores should be prevented by appropriate measures.

3. Confirm the diagnosis by interpretations of the findings of physical examination and investigations, e.g., radiographs.

4. Identification of associated diseases in which physiotherapy or any of its modalities are contraindicated.

5. Plan the procedures of physiotherapy on an individual basis.

6. *Reviewing patient's response to the therapy:* The therapeutic programme may be modified, if necessary.

7. At discharge, advise for regular home exercise with emphasis on the prevention of recurrence and for reporting for follow-up at regular intervals.

8. Review the patient at home or at work and offer guidance.

Once the fracture is reduced, the physiotherapist has to take the major responsibility of restoring normal to near-normal functional self-sufficiency of the fractured limb as well as the whole body.

Physiotherapy care during immobilization

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■ The major principle of management is to retain the perfect anatomical alignment of the fractured bony fragments, achieved by closed reduction or open reduction and internal fixation (ORIF).

■ Try to minimize the adverse effects of acute inflammation and immobilization like pain, oedema and active movements of the distal joint with the affected limb placed in elevation.

Checking POP cast

■ Ensure that it is neat and tidy.

■ Ensure that it is not digging in the limb at any end.

■ Ensure that it is not extending and blocking the movements of the distal joints free from POP cast (e.g., metacarpophalangeal [MP] joints in the upper limbs and metatarsophalangeal [MTP] joints in the lower limbs).

■ Check the finger/toe tips for cyanosis, cold feel, lack of active mobility by using thin long objects likes a metallic or plastic foot ruler.

■ Check POP cast – thoroughly to prevent complication due to improper POP.

■ Joints and muscle complexes not included in the immobilization should be vigorously exercised to improve circulation to the limb.

■ The muscle groups under immobilization should be

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exercised with isometrics within the limit of pain and discomfort.

■ Gradually increase the strength and duration of these isometric contractions.

■ Rest is only for the affected area and limb and not for the whole body; direct the patient to carry out activities of daily living (ADLs) by the nonaffected part of the body.

■ Begin bedside standing on one leg and non-weight-bearing (NWB) ambulation on a walker.

■ Explain the expected schedule of exercise on the nonaffected side.

■ Each fracture is susceptible to develop related complications besides the usual complications of immobilization. Educate the patient on the symptoms and alarm of such susceptible situations and report immediately to the nurse to prevent them from occurring, so that necessary care can be taken on the spot (e.g., tight POP cast 0 bivalve it examining the fracture site and take necessary steps, may be replastering).

■ This will greatly prevent the miseries of organized complication, after the removal of immobilization.

■ During the entire phase of immobilization, keep a watch on the possibility of developing complications due to the immobilization itself.

■ Keep a watch on general complications of immobilization,

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e.g., plaster cast.

■ Tight POP cast or a bandage may cause cynosis, ischemia, compartment syndrome or nerve compression, pressure sore, etc.

■ Loose POP cast: Attempts or involuntarily moved immobilized limb will give rise to sharp intractable pain at the fracture site and the whole limb, especially during NWB walking on a walker.

■ Eventually it leads to nonunion.

■ Skeletal traction sites of pin piercing the skin should be examined every day for suspected infection. Skeletal long pin may even cause injury to the soft tissue or vessels.

■ During surgery, the peripheral nerve may be injured. This may be noticed late only after immobilization.

Besides all these, immobilization itself has many adverse side effects, e.g., weakness of muscles under immobilization, disuse atrophy and loss of tone and joint stiffness.

Make it a point to take advantage of immobilization to promote an activity-oriented lifestyle, e.g.,

1. General body exercise, not with breaks but in a continuous mode.

2. Strengthen functional muscle groups to ease functional performance of the whole body. Besides, focus on muscle groups at the next stage of mobilization.

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3. Use this opportunity to take advantage of educating and practising lifestyle exercises – both cardio-protective and diseases-preventive modes of exercise are must for each patient requiring longer period of recovery.

The possibility of generalized detoning of all the systems and the organs of the body due to sedentary attitude can be controlled by initiating early activities to the different body parts encouraging functional use.

Physiotherapy during stage III mobilization

Responsibility of the physiotherapist

■ The physiotherapist provides education, guidance and supervision to a patient to fulfil all the requirements and follows the specific methodology of the exercises taught.

■ The best and sure way to expect excellent outcome is to perfectly train a patient on the methods of self-performance rather than depending on a physiotherapist.

■ Of course, specialized exercise techniques and initial training for functional independence will be provided and guided by a physiotherapist.

■ Intermittent evaluation of progress will be monitored regularly by the treating physiotherapist.

Objective of physiotherapy

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■ Physiotherapy restores preinjury status to the affected limb.

■ The most important aspect is to mobilize the immobilized joints and all functions (e.g., strength, power, endurance, and flexibility) of the muscles of immobilization.

Methodology of approach

■ Examine the health of the skin under the cast, and surgical scar in operated cases.

■ Soothing massage for a short period over the skin, before exposure to superficial heat like that of infrared ray, radiant bath, etc., will prepare the limb for mobilization.

■ Always begin with small-range, free and relaxed rhythmic pendulum movements to ensure better relaxation and educating the exact groove of the range of motion (ROM).

■ Gradually introduce progressive modes of exercise like self-assisted, self-resisted ones performed several times by the patient.

■ Techniques like proprioceptive neuromuscular facilitation (PNF) and progressive resistive modes are introduced gradually to meet the goal of optimal muscle functions, full or at least a functional range of joint movement of the injured joint or a bone close to the site of a fracture.

Functional use – Physiotherapy is first initiated as an assisted hand and progressed later to an independent one. Similarly,

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stable and free ambulation is also initiated.

In patients who have suffered irreversible neural, muscular or skeletal damages, alternative methods should be planned and taught to perform functional activities like:

1. Hypertrophy of the intact muscle groups to substitute for the paralysed muscle groups

2. Controlled release or relaxation of the agonistic group to perform antagonistic action (graduated release of the contracted biceps to achieve controlled elbow extension in the paralysis of triceps)

3. Educating a patient on the tricky movements by modifying the movement pattern, strengthening the substituting muscles and by use of gravity, postural modifications and/or assistive aids

Examples

1. Hypertrophy of latissimus dorsi, triceps, wrist extensors and finger flexors to facilitate crutch walking, hypertrophy of the long head of biceps to abduct arm in the absence of deltoid by fixing shoulder in external rotation

2. Jerky shoulder girdle elevation with trunk deviation to the opposite side for momentary shoulder abduction

3. Jerky pelvic elevation with trunk deviation to the opposite side to step forward when the limb is flailed or the knee joint as a fixed extension deformity

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4. Suggesting modification in the usual aids and appliances to assist function

5. A brief review of specialized assistive techniques in physiotherapy to facilitate early recovery during the postimmobilization period

Specialized assistive therapeutic techniques in physiotherapy

1. ***Massage:*** All the five manipulations, e.g., effleurage, stroking, kneading, rolling–wringing and Frictions, have a selective influence on various tissues of the body. Above all, the feeling of betterment and relaxation which follows it has no parallel. As such, one must try to incorporate a brief session of massage.

2. ***PNF:*** Proprioceptive neuromuscular facilitation is a specialized exercise technique based on the most beneficial therapeutic principles to promote recovery following any neuromuscular disorder.

Moreover, its basic principles may be used individually to emphasize certain aspects of the therapy (e.g., resistance, approximation, pattern of movement).

3. ***Manipulation and mobilization:*** To restore the anatomical alignment of displaced skeletal units (e.g., facet joints), to relieve pain and above all to mobilize stiff and painful joints.

4. ***Manual therapy:*** This has revolutionized the treatment procedures of tissue repair, systematic collagen remodelling, the dynamics of tissue fluid, resolution of tissue damages,

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and permanent gain in the length of the contracted or shortened musculotendinous tissues.

5. ***McKenzie's technique:*** A technique emphasizing correct body positioning and self-performed spinal manipulation has simplified the resolution of most popular common low back pain.

Such new, specialized approaches and techniques are being developed, but each one demands specialized training to understand its nuances.

However, nothing can beat proper guidance even in a few specific exercises, performed willingly in several short bouts.

A brief review of the assistive physiotherapeutic modalities in orthopaedics is depicted in Table 4-4.

Table 4-4

Brief Review of the Assistive Physiotherapy Modalities in Orthopaedics

Modality	Technique and Contraindications	Therapeutic Benefits
Cryotherapy (cold)	• Crush ice (28–32°F or 0–20°C) is formed into packs and applied directly over the site of injury or pain for 15 to 20 minutes transcranial direct-current	• Ideal to subside the ravages of inflammation, ideal in closed wounds • Ideal for

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	stimulation (TDS) • Cold water immersion • Massage with ice cube contraindications; anaesthetic areas, circulatory insufficiency, open wounds or gross oedema	thermal burns, to reduce localized muscle spasm and collagenosis
Thermotherapy (a) Superficial heating modalities	• Hot packs: conventional hot water bag wrapped in a folded wet towel applied directly for 15 to 20 minutes TDS • Infrared lamps: direct application of dry heat by IR rays for 18–20 min • Paraffin wax bath: a mixture of liquid paraffin and petroleum jelly is melted. 10 dips forming 10 layers of wax covering maintains heat and also soothes the skin Contraindications: Acute	• Improves localized circulation and nutrition; relieves superficial pain, relaxes joints and muscles, softening of the superficial subcutaneous tissues and the skin • Ideal for stiff and painful hands

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	injuries, epiphyseal areas or neoplasia	
(b) Deep heating modalities	• Short wave diathermy (SWD): deeper tissue heating up to 30–50 mm depth through electromagnetic induction by high-frequency currents. Never used in acute injuries • Ultrasonics (US): high-frequency sound waves with deeper thermal effects at the tissue interface. It brings about molecular rearrangement and is ideal to reduce adhesions, reduce haematoma; safe to be used in acute conditions. Contraindications: neoplasia, metallic implants, pregnancy, myositis	• Ideal in deeper chronic joint pains, helps in the concentration of WBCs and antibodies • Reduces deeper localized pains due to neuromuscular pathology • Improves membrane permeability, collagen synthesis, pain threshold, resolution of scar tissue and joint adhesions, wound healing and remodelling of the scar

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Hydrotherapy: whirlpool	• Water heated at (98–104°F or 39–40°C) is constantly kept whirling; it assists active movement of the limb and joints immersed in a comfortable manner Contraindication: anaesthetic skin, open wounds	• Has an overall comfortable feeling due to warmth, elimination of gravity and the movement of water • Promoting the active efforts by the patient and therefore is ideal for postoperative mobilization
Therapeutic pool	A deeper pool where any joint movement including ambulation is possible	Ideal for ambulatory training and general body exercise like swimming
TENS:	Direct electrical	Mainly reduces

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Transcutaneous nerve stimulation	stimulation by low as well as high-frequency currents of less or more than 10 Hz is applied. Contraindications: anaesthetic skin, open wounds	the acuteness of pain by blocking the pain pathways. Ideal for postoperative or chronic pains
Laser (low-frequency light waves)	Low-frequency light waves produce photochemical reactions within the tissue cells	Relieves acute as well as chronic muscular or neuropathic pain
Interferential currents	It simultaneously applies two out of phase currents	Spontaneous reduction of musculoskeletal pain as well as constant pain in chronic conditions
Iontophoresis	• It involves transfer of the charged ions intradermally by means of a direct electric current.	Useful in reducing: • Fungal skin infection

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	• Drugs like dexamethasone are transferred intradermally	• Ischaemic ulcers • Oedema • Applying local dermal anaesthesia
Electrotherapeutic and diagnostic procedures	Examples include RD test, electromyography (EMG) nerve conditions velocity test and therapeutic electrical stimulation. The specialized tests are covered in Chapter 14	

Physiotherapeutic management following specific methods of fracture treatment

1. *Fractures treated without any splinting*: Some fractures are occasionally treated without any splinting, reduction or surgery when surgery is contraindicated. In such cases, the fracture is ignored; and controlled mobilization is started at the earliest. Initiation of safe and adequate mobility to regain functional independence is the important role of physiotherapy in such fractures, irrespective of union or

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alignment of the fracture, e.g., compression fracture of the spine, fractures of ribs, and fracture neck of femur in a sick patient.

2. *Fractures treated by traction*: Certain fractures (e.g. trochanteric fracture) in elderly patients, where surgery cannot be done, are treated by traction of long duration. The physiotherapist should check the alignment and the force of the traction; he/she should also detect development of pressure sores or nerve palsy (the most common being lateral popliteal nerve) due to pressure from a splint or bandage. Isometrics to the quadriceps, hamstrings and ankle movements should be given regularly. Ankle movements are particularly important as they improve circulation in the calf veins and thereby prevent deep vein thrombosis.

3. *Fractures treated by cast brace*: A fracture of the mid-shaft of femur is at times treated by a cast brace having an orthotic mechanical knee joint. It is the responsibility of the physiotherapist to check the alignment of the knee joint and begin early re-education in walking.

4. *Fractures treated by internal fixation*: A fracture treated by internal fixation usually does not require prolonged external immobilization after the operation. The immobilization is maintained only for 2–3 weeks, after which mobilization can be started.

5. *Fractures and dislocations associated with ligament injuries*: Certain fractures and/or dislocations around shoulder, elbow, interphalangeal joints and ankles are associated with injury to the joint capsule and ligaments. Extensive efforts

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are, therefore, needed to mobilize these joints and also to treat the accompanying soft tissue damage.

6. *Fractures treated by external fixator:* In a compound fracture with soft tissue loss, the fracture is stabilized with an external fixator. The extent of injury to the soft tissues should be assessed and inspection of the open wound should be done frequently for infection. Vigorous movements should be started early to the joints free from immobilization and even NWB crutch walking can be initiated early. The movements of the joints adjacent to the fractured bone are deferred till there is definite evidence of fracture union. Once the union is ascertained, extensive physiotherapeutic measures are taken to improve mobility of the joint, strength and endurance of the concerned muscles and early functional independence.

7. *Fractures treated by total joint replacement*: The greatest advantage of this procedure is that it allows early mobilization and ambulation besides providing stability to the joint. The physiotherapy is directed to re-educate the functional activity at the earliest.

8. *Fractures treated by leaving them alone*: Certain fractures, which cannot be treated by standard procedures if the patient is not fit for surgery, are left alone. The fracture is neglected and patient's mobilization is started as early as possible by using pain-relieving modalities, manual assistance, aids and devices to provide maximum self-sufficiency.

Fractures of the lower extremity: Specific considerations

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Physiotherapeutic management of fractures of the lower extremity demands a different type of approach for two reasons:

1. Its important function of ambulation

2. Its role in the adaption of functional positions, e.g., cross-leg sitting and floor squatting

The physiotherapist's priorities should be as follows:

1. To reduce the impact of stresses on the three major weight-bearing joints of the lower extremity

2. To acquire the requisite ROM

3. To improve strength, endurance and flexibility of the functionally important muscle groups

1. *To reduce the stresses on the weight-bearing joints:* The weight-bearing joints, especially the hip and the knee, are exposed to tremendous amount of stresses during ambulation and while adapting functional positions. The resultant joint force was found to be approximately four times the body weight at the hip and three times at the knee (Paul, 1967). The smooth absorption of the ground reaction forces is the primary requirement for rhythmical and effortless ambulation. When these forces are not absorbed by the weight-bearing joints, the muscles and ligaments are put to extra strain and early fatigue. The weight-bearing joints should be in perfect alignment to accept the impact of these forces. The alignment can be maintained by avoiding tightness, contracture or deformity (Wallace, 1983). The physiotherapy programme

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must be directed to avoid this situation right from the first day.

2. *To acquire the necessary ROM:* Regaining an adequate free ROM is essential for the various activities of the lower limb such as walking, climbing, floor squatting, cross-leg sitting and kneeling.

The minimum ROM required for ambulation and chair sitting is shown in Table 4-5 (Johnston and Smidt, 1969).

Table 4-5

Minimal Required Functional ROM for Ambulation and Chair Sitting

Joint Movement	ROM for Ambulation	ROM for Chair Sitting
• Hip Flexion • Extension • Abduction • External rotation	20–25°	50–52° 10° 12° 13–15°
• Knee Flexion • Extension	60°	60–70° 170°

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• Ankle • Dorsiflexion • Plantar flexion	10–15° 45–50°	5° 15°
• Toes Flexion • Extension	20–25° Full	

However, the task of floor squatting and cross-leg sitting is possible only when hip flexion, abduction and external rotation and the knee flexion and ankle dorsiflexion acquire a near-normal ROM. Therefore, our objective in mobilization should be aimed at regaining a near-normal range.

Specific movements and limb positioning have a common tendency to develop contractures. Ideally, they should be performed in the neutral position and encouraged to move through full ROM.

Common sites of contractures

Hip	Flexion, abduction, adduction, occasionally rotation
Knee	Flexion
Ankle	Plantar flexion
Toes	Flexion (curling)

3. *To improve strength, endurance and flexibility:* Several

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repetitions of strengthening, endurance and stretching exercises should be done. They should be simple, objective and within the limits of discomfort. The programme should include the following:

(a) It has been found ideal to initiate isometric contractions to the important muscle groups of the hip, knee and ankle as early as possible.

(b) One must remember that the responsibility of the physiotherapist does not end with demonstrating or teaching isometric contractions. The patient usually demonstrates ideal performance of exercises to the physiotherapist on ward round. However, he/she neglects it during the rest of the time. As soon as ROM exercises are permitted, preference should be given to self-built-up internal tension exercises and eccentric exercises.

The following muscle groups need concentrated efforts for stable ambulation and standing.

Hip: extensors, abductors

Knee: extensors, flexors

Ankle: dorsiflexors, plantar flexors

In our experience, emphasis on these muscle groups is essential to promote early stable standing and walking.

Walking re-education

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Prewalking education

Re-education in walking should begin as early as possible after surgery or plaster application for a fracture. One should not wait till the fracture is united. The basis of locomotion is stability and smooth movements.

The stability of all the three principal weight-bearing joints has to be ensured. Strong and repeated isometrics to the glutei should be initiated early, as they are the main guiding force to provide the pelvifemoral stability in standing and single leg balancing. NWB supine lying thrust of the leg in the axial direction (Fig. 4-20) helps in creating partial loading situation to the injured limb, which stimulates callus formation and promotes healing of the fracture. Isometrics to the quadriceps and hamstrings are important in providing co-contractions to stabilize the knee on weight bearing. Ankle and foot stability is of primary importance during the single leg mid-stance when the whole body weight is balanced on it. Intrinsic muscles play a major role in stabilizing the foot on the floor. Therefore, early initiation of exercises to the intrinsic muscles and the anterior and posterior tibial muscles plays a vital role.

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FIG. 4-20Application of early partial loading: Axial thrust to the leg is applied when supine lying by pressing a pillow with the foot, maintaining the knee joint in full extension with the ankle and foot in neutral. Hold and release pressure with Quadratus lumborum action.

Mobility at all the three weight-bearing joints is important. The following ROM is necessary for smooth ambulation and should be regained as early as possible:

Coordinated controlled movements of both the legs are also essential for effective walking. This aspect does not usually get enough attention in the early stage.

The patient should be educated on the exact sequence of walking. Supine cycling (Fig. 4-21) improves controlled coordination and induces relaxation and confidence.

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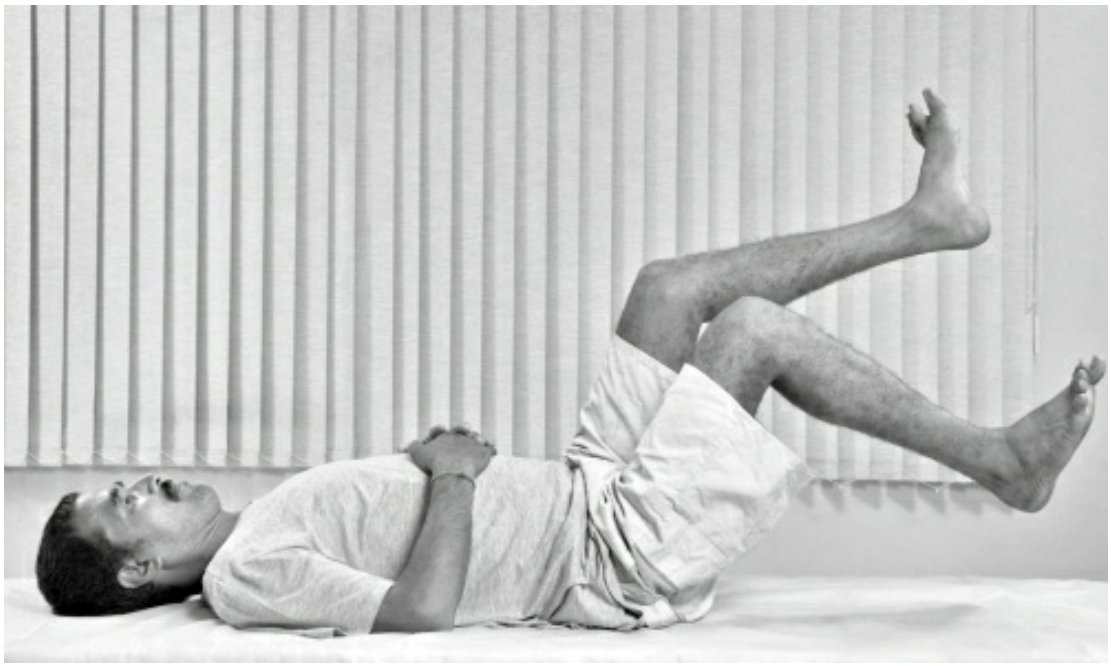

FIG. 4-21Supine cycling to re-educate on prewalking controlled coordination.

The need for any orthosis or supporting ambulatory aid should be assessed at this stage and orthosis is fabricated for use on the very first day of ambulation.

These preambulatory sessions should be well understood and practised by the patient regularly.

Crutch walking: Crutch walking is a common mode of early ambulation following fractures of the lower extremity.

1. It helps in early functional ambulation and a back to work situation, even before the fracture or the soft tissues have healed.

2. It supports the body weight by relieving undue stress on the fractured leg.

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3. It may help in early union of the fracture due to compressive impact.

4. It provides stimulus for growth and union.

5. It improves the bony mass, thus preventing osteoporosis.

6. It improves blood circulation to the limb.

7. It facilitates re-education of the normal gait pattern.

8. It offers stability and confidence to the patient.

Basic principles

(a) ***Crutch measurement:*** Crutch measurement should be taken from the anterior fold of the axilla to the medial malleolus. This prevents axillary pressure and crutch palsy. In spite of the correct crutch size, patients tend to exert pressure through the axilla. Alternatively, measure from a point 2 inches below the axilla to a point 6 inches in front and 2 inches lateral to the foot.

Elbow crutch should be measured from the point of the elbow to the ground; the cuff should cover the proximal third of the forearm, about 1–2 inches below the elbow.

(b) ***Weight bearing on crutches:*** With either type of crutches, the weight bearing should be through 30-degrees flexed elbows and hands with extended wrist.

With elbow crutches, the body weight should be transmitted

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through the forearm.

Cane and walker measurements: 20–30-degrees of elbow flexion measured from the greater trochanter to a point 6 inches to the side of the toes.

(c) ***Strengthening of muscle groups:*** Special attention to strengthen certain muscle groups like triceps, shoulder depressors, latissimus dorsi, wrist extensors and finger flexors in the upper extremity is necessary in the preambulatory period. In the lower extremity, the following muscle groups should be strengthened: glutei, quadriceps, ankle dorsi and plantar flexors and toe flexors.

(d) ***Standing:*** Correct standing posture should be assured with the head erect, shoulders and pelvis properly levelled, hips and knees extended and feet exactly below the hip joints. The accuracy of weight transfers on both the legs and then on alternate legs is important to prevent limp. Any limb length disparity should be compensated before the patient is made to stand. When standing is initiated with crutches, the crutches should be held away from the body. They should be placed 6 inches in front and at least 4 inches lateral to the feet from below. This gives wider base and support areas. Extrinsic stability is enhanced further with better arm stabilization (Fig. 4-22).

(e) ***Crutch balance:*** Balancing the body on a single crutch is taught first. One crutch is moved freely in all directions, maintaining steady balance on one or both legs and one crutch. The same procedure is then repeated on the other side.

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(f) ***Proper sequences of gait cycle:*** Proper sequences of gait cycle including even steps and stride length should be practised first on parallel bars and later on with crutches.

(g) ***Techniques of transfers:*** Techniques of transfers forward, backward, side walk and turning with crutches should be taught. However, independence in ambulation cannot be completed without freedom in negotiating the stairs and slopes.

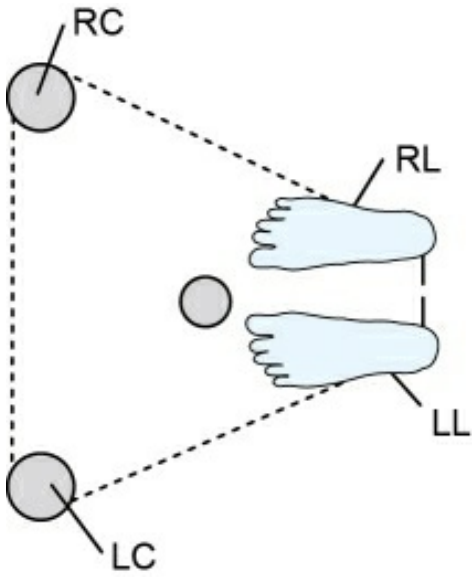

FIG. 4-22Ideal-standing crutch stance to provide larger supporting base and supporting areas. RL: Right leg, RC: Right crutch, LL: Left leg, LC: Left crutch.

Methods of crutch walking (fig. 4-23)

1. *Swing to and swing through gait:* In this technique, both crutches are moved forward, one by one. The whole body weight is then transferred on crutches and the patient swings his/her body forward up to the arbitrary horizontal line

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formed by the tip of the crutches. This is later on progressed to the 'swing through' gait in which the patient swings his/her legs beyond the arbitrary horizontal line (Fig. 4-23A and B).

Here the propulsive force is generated by pushing the body forward on the arms, which are stabilized by the fixed points of the crutch tips with the ground. The major force to propel the body is provided by the latissimus dorsi muscle.

2. *Partial weight bearing (PWB)* (three-point gait): In this gait, both the crutches and the affected leg move together. The body weight is transferred over these three points of contact and the sound limb is brought forward. This can be progressed to one crutch in a contralateral pattern. Even stepping is monitored carefully (Fig. 4-23C).

3. *Alternate crutch and leg gait* (four-point and two-point gait): Initially, the right crutch is put forward followed by the left leg, then the left crutch is put forward followed by the right leg. The gait can thus be progressed by simultaneous movements of the right crutch and the left leg, and vice versa (Fig. 4-23D).

4. *Shadow walking* (NWB gait): It aims at maintaining the normal pattern of gait in the absence of actual weight bearing. It is difficult to learn, but once organized, it helps in establishing the correct pattern of the gait. The crutch on the opposite side of the NWB limb is put forward first to be followed by forward movement of the NWB leg. Next, the other crutch is put forward to be followed by the normal limb (Fig. 4-23E).

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Relaxation of the whole body and smooth ambulation training should be emphasized to prevent undue fatigue and excessive energy consumption to ensure confidence.

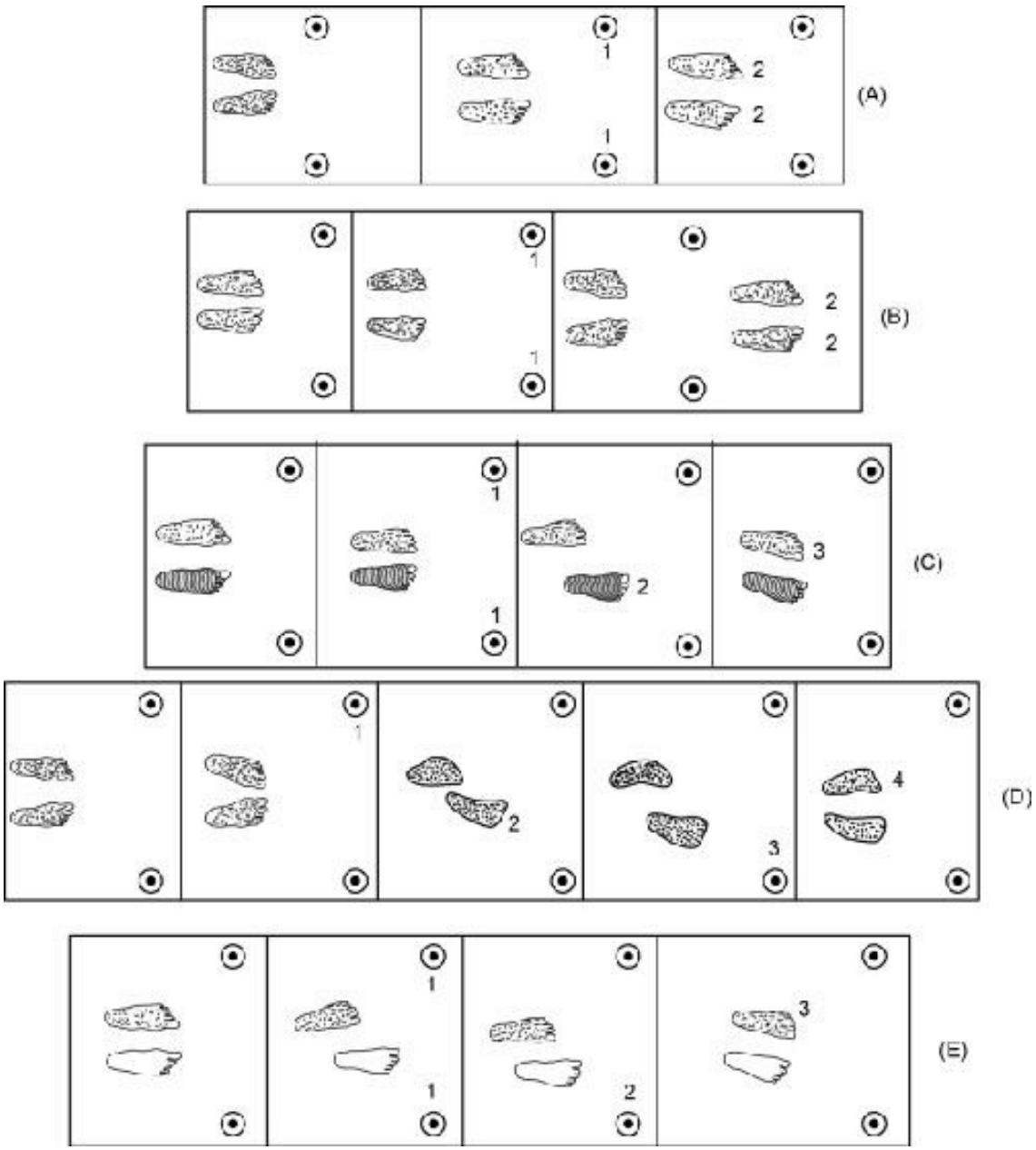

FIG. 4-23Types of crutch gaits: **(A)** Swing to gait. **(B)** Swing through gait. **(C)** Partial weight-bearing gait. **(D)** Four-point gait. **(E)** Shadow walking non-weight-bearing gait.

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Principles and methodology of ambulatory training

The following guidelines in bearing body weight on the fractured limb must be strictly observed during the sequential stages of ambulation.

In all fractures of the lower extremity, it is most important to know how much of body weight is to be put on the fractured limb.

There are three basic stages of weight bearing:

i. NWB: This does not allow any type of body weight on the fractured limb.

ii. PWB: Weight could be placed in a graduated manner as follows:

■ Toes-down or toe-down weight bearing (TDWB): Toes are put down on the ground to accept partial body weight.

■ Weight bearing to tolerance (WBTT): The body weight is put on the affected limb till it does not cause pain or discomfort at the fracture site.

iii. Full weight bearing (FWB): Full weight of the body is borne on the fractured limb. FWB is always started initially with an assistive aid which is weaned off gradually. The use of a cane is preferred in elderly individuals as a safety measure.

Methodology

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■ NWB: Use parallel bars to enthuse confidence and to learn the normal gait pattern. Progressing to crutches/crutch or cane.

■ TDWB: Always begin TDWB with a walking aid (walker) or in parallel bars. Begin TDWB when an active leg control is adequate and the patient is able to perform the straight leg raise (SLR) correctly.

■ WBTT: The best method of teaching progressive controlled weight bearing and reducing subjective fear complex is to give a trial on a weighing scale to assess the weight the patient can take without pain. Progress weight bearing gradually, by 5–10 kg increments, to the point of pain-free FWB.

■ FWB: Always begin with an assistive aid and give vigorous gait training to prevent organized limp for no cause. Radiographic evaluation provides important guidance to finalize the methodology of WB to be followed.

General plan of weight bearing in lower limb fractures

By 6 weeks: PWB on the crutches

By 8 weeks: PWB on a cane

By 12 weeks: Assisted ambulation or with slight support or begin with and progress to unsupported ambulation

By 16–24 weeks: Graduated resumption of sports

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Weight bearing in lower limb fractures is depicted in Table 4-6.

Table 4-6

Weight Bearing in Lower Limb Fractures

Fracture and Type	PWB	FWB
1. **Pelvis** Stable Unstable	• TDWB 0–7 days • WBTT 4–8 weeks • TDWB by a week • WBTT >7 days	8–12 weeks 12–16 weeks
2. **Hip** Posterior dislocation	• WBTT >7 days	6–12 weeks
3. **Femur** (a) Neck (intra- and extracapsular)	• WBTT 3–7 days THR: TDWB or • WBTT cemented 2 days • TDWB noncemented • TDWB 4–6 weeks	6–12 weeks

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(b) Shaft Stable Unstable	WBTT 0–6 weeks WBTT 6–12 weeks TDWB 0–6 weeks	6–12 weeks 6–12 weeks >12 weeks
(c) Distal end	WBTT 8–12 weeks	3–6 months
4. **Patella**	WBTT 2–3 weeks	6–12 weeks
5. **Tibia** Plateau (10 mm depression) Shaft – Treated conservatively – Treated with IF or external fixator Distal tibia(pilon fracture)	TDWB 8–10 weeks WBTT 3–10 weeks TDWB 0–6 weeks WBTT 6–12 weeks TDWB 6–8 weeks WBTT 8–12 weeks	12 weeks >12 weeks >12 weeks

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6. **Ankle**	TDWB 2–3 weeks	>4 weeks
Stable	WBTT 3–4 weeks	>6 weeks
Unstable (treated by ORIF)	TDWB 2–6 weeks	

Fracture management by open reduction and internal fixation

Orthopaedic management

Management of an open fracture

■ Stop bleeding by applying a compression bandage.

■ Splint the injured limb to prevent further damage.

Wound management

1. Irrigation and debridement: The former flushes the foreign matter and contaminated blood clots. In irrigation, large quantity of normal saline reduces bacteria. It cleans all the soft tissue, e.g., skin, fasciae, muscles, tendons, nerves, even bones and joints.

2. Wound coverage: It plays an important role in preventing tissue necrosis and infection.
In compound fractures, wound coverage can be obtained by any of the following methods, of course, apart from starting appropriate antibiotics:

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1. Primary wound closure

2. Delayed primary closure

3. Secondary closure

4. Skin grafting, when the wound cannot be closed by any of the afore-mentioned methods

Fracture stabilization

In open fracture, the wound needs regular dressing – access directly to the wound is essential.

Treatment

When the limb is immobilized in a plaster cast, a window is made in the POP for dressing and wound inspection.

1. The window in POP is closed and the plaster is completed after the wound has completely healed.

2. *Skeletal traction*: In open tibial fractures, skeletal traction is applied and limb is placed on a Bohler Braun splint.

3. *External fixator* (Fig. 4-24). It is the most commonly employed method in the treatment of open fractures. It provides stability to the fracture while providing easy access to the wounds for inspection, dressings and maintenance of wound hygiene. It is also ideal for any intervention and adjustments. In open fracture of tibia, three pins each are applied to the proximal and distal fragments.

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4. *Internal fixation*: Although not a very favourite method in compound fractures, it can be undertaken in selective cases.

(A)

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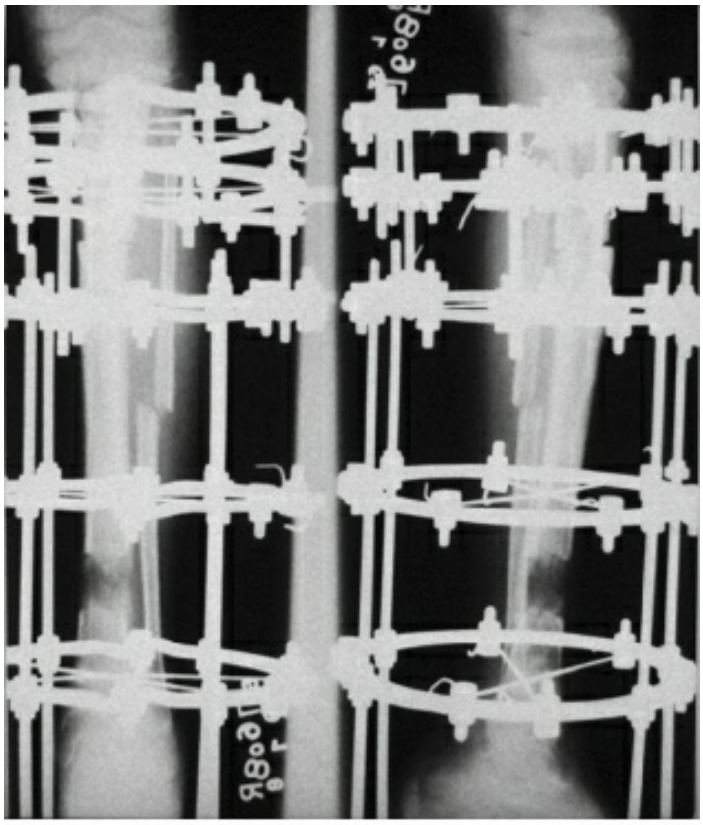

(B)

FIG. 4-24**(A and B)** Clinical and X-ray picture of a ring external fixator applied in the leg. It is also called as Illizarov external fixator.

Complications

- Tetanus
- Gas gangrene
- Chronic osteomyelitis
- Nonunion

Physiotherapy in fractures treated by open reduction and internal

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fixation

■ Before suture removal, follow these points:

■ Carefully watch for any signs of infection.

■ Maintain elevated position of the limb.

■ Only gentle movements are allowed for the distal joints.

■ Active exercises are encouraged within a pain-free range to the affected joints.

■ Gentle isometrics for the affected joints.

■ Vigorous exercise for the nonimmobilized parts.

■ After suture removal, follow these points:

■ Affected joints are gradually encouraged to perform active small ROM exercises

■ Graduated sitting up in bed and standing with arms supported is begun.

■ If permitted, gradual weight bearing is initiated on the affected limb for a smart period.

■ Progress further rehabilitation to FWB ambulation as in closed fractures.

Open Fractures: As open fractures communicate openly with the external atmosphere, they are usually surgical

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emergencies (Fig. 4-25).

FIG. 4-25Open Fracture of the distal forearm and wrist.

Moreover, due to exposure to sudden violent trauma, these injuries may be associated with a multiskeletal and multisystem trauma, and the patient is usually in shock. Therefore, the first objective is to stabilize the patient's general condition. Wound is to be kept sterile and clean to prepare for the necessary surgical procedure at the earliest.

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After debridement and wound irrigation, the fracture is immobilized by an external fixator which is the most preferred method of immobilization in compound (open) fractures.

Physiotherapy management in compound fractures

■ Depending upon the severity of compounding, these types of fractures are fixed mostly by external fixators or by interlocking nailing.

■ The first priority goes to wound care and wound inspection at regular intervals.

■ Care should be taken of the sites of the pin insertion.

■ Limb is kept to maximum possible elevation.

■ Gradual isometrics are taught to the immobilized muscles.

■ Carefully supported patient is encouraged to self-standing and balancing at the bedside.

■ The patient may be encouraged to use crutches and take lessons on crutch standing or balancing.

After bony and soft tissue healing, follow these points:

■ Light active exercises may be begun as early as possible.

■ Increase the intensity of the exercises to make them vigorous.

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■ The patient is taught to balance with required assistive devices, preferably on bilateral axillary crutches to ensure balance.

■ Strengthening and ROM exercises especially in a self-performed manner are welcomed.

■ Training in ambulation is introduced in gradual steps and progressed along with vigorous ROM and muscle strengthening procedures.

Pathological features

The cause of such fractures is bone pathology which has made the bone weak following certain local or generalized skeletal disease or a disorder.

Clinical features

There is a history of discomfort and pain at the bony site of the suspected fracture.

Generalized Disorders	**Local Disorders**
Perioperative pathological fracture	
Senile osteoporosis	Metastatic carcinoma
Lower end of radius	Primary in the lungs, breast, prostate, thyroid or kidney.
Ribs	
Neck of	**Common sites**

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trochanter femur	
Thoracic or lumber body	Thoracolumbar vertebral bodies
Shaft tibia or femur	Proximal half of humerus
Paget disease	Bone cyst at a long bone

Repetitive microtrauma is the usual cause and the common site is the third metatarsal (MT) bone. There is always an increase with exertion or activity significant local tenderness, localized swelling. X-ray shows a fluffy callus surrounding a faint fracture line Fig. 4-26

FIG. 4-26Stress Fracture of the third metatarsal. There is exuberant fluffy callus seen around a faint fracture line in the third metatarsal bone.

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It heals and gets united just by rest and some orthotic support.

Common sites (table 4-7)

■ March fracture (second MT bone) or a continuous marching (e.g., in soldiers)

■ tibia, fibula (caused by overrunning or dancing)

■ Occasionally, fracture of femur

Table 4-7

Site of Injury Involving Blood Vessels and Nerves

Site of Injury	Involved Blood Vessel	Injured Nerves
Upper limb		
Fracture of clavicle	Subclavian vessels	Brachial plexus
Fracture of proximal humerus	Axillary vessels	Axillary nerves
Fracture of supracondylar humerus	Brachial vessels	Radial nerve
Posterior dislocation of elbow	Brachial vessels	Median nerve
Fracture of both bones of the forearm	Anterior interosseous artery	
Lower limb		

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Hip dislocation (posterior)	Femoral vessels	Sciatic nerve
Hip dislocation (anterior)	Femoral vessels	Femoral nerve
Supracondylar fracture of femur	Popliteal vessels	
Dislocation of knee	Popliteal vessels	Common peroneal nerve
Fracture of proximal tibia	Posterior tibial vessels	Posterior tibial nerve
Fracture of tibia and fibula	Posterior tibial vessels	
Injuries of ankle	Posterior tibial vessels	
Monteggia fracture		Posterior interosseous nerve
Fracture of hook of hamate		Deep branch of ulnar nerve
Injury of the wrist		Median nerve
Fracture of neck of fibula		Lateral Popliteal nerve

Treatment

Complete rest for 1 week

Physiotherapy management

Pathological fractures are commonly treated by ORIF, either

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with or without bone cement and bone grafting. The union of these fractures may take any of the following courses:

- may unite in usual time
- may take longer time
- may remain unidentified
- or may unite only after chemo or radiotherapy

The results of physiotherapy in achieving independent ambulation always remain unpredictable.

In such difficult situations, wheel chair ambulation remains the only alternative. However, such patients are treated to be as self-sufficient as possible within the limits of the disease and the disability. Concentrate only on the able limbs, and teach the patients to use them as much as possible (Table 4-8).

Table 4-8

Physiotherapy Guidelines for the Fractures Treated with POP Cast, Poststabilization

During Immobilization	During Mobilzation
Limb elevation to reduce oedema	Elastic bandage and limb elevation
Start with slow-speed small-range isometrics for the muscle groups under immunization	Active exercise for the affected and unaffected joints
Earliest starting functional	Isometrics, isotonics and

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activities by unaffected limb and slowly taken over by affected limb (maybe with assistance)	isokinetics for efficiency of the limb
Nearly full functional use by the affected upper limb and crutch walking or walking with a cane	Progress functional activities with the affected limb; ambulatory activities and gait training

Open fractures

In an open fracture, the integrity of skin is lost, and therefore the fractured bone communicates with the exterior environment.

Open fractures are also called compound fractures. Being open, they are highly susceptible to infection due to contamination by dust particles, bacteria, gravel, etc.

Contamination of a wound by bacteria

■ May block fluent flow of blood to bone, fasciae muscles, thereby further increasing the infection.

■ Impaired vascularity to the uniting fracture may result in delay in fracture union or may even cause nonunion.

■ Open fractures are classified into five classes according to the size of the fracture, skin wound, tissue damage and the level of contamination: for example, the smallest wound of size <1 cm is considered class A and the largest with

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extensive skin damage and an arterial injury is class 5 fracture (also called class E fractures).

Complications of fractures

Prevention of complications as a result of fractures is the most important milestone in successful management and early recovery. The complications are classified into the following three categories (Table 4-9):

■ Immediate or early complications

■ Intermediate or delayed complications

■ Late complications

Table 4-9

Complications of Fractures

Early Complications	**Delayed Complications**	**Late Complications**
• Hypovolemic shock • Injury to the major blood vessels • Injury to the nerves	• Adult respiratory distress syndrome (ARDS) • Infection • Deep venous thrombosis (DVT) • Compartment	• Delayed union • Nonunion • Malunion • Joint stiffness • Avascular necrosis (AVN)

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• Injury to the muscles	syndrome • Crush syndrome	• Reflex sympathetic dystrophy (RSP) • Late nerve palsy • Myositis ossificance and ectopic ossification • Secondary osteoarthritis • Limb length disparity • Prolonged bed immobilization • Volkmann ischaemic contracture (VIC)

Basic principles of preventing complications following fractures

■ Knowledge about the possible complication in relation to the individual fracture and methods of its prevention

■ Early detection by skilled critical regular monitoring

■ Educating and guiding a patient on the expected early signs and symptoms of the possible complications related to

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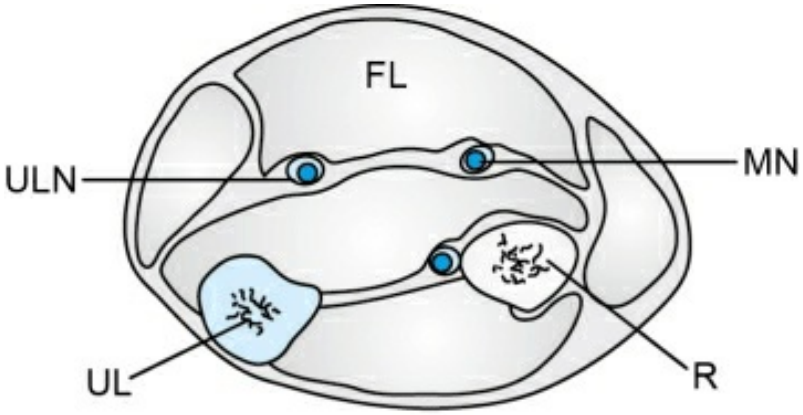
a particular fracture, and to report immediately (the complications of fractures are presented in Table 4-10 and Figures 4-27–4-32)



Forearm compartments
(seat of nerve and vessel
compression syndrome)

FL = Flexor compartment
ULN = Ulnar nerve
MN = Median nerve
UL = Ulna
R = Radius

FIG. 4-27Compartment syndrome (cross-section of forearm).

FIG. 4-28Volkmann ischaemic contracture (VIC).

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FIG. 4-29Atrophic nonunion. Note the sclerosis at the fracture ends and little callus. The medullary canal is closed at the fracture site.

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FIG. 4-30Reflex sympathetic dystrophy (RSD) of right hand. The normal left hand is shown for comparison.

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FIG. 4-31Cubitus valgus deformity on the right side.

FIG. 4-32Ectopic new bone formation (myositis ossificans) on the anterior aspect of the elbow.

Table 4-10

Nature of Injury and the Possible Complications

Nature of Injury	**Possible Complication**
• Violent trauma RTA, multiple fractures, compound fractures, fractures of hip, pelvis, femoral head, neck; fractures of skull, spine or violent visceral injuries	• Hypovolaemic shock

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• Fracture of proximal humerus, through the waist of scaphoid bones, injury to lunate bone (Kienbock disease), fracture of neck, head or posterior hip dislocation	• Avascular necrosis
• Supracondylar fracture of humerus or fracture of both bones of forearm, elbow joint dislocation	• Volkmann ischaemic contracture (VIC) • Myositis ossification at elbow
• Fracture of both bones of the forearm or leg just proximal to the wrist or ankle, respectively	• Compartmental syndrome
• Fractures of radius and ulna at the same or close level to each other	• Cross-union
• Colles fracture or fractures at the distal end of radius	• Reflex sympathetic or Sudeck dystrophy (RSD)

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• Major fractures around the hip – central dislocation, fractures around the hip joint	• Deep venous thrombosis (DVT)
• Fracture of skull, vertebral column, posterior or central dislocation of hip	• Ectopic ossification

To deal effectively with the complications following fractures, one must carefully keep a watch on the possible or incoming complication common to certain types of injuries or fractures as presented in the following tabular format.

(A) Immediate complications

Hypovolaemic shock

Causes

- Severe trauma (road traffic accident [RTA])
- Multiple fractures
- Fractures: pelvis and long bones
- Severe visceral injuries

Clinical features

- Shock
- Coma

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- Cardiorespiratory failure
- Excessive external or internal bleeding (blood loss of >1500 mL)
- Renal failure

Therapeutic approach

- Control bleeding by the following:
- Localized external pressure at the bleeding point
- Compression bondage
- Keeping limb in elevation
- Start i.v. line 1 colloids after blood grouping and cross-matching
- Instant cardiopulmonary resuscitation
- Restoration of cardio respiratory function
- Restoration of blood fluid volume
- Immediate surgery to repair vessel and nerve
- Catheterization of urinary bladder
- Measures to prevent infection
- Instant splinting of the injured limb

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• Pelvic compression clamp to prevent excessive bleeding and stabilize pelvic fracture as well

Specific physiotherapy measures

• Limb supporting splint

• Chest physiotherapy to improve respiratory function

Injury to blood vessels

Causes

• Blunt or sharp injury

Blood vessel may have the following:

• Vasospasm

• Incomplete or complete tear

• Compression by fracture fragment, haematoma, tear, internal thrombus, tight POP cast or bandage

Clinical features

• Limb may be cyanosed, cold and pale at the distal end.

• There may be pulselessness or feeble pulse.

• Gradual onset of ischaemia may lead to gangrene.

Therapeutic approach

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- Supportive splinting
- Immediate reduction of the fracture
- Explore and repair artery or vein and improve distal circulation

Specific physiotherapy measures

- Localized pressure at the bleeding points
- Compression bandage
- Limb support and keep in elevation (no thermotherapy)
- Early possible active, or assisted movements to distal joints
- Intermittent monitoring

Injury to nerves

Causes

Nerve may be injured by crushing, stretching, compression or by division.

Clinical features

- Assess neurovascular status distal to injury for the following:
- Gradual sensory impairment in its distribution
- Paresis or paralysis in the innervated muscle groups

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- Cold limbs, of associated vessel injury

Therapeutic approach

- Provide splint to prevent overstretching of the injured nerve and contractures

- Protect anaesthetic areas from heat, cold or injury

- Repair of the severed nerve

Specific physiotherapy measures

- Provide suitable splint (static)

- Conduct diagnostic tests to assess injury

- Continue distal movements

After repair – sensory and motor

- Re-education

- Biofeedback

- Functional restoration

Injury to muscles

Causes

- Direct or indirect injury

Clinical features

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• Localized haematoma, swelling over the injured area with redness, warmth and tenderness

• Painful isometric as well as isotonic contractions

• Painful or lost function of the injured muscle, if cut

Therapeutic approach

• Fast healing due to abundant blood supply

• Rest and support to the adjacent joint

• Immobilization by splint or bandage

• Nonsteroidal anti-inflammatory drugs (NSAIDs)

Specific physiotherapy measures

• Prevent contractions by supportive splint.

• Muscle injury heals by fibrosis and may form adhesions. Early movements are therefore begun to prevent contractures.

(B) Delayed complications

Ards

Causes

• Multiple fractures, or fracture of pelvis, or long bones

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• Inflammatory reaction set up by microemboli of fat released from the fracture (bone marrow)

• Dyspnoea

Clinical features

• Dyspnoea with increased rate of respiration due to deficiency of gaseous diffusion in the lungs

• Multiple opacities in the lung

• Small patches on the chest wall

Therapeutic approach

• Oxygen to restore PaO_2

• Tracheostomy

• Positive pressure ventilation

• Pharmaceutical drugs – steroids, heparin, low-molecular-weight dextran, antibiotics, etc.

• Definitive fracture treatment

Specific physiotherapy measures

• Concentrated chest physiotherapy procedures

• Early mobilization with monitored breathing

Infection

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Causes

- In open fractures
- After surgical operations
- Neglected wounds

Clinical features

- Healthy wound is erythematous and clean
- If contaminated with dead soft tissue, may even destroy bone (necrosis)

Therapeutic approach

- Antibiotics
- Regular dressing
- Wound care
- Irrigation
- Debridement
- Wound closure

Specific physiotherapy measures

- Rest and proper splinting
- If the limb is immobilized, vigorous active movements are

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given to the free joints to augment circulation

• IR, ultrasonics or UV radiation or hydrotherapy

Deep venous thrombosis (dvt) and pulmonary embolism

Causes

• Major fracture around the hip joint, spine, femur, tibia

• Pathogenesis Virchow's triad of venous stasis, vascular damage and hypercoagubility

• Thrombus formed in the venous plexus may lead to clot formation which may get detached and pass onwards to the lungs or brain with possible fatal consequences

Clinical features

• Delayed clinical signs (by 4–8 days)

• Pain, redness, warmth with oedema in the calf muscles

• Positive Hoffmann sign (forced ankle dorsiflexion produces calf pain)

• Fever may be present

Therapeutic approach

• Elastic compression bondage

• Anticoagulant therapy

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Specific physiotherapy measures

- Measures to reduce pain (no thermotherapy)
- Early pain-free active limb movement
- Vigorous toe and ankle movements with limb well supported in elevation

Compartment syndrome (orthoengorge)

Causes

- Vascular compromise occurs in tight compartment due to tight bandage or POP applied after an injury
- Common sites: inflammation
- Lower forearm above the wrist
- Lower leg above the ankle joint
- Supracondylar fracture in children and crush injuries in adults

Clinical features

- Excruciating local pain (poorly localized)
- Pale, cold distal part of the limb, with reduced or no pulsation
- Passive extensions of fingers elicit pain due to an ischaemic necrosis of the tissues contained within the volar

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compartment following an improperly fitting forearm splint /POP

Therapeutic approach

- Remove tight bandage or POP.
- Keep limb in elevation and observe for a few hours.
- If no improvement, perform surgical decompression by dividing skin and fasciae.
- Leave wound open till swelling completely subsides.
- Close the wound by secondary suture or skin grafting.

Specific physiotherapy measures

- Careful examination and regular monitoring of the immobilization
- Vigorous active and resisted fingers toe movements
- Monitor the progress
- Early protected functional use of the related limb

Volkmann ischaemic contracture (vic)

Causes

- Impaired vascular integrity results in muscular ischaemia. The ischaemic muscles are gradually replaced by fibrous tissue which progresses to fibrosis, contractures and

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shortening of the muscles, hence the name.

• It mainly affects the flexor group of muscles of forearm and fingers. Tight bandage or POP cast is the main cause.

• Ischaemia may damage the peripheral nerve too.

Clinical features

• Severe pain – from forearm to hand

• Gradually progresses to sensory and motor paresis to paralysis

• Progresses to flexion deformity at the wrist and fingers

• Develops typical Volkmann sign

• Fibrosis of the flexors of wrist and fingers causes shortening and fixed flexion deformities at the wrist and fingers.

Therapeutic approach

• If detected early, remove compressive cause, begin with vigorous physiotherapy with dynamic orthosis – good results

• Late, moderate cases: Flexor-slide (Maxpage) operation of releasing flexor group of muscles from their origin

• Severe cases: Shortening of the bones of the forearm, proximal row of carpal bones with wrist arthrodesis in

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functional position

Specific physiotherapy measures

- Early full ROM exercises with emphasis on full finger extension with wrist joint extended fully

- Dynamic VIC splint: Splint to retain continuously stretch on flexors of wrist and fingers

- Active mobilization

- Functional training in postsurgery patients: Re-education of the muscle function and full ROM

- No heat or electrical modality

Crush syndrome (2–3 days following injury)

Causes

- Massive crushing of the muscle tissue following violent direct trauma (e.g., RTA, natural calamities like earthquake)

- May occur due to inappropriate application of tourniquet, gas gangrene or acute compartmental syndrome

Clinical features

- Muscular crushing results in the release of myohaemoglobin into the circulation. It spreads to the renal tubules leading to renal failure

- Scanty urine

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- Urinary incontinence and reduced urinary output

- Acute renal failure

Therapeutic approach

- Catheterization

- Immediate application of tourniquet and its gradual release to limit the entry of deleterious substances in circulation

- Haemodialysis – to prevent total renal failure

Specific physiotherapy measures

- Superficial thermotherapy to lower abdomen and deep pressure massage (kneading)

- Early sustained upright posture (may be assisted, e.g., an on tilt table)

- Counselling to overcome depression

Prolonged bed immobilization

Causes

- Certain conditions, like RTA, fractures of the hip joint in elderly, spinal head injuries or operable cases, require longer bed immobilization or unconsciousness.

- Longer immobilization invariably results in a number of complications including gross detoning of all the systems

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and the organs of the body.

Clinical features

- Hypostatic pneumonia
- Deterioration of all the vital functions
- Muscular, other soft tissues weakness, and bone demineralization
- Joint contractures and stiffness
- DVT
- Deterioration in the renal function with susceptibility to urinary infection
- Pressure sores
- Generalized systemic and organs detoning
- Depression and anxiety

Therapeutic approach

- Prevention of all these complications is the major need rather than treatment.
- Physiotherapy in the form of multiple measures from chest physiotherapy, to critical monitoring of early initiation of individually planned exercise training and functional training predominate the therapy. It can prevent, if not, still play a major role in reducing the gravity of such

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complications if and when they occur.

(C) **Late complications**

Prolonged bed immobilization

Causes

When the bone fails to unite in the stipulated time.

- Severe anaemia
- Localized bone disease
- Reduced blood supply at the fractured site
- Malnutrition

Clinical features

- Continued pain at the fracture site with stiffness in the adjacent joint
- Crepitus at bony ends with passive movement
- Radiological investigation confirms nonunion

Therapeutic approach

- Extensive measure to treat the underlying disease causing nonunion
- If no signs of union: Bone grafting with or without internal

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fixation

Specific physiotherapy measures

- Ensure correct immobilization, strictly preventing stress on the fracture site

- Active resistive exercises to improve overall circulation of limb

- Repetitive movements of the distal free joints

Nonunion of a fracture

Causes

- Extensive bone loss due to injury

- Incorrect or inadequate treatment (e.g., reduction and immobilization)

It could be of two types:

- Atrophic – rounded off fractured bony ends with no evidence of callus formation

- Hypertrophic – excessive bone formation at the site of a fracture (elephant-foot) but with the fracture line still existing

Clinical features

- Adequate stabilization of the fracture may occur.

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• Pseudarthrosis or a false joint may be evident at the fracture site – on passive movement or on bearing weight with inability to bear body weight femoral neck, scaphoid bone, long bones like humerus or tibia.

• Movement at the fracture site is pain-free and abnormal.

Radiological investigations:

• Bone sclerosis with obliteration of medullary cavity

Therapeutic approach

• External fixation by Ilizarov fixator

• Bone grafting with or without internal fixation

• Bone grafting with or without internal fixation

Specific physiotherapy measures

• Early graded functional training, with fixator

• Early graded safe weight bearing with bilateral axillary crutches

• Vigorous hip movements in supported standing on the normal limb

Malunion and delayed union of a fracture

Causes

• Union of fracture occurs in a malposition like angulation or

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rotation

Clinical features

- Obvious malposition of the fractured bones
- Limb length disparity

Therapeutic approach

- Leave alone if the function without discomfort is retained
- Corrective osteotomy with internal fixation and bone grafting

Specific physiotherapy measures

- Progressive functional training
- Assisted active movements at the initial stage
- After healing of osteotomy, vigorous functional training

Stiff joint

Causes

- Traumatic: when the injury or fracture is close to the joint
- Nontraumatic – when the disease process involves joint

Clinical features

- Adhesion formation taking place around the joint

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- More susceptible joints: shoulder, elbow, hand and knee

- Initially painful stiffness, later the pain is reduced but stiffness remains

Therapeutic approach

- Vigorous physiotherapy

- Wedge POP

- Manipulation under general anaesthesia (GA) (not very popular due to reformation of adhesions)

- Surgical release of adhesions

Specific physiotherapy measures

- Starting early vigorous mobility exercise

- Low-intensity, pain-free, sustained stretch and hold

- Continuous passive motion (CPM)

Avascular necrosis

Causes

- In certain fractures, the blood supply to a segment of bone is deficient and is susceptible to bone necrosis (e.g., fracture of head femur, fracture of proximal half of scaphoid through its waist, body of talus)

- Prolonged steroid therapy

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- Alcoholism
- Renal dysfunctions
- Postpartum

Clinical features

- Early aching type of pain occurs on the anterior aspect of hip or thigh or groin – even at rest.
- ROM of hip joint is full, painful at the extreme range.
- Later on stiffness develops and there is more pain.
- Use of hand is painful in scaphoid involvement.
- Radiographically affected bone appears more dense (sclerotic) and may have areas of collapse at advanced stage of the disease. Bone scan provides early detection of bony sclerosis.

Therapeutic approach

- Core decompression of femoral head by vascularized bone grafting and internal fixation is performed.
- In extensive destruction of the head of femur, total hip replacement (THR) is advisable.
- In scaphoid bone involvement, ORIF by K wire is advisable.
- Fractured neck of talus needs to be treated immediately to

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prevent avascular necrosis (AVN) of the body of talus, as the blood supply to the body of talus passes through the neck of talus.

Specific physiotherapy measures

• Hypertrophy of the functional muscle groups over the affected bone and joint

• Maintenance of functional ROM

• Adequate support (aid) to relieve ambulatory body weight or power movements of upper limp

Reflex sympathetic dystrophy (rsd)

Causes

• Sympathetic disturbances

• Generally seen after fracture of distal end of radius (Colles fracture)

• When occuring at the wrist joint, it is called Sudeck atrophy

Clinical features

• Hand is oedematous with severe pain and redness.

• Skin is cold and may be cyanosed (blue).

• Wrist, palm and fingers are tender with painful stiffness.

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• Radiograph shows osteoporosis.

• Bone scan shows increased uptake.

Therapeutic approach

• Sympathetic block by anaesthetic injection near the sympathetic ganglion in the axilla or Cervical sympathectomy

Specific physiotherapy measures

• Suitable supporting and resting orthosis

• Pain relief by transcutaneous nerve stimulation (TENS) or cryotherapy (no thermotherapy)

• Maintain ROM of involved finger and wrist joints by assisted passive ROM

• Progressive active ROM exercises

• Graduated pain-free functional training in improving hand functions

Late nerve palsy

Causes

• Nerve entrapment in a fractured bone

• Progressive development of deformity following fracture – putting stretch on the nerve causing neuritis or delayed nerve palsy (e.g., development of cubitus valgus putting

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stretch on the ulnar nerve behind the medial epicondyle following fracture of the lateral condyle of the humerus).

Clinical features

Gradual development of the symptoms and signs of ulnar nerve compression in the tissues of its innervation, e.g.:

• Paraesthesia, sensory loss in its distribution in the hand

• Paresis leading to paralysis in the muscles of its innervation

• Gradual development of the deformity of ulnar claw hand

Therapeutic approach

• Surgical release of the stretched nerve by transposing it to the anterior aspect of the elbow to relieve stretch (anterior transposition) on the ulnar nerve or Tardy ulnar nerve palsy

Specific physiotherapy measures

• Strict monitoring of the possible stretch symptoms and signs

• Hand splint static to prevent contracture and deformity

• Active movements or bio feedback to put in voluntary efforts

Postsurgical measures:

• Wound care

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- Dynamic hand splint
- Assisted active exercises
- Biofeedback to re-educate the deficient movements

Myositis ossification or ectopic ossificans

Causes

- Myositis ossification: Following injury or fracture, new bone formation takes place due to bleeding into the periosteum, joint capsule and the muscles with formation of haematoma; passive movements, forceful or hard massage aggravates bone formation.
- Ectopic ossification – head or spinal cord hip injury forming ectopic ossification at the hip joint

Rarely shoulder, knee or ankle may develop myositis.

Clinical features

A classical example is the injury to or around the elbow.

Early local signs:

- Warmth, redness and tenderness
- Painful limitation of ROM
- Late-stage loss of movements in the terminal ranges (both flexion and extension)

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Radiographically, initially fine amorphous flakes of calcium – progress to calcified mass blocking ROM, which becomes pain-free with mechanical blockage to the movement

Therapeutic approach

• Careful handling of the suspected sites:

• Early immobilization

• Careful graded mobilization when the acute symptoms disappear

• Following radiological consolidation of the myositis mass, it may be surgically excised (controversial due to recurrence).

• In grossly blocking functional activities, excisional or replacement arthroplasty may be undertaken for ectopic ossification.

Specific physiotherapy measures

• Trauma at the elbow, shoulder, hip, knee and ankle should be carefully handled, monitoring correct early immobilization and the signs and symptoms of acute stage to prevent it from occurring.

• On removing immobilization, gradual initiation of only relaxed rhythmic free active movements is given and ROM is progressed.

• No massage, or passive movements or manipulation is required.

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• Postsurgery, concentrate on functional training emphasizing on achieving functional ROM.

Secondary osteoarthritis

Causes

Degenerative wear and tear in the weight-bearing joints

• Age-borne disease

• History of injury/fracture close to the joint

• Avascular necrosis (AVN)

Clinical features

• Pain on weight-bearing or pressurized power hand functions

• Tenderness and crepitus

• Synovial inflammation

• Progressive stiffness in the joint

• Joint deformity

• Painful limp

Radiological investigation

• Narrowing of the joint space with formation of osteophytes and loose bodies

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• Subchondral sclerosis, cystic changes in the joint

Therapeutic approach

• NSAIDs to relieve pain

• Chondroprotective drugs like glucosamine, chondroitin sulphate

• Intra-articular sodium hyaluronan injection

Surgery

• Arthroscopy

• Intertrochanteric osteotomy

• Joint replacement arthroplasty

Specific physiotherapy measures

• Deep heating modality to relieve pain

• Exercises mainly to retain full ROM

• Education of a patient on proper body mechanics in functional activities

• Gait training with ambulatory aids

Surgical

• Early isometrics

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- Graduated mobilizational and functional activities

Limb length disparity

Causes

- Malunion overlapping or angulation at the fracture site
- Loss of bone piece at the time of injury
- Bone compression at the cancellous bone end
- Damage or bone disease at the epiphyseal plate
- Reduced blood supply, e.g., post polio residual paralysis (PPRP)
- Lengthening: Increased vascularity at epiphyseal plate

Clinical features

- Limp during ambulation
- Cosmetic deformity

Late: Secondary osteoarthritis (OA) at the involved joint

Therapeutic approach

- Growth stimulating procedures
- Electrical stimulation by DC current of ≤1 V
- Electromagnetic method

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• Surgical distraction technique following osteotomy and distracting bones and applying external fixator

Specific physiotherapy measures

• Shortening exceeding 2 cm or half compensatory shoe raise

• Following surgery – functional training ambulation with bilateral axillary crutches (PWB) to hasten callus formation

• Vigorous strengthening exercise including moving operated leg

Rare complications

Cross-union: Mid-shaft fracture of radius and ulna at the same level may result in a cross-union in between both the bones (Fig 4-33). It happens due to the dispersal of haematoma of a fracture and extension of the callus formation – restricting the rotary forearm movement of pronation and supination.

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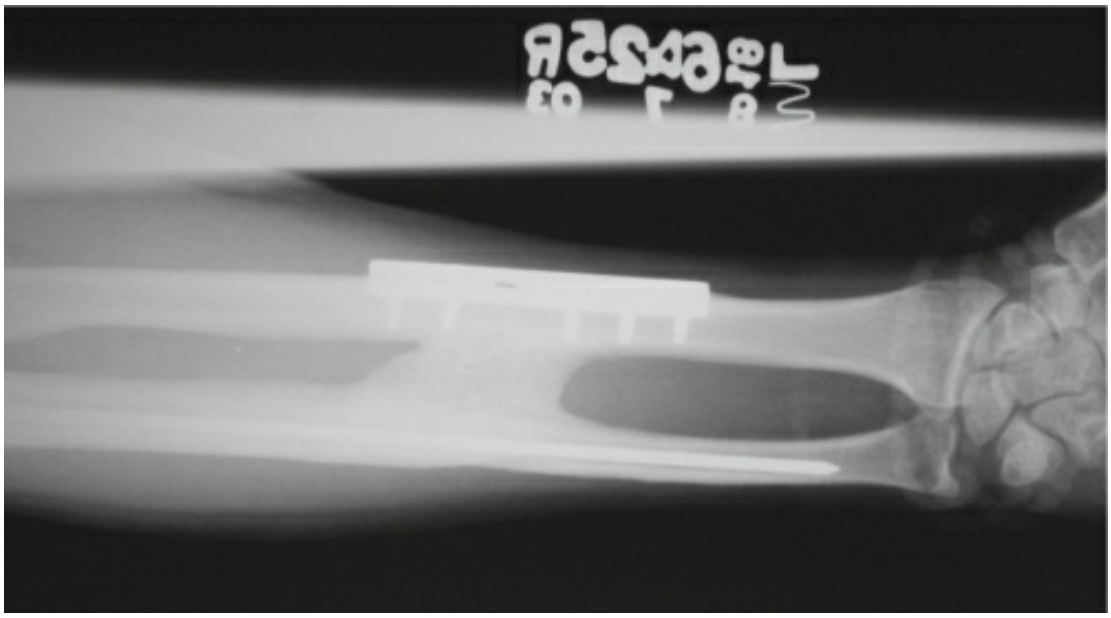

FIG. 4-33Cross-union between radius and ulna.

In children, it is treated by manipulation under GA followed by POP immobilization. For 3–6 weeks, in adults, ORIF with intramedullary nailing is done.

Physiotherapy for this complication mainly concentrates on achieving stable functional midprone position of forearm.

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CHAPTER 5

Injuries around the shoulder

OUTLINE

- Fractures of the clavicle
- Fractures of the scapula
- Dislocation of acromioclavicular (AC) joint
- Dislocation of sternoclavicular joint
- Dislocation of shoulder
- Anterior dislocation
- Posterior dislocation
- Luxatio erecta
- Recurrent anterior dislocation of shoulder
- Fracture dislocation of shoulder
- Fracture of greater tuberosity of humerus
- Fractures of the proximal humerus

Fractures of the clavicle

Fracture of the clavicle is one of the commonest injuries, seen at all ages. It is commonly fractured at the junction of its middle and lateral third; fracture of the lateral third is the other common site.

Mode of injury

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Fractures of the clavicle usually result from a fall on the outstretched hand (Fig. 5-1A and AA) or due to a direct trauma to the bone.

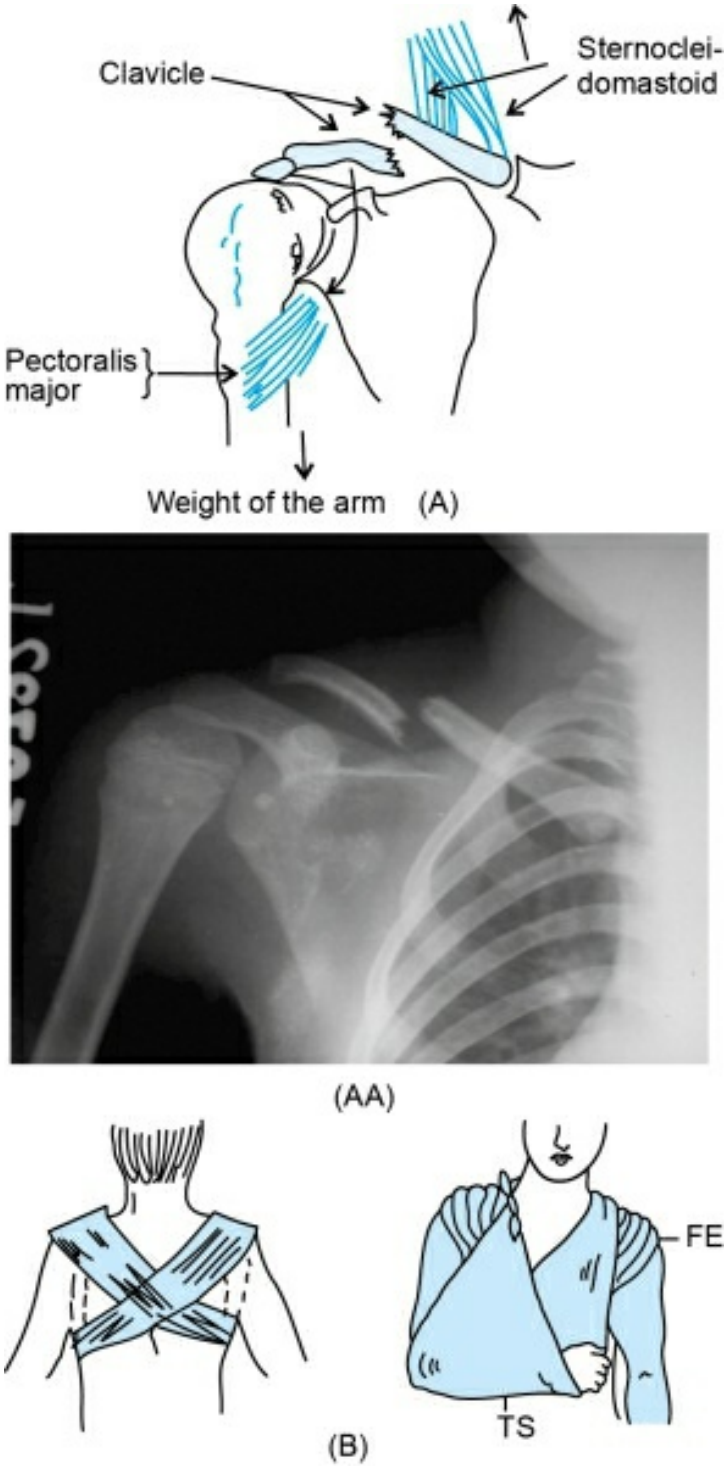

FIG. 5-1 Fracture clavicle. **(A)** Common fracture site. (AA) Radiograph. **(B)**

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Immobilization by figure-of-eight bandage (FE) with triangular sling (TS).

Diagnosis

The clinical diagnosis of a fracture is usually not difficult as it is a subcutaneous bone. In fractures of the middle third, the lateral fragment is displaced forwards and downwards by the weight of the limb while the medial fragment is pulled upwards by the sternomastoid muscle (Fig. 5-1A).

Treatment

1. A triangular sling to support the affected limb is all that is needed in undisplaced fractures in adults and even for displaced fractures in children. The sling is maintained for a period of 2–3 weeks.

2. A figure-of-eight bandage is tied over a pad of cotton wool in each axilla and crossed between the scapulae in such a way that both the shoulders are braced up (Fig. 5-1B). The figure-of-eight bandage is kept in position for a period of 3–4 weeks. The affected limb is also supported in a triangular sling. However, the current trend is to support the limb only in a triangular sling (without using a figure-of-eight bandage). A tight figure-of-eight bandage can cause compression in the axilla, thereby causing vascular embarrassment or pressure on the brachial plexus resulting in tingling, numbness or paraesthesia in the affected upper limb. When such a situation arises, the bandage should be removed and the limb should be supported in a sling.

The figure-of-eight bandage may get loosened after a few days and needs to be tightened or changed.

The fracture almost always clinically unites in 3 weeks. The sling and/or figure-of-eight bandage should be discarded after 3 weeks and the shoulder be mobilized.

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3. Open reduction and internal fixation (ORIF) may be indicated rarely in cases where sharp spurs of the bone endanger the underlying vessels or threaten to perforate skin. The clavicle can be internally fixed with a nail or a special plate (Fig. 5-2).

4. In a patient with multiple injuries who is totally bedridden and cannot be made to sit up, the figure-of-eight bandage cannot be tied. In such a situation, a roll of cotton wool or a towel is placed between the two shoulder blades. This braces the shoulder backwards and reduces the fracture. This is maintained for a period of 3 weeks.

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(A)

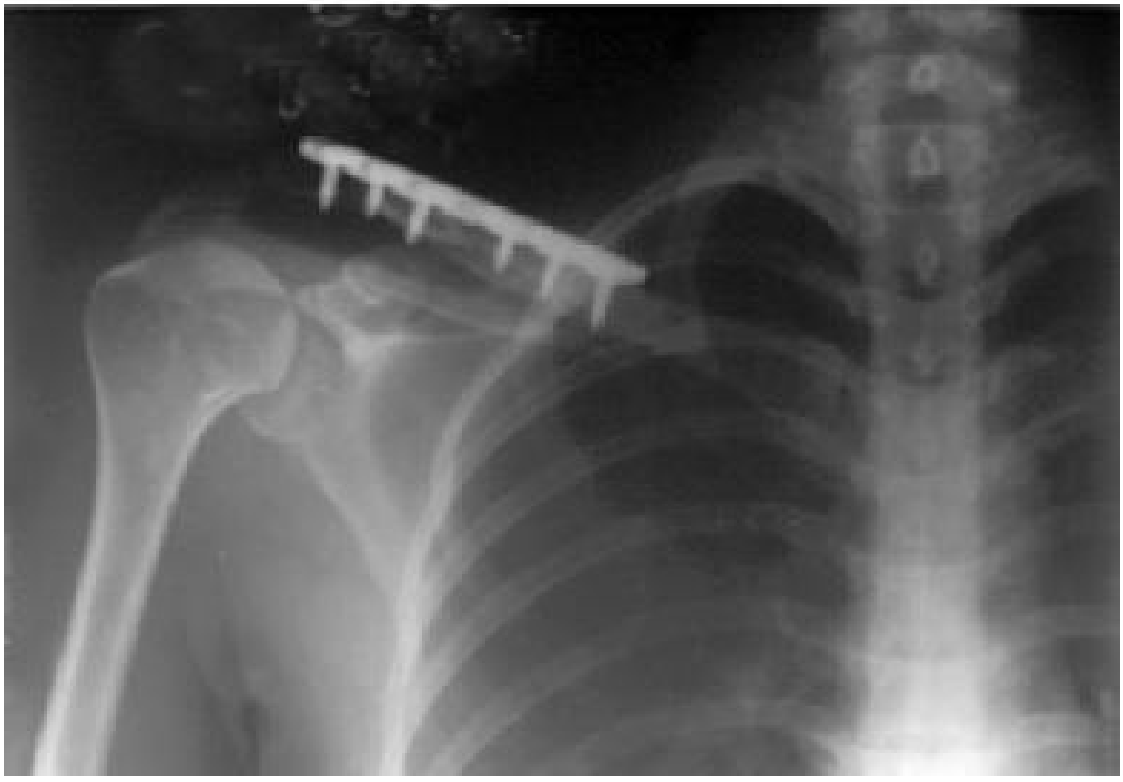

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FIG. 5-2 A displaced fracture of the clavicle treated by open reduction and internal fixation. **(A)** Preoperative radiograph. **(B)** Postoperative radiograph.

Complications

1. Injury to the subclavian vessels or brachial plexus can be caused by a spike of the bone.

2. Malunion: Although displaced fractures treated conservatively often malunite, remodelling of the bone, in due course of time, corrects the deformity of the bone. It does not usually lead to any functional disability.

3. Nonunion of the clavicular fracture is very rare. In an established case of nonunion, ORIF and bone grafting are indicated.

Physiotherapeutic management

Basic objective: To restore active full range of all the movements of the shoulder complex.

1. ***Conservative treatment***

During immobilization (first 3 weeks)

(a) To check the alignment of the fractured bone ends with immobilization.

(b) To check the arm sling to ensure that there is total support to the elbow, to avoid gravitational force exerting any pull in the shoulder girdle and the shoulder joint complex.

(c) When the figure-of-eight bandage is applied, make sure

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that it is holding the scapula in a properly braced up position.

(d) Confirm that the bandage in the axillae is not causing undue pressure on the brachial plexus.

(e) Properly supported resistive full range movements to be explained to the patient for the elbow, forearm, wrist and hand.

Mobilization (after 3 weeks): Mobilization should be initiated in a small range; relaxed movements using Codman's pendulum exercise regime gradually increasing the range as further relaxation is achieved.

For further increase of range, relaxed passive movements with the patient in supine position should be initiated at the earliest. Attempts should be made to get to the extreme of each range with emphasis to hold the terminal position. As this technique is invariably discomforting, especially in the terminal range of elevation and external rotation, suitable adjunct like hydrocollator pack may be used before, after or even during this manoeuvre.

Resisted exercises using dumbbells or self-resistance should be practiced in between the sessions of stretching.

Self-resistive exercises and mobilization with a wand should be taught as home exercise regime, besides functional use of the whole limb.

The results are excellent and by 6 weeks, the patient should get back fully mobile and with a fairly strong shoulder.

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2. ***Surgical treatment***

In the event of ORIF, gradual mobilization should be started by 8–10 days.

Initially, the mobilization is started within the sling by teaching relaxed pendulum movements assisted by gravity and momentum.

Pain at the site of operation needs special attention and should be taken care of by using suitable adjuncts such as thermotherapy or cryotherapy.

Rest of the management technique should be progressed on the same lines as described for fractures treated by conservative approach.

The functional results are excellent by 6 weeks following surgery.

CAUTION

1. While initiating early movements within the sling, it is necessary to confirm that no movement is occurring at the fractured bone ends.

2. Injury to the brachial plexus, though rare, should be observed with careful examination and taken care of at the earliest.

Fractures of the scapula (fig. 5-3)

The scapula may be fractured through:

1. The body

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2. The neck

3. The spine of scapula

4. The coracoid process

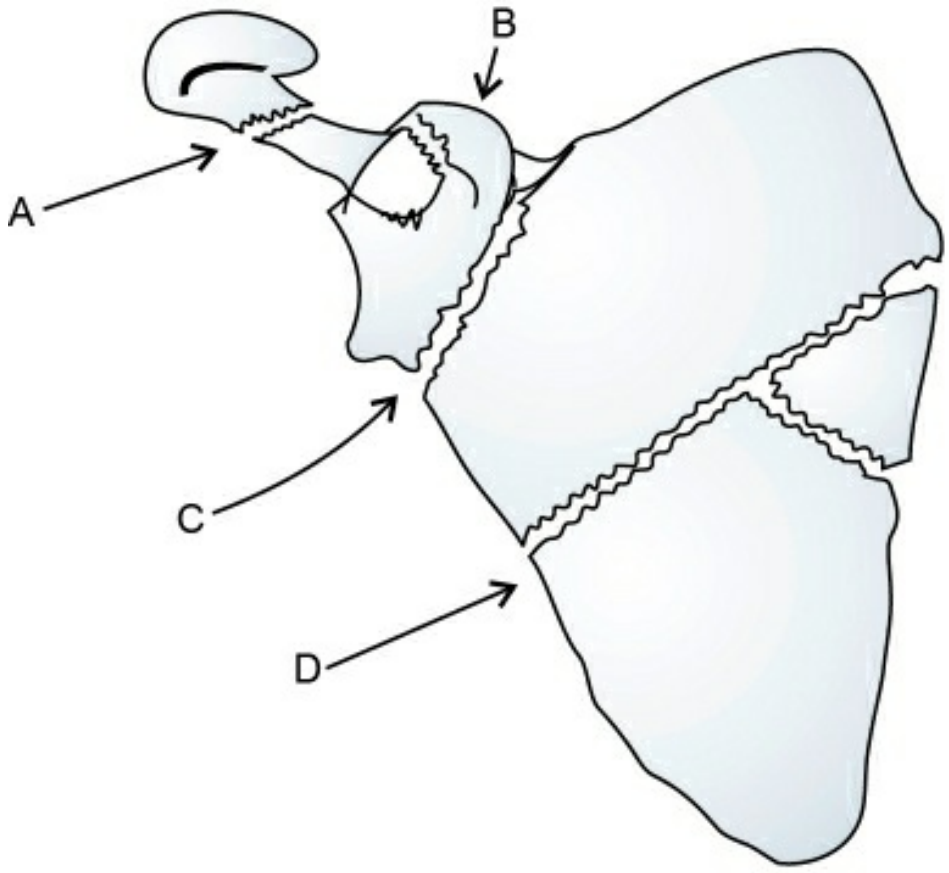

FIG. 5-3 Fracture of the scapula through: **(A)** acromion process, **(B)** coracoid process, **(C)** neck and **(D)** body.

Mode of injury

- Direct or crushing injury
- Fall on the shoulder or on the outstretched hand

The scapula is completely surrounded by muscles and fascia and

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hence, displacement of the body of scapula is unimportant. However, a displacement through the glenoid fracture, which constitutes an intra-articular fracture, needs accurate reduction.

Treatment

Fracture of scapula is generally treated by conservative methods. The limb is supported in a sling for about 2 weeks. Mobilization of the shoulder is started as soon as the pain permits.

Operative treatment

Operative treatment in the form of internal fixation by screws or plate is taken up when there is marked displacement of fragments, particularly in comminuted fractures of neck of scapula involving the glenoid also. The congruity of the glenoid articular surface needs to be restored (Fig. 5-4).

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(A)

(B)

(C)

FIG. 5-4 Comminuted fracture of the scapula treated by open reduction and internal fixation. **(A)** Preoperative radiograph shows comminuted fracture involving the glenoid. **(B)** A 3-dimensional CT scan reconstruction image. **(C)** Fixation by various plates and screws restoring the articular surface of the glenoid.

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Physiotherapeutic management

Basic objective: To regain active full range of all the movements of the shoulder complex. Because the scapula is enveloped all round by strong muscles, displacement of the fracture fragments is rare. As the period of immobilization is short (2 weeks), mobilization is not difficult.

During immobilization (first 2 weeks): Physiotherapeutic management is the same as outlined for fracture of the clavicle.

Only isometric exercises to the shoulder girdle muscles can be initiated early.

Mobilization: The scapula with its extensive muscular attachment plays an important role in the strength as well as range of all the basic movements of the shoulder complex. Therefore, the degree of pain and discomfort at the initiation of mobilization is a common feature following its fracture.

Proper stabilization to the body of the scapula and suitable physiotherapeutic modality to control pain is essential.

Mobilization is gradually progressed as detailed for the management of fracture of the clavicle.

Extra emphasis is to be given to the programme of strengthening exercises using proprioceptive neuromuscular facilitation (PNF), dumbbells and self-resistive exercise techniques.

In the event of surgery or in older patients, special mobilization techniques may be necessary for the scapula.

Full range of fairly strong movements of the shoulder complex should be obtained by 4–6 weeks.

Dislocation of acromioclavicular (AC) joint

This injury results from a fall on the shoulder with impact on its outer side. There is tenderness and swelling of the joint and the examining finger finds a difference in the level of the outer end of the clavicle and the acromion (Fig. 5-5A).

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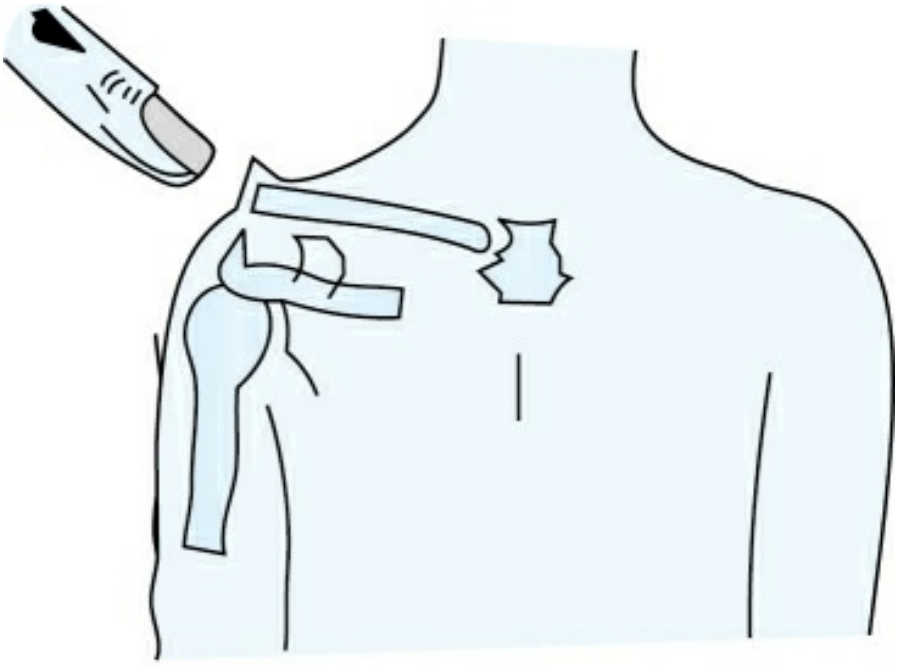

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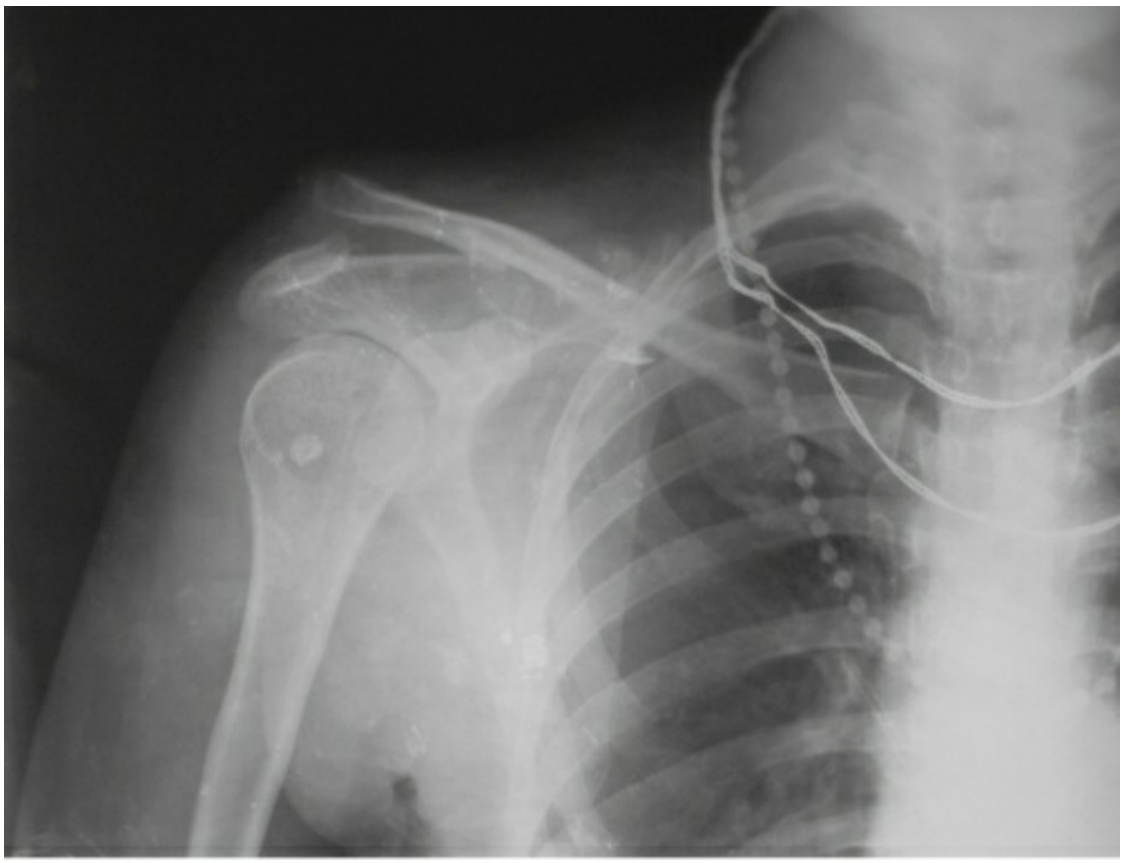

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FIG. 5-5 **(A)** Dislocation of acromioclavicular joint: clinical examination. **(B)** Subluxation of the acromioclavicular joint.

Diagnosis

Radiograph will show the lateral end of the clavicle at a higher level in relation to the acromion (Fig. 5-5B).

Treatment

1. Conservative: Strapping of the joint for 3 weeks.

2. Surgical: ORIF is performed using special plates, Kirschner wires (K-wires) (Fig. 5-6) or by tension band wiring.

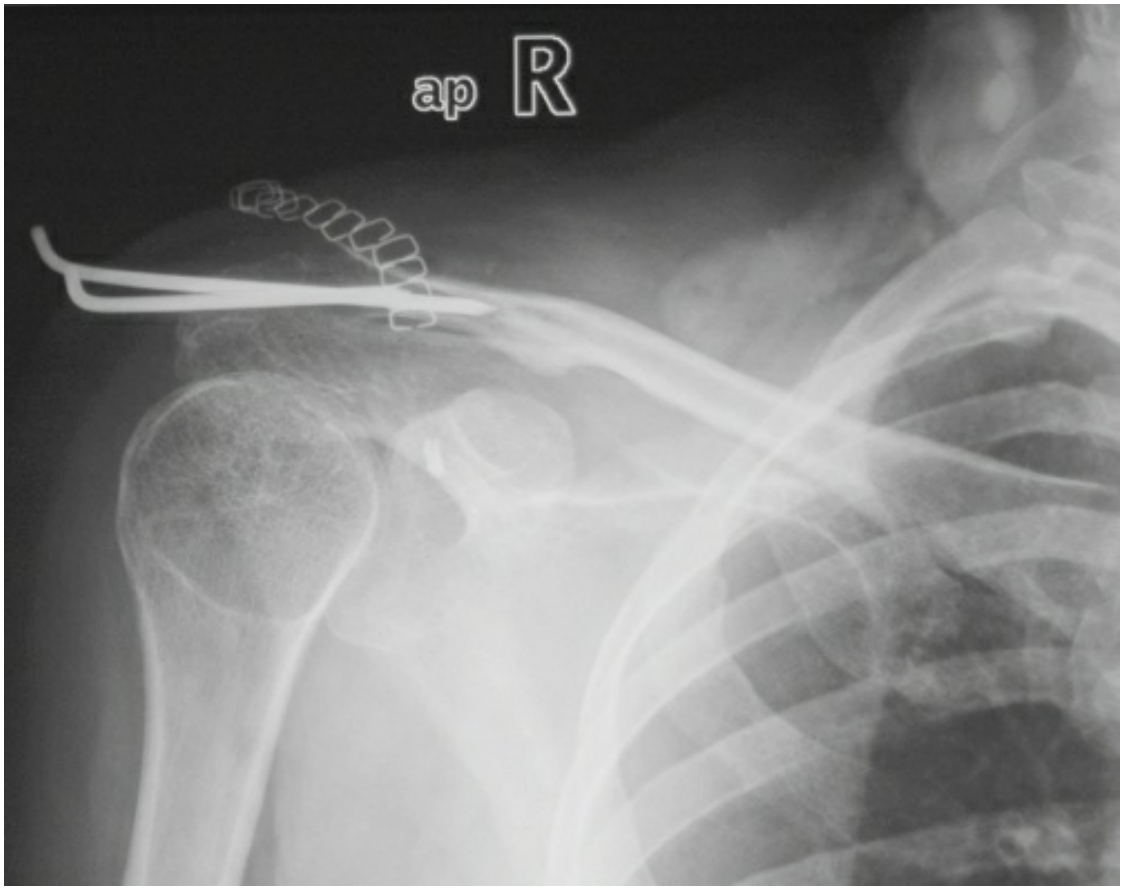

FIG. 5-6 Open reduction of the dislocation and fixation by K-wires.

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It is also necessary to reconstruct or repair the coracoclavicular ligaments. These days, the coracoclavicular ligaments can be reconstructed using synthetic threads called *Mersilene tape* or *tight rope* or *mini anchor sutures* (Fig. 5-7).

FIG. 5-7 Pre- and postoperative X-rays of dislocation of AC joint. Postoperative X-ray shows reconstruction of coracoclavicular ligaments using mini anchor sutures in the coracoid process.

A relatively minor injury in an elderly person may be treated conservatively; while for a major injury in an active young person, early operative treatment will yield best results.

Physiotherapeutic management

Basic objective: To regain active full range of motion at the shoulder complex.

1. **Conservative treatment**

During immobilization (first 3 weeks): As it involves strapping, movements are deferred to the shoulder joint for 2–3 weeks.

(a) Careful checking of the immobilization.

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(b) Full range and strong movements to the elbow, forearm, wrist and fingers should be started immediately.

Mobilization (3 weeks onwards)

1. Start with adequately supported pendulum swinging with the sling. The arc of the movement should not cause pain; however, the AC joint and the shoulder girdle should be well supported to protect the conoid and trapezoid ligaments and the torn joint capsule.

2. Relaxed passive mobilization with the patient in supine position may be initiated. More emphasis is needed on passive abduction elevation as well as horizontal adduction and horizontal abduction. These movements put stretch on the AC joint.

3. Assisted active movements with emphasis beyond 90 degrees of abduction needs to be concentrated and regained at the earliest as the AC joint has a vital role to play in the range of abduction–elevation beyond 135 degrees.

4. Appropriate thermotherapy modality may be used as an adjunct to relieve pain and induce relaxation. Sling should be discarded and exercises to be progressed to self-resistive regime at home and by using graduated dumbbells in the department.

Full range, strong active function should be regained by 6–8 weeks.

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2. **Surgical treatment**: As the procedure involves internal fixation and repair of the coracoclavicular ligament, the approach of physiotherapy differs slightly.

(a) Shoulder mobilization is to be started after 4 weeks of surgery.

(b) The movements are more painful and there is greater reluctance by the patient towards mobilization. This could be helped by thermotherapy before and after the regime of exercises.

(c) Self-resisted isometric shoulder horizontal abduction and horizontal adduction has a special significance for strengthening the repaired coracoclavicular ligament.

Rest of the treatment procedure follows on the same lines as described for conservative management.

Near-normal function and full active range of shoulder movements should be regained by 8–10 weeks.

Dislocation of sternoclavicular joint

This is a rare injury that occurs following a major road accident; the mechanism of injury is lateral compression of the shoulder or a direct blow to the chest.

The dislocation can be anterior (commoner variety) or posterior.

Diagnosis

Plain radiograph may not help much in the diagnosis but a CT scan will clinch the diagnosis.

Treatment

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The dislocation is reduced by manipulation and maintained in a figure-of-eight bandage.

Dislocation of shoulder

The types of dislocation of shoulder include:

1. Anterior

2. Posterior

3. Luxatio erecta

Since anterior dislocation of the shoulder is the commonest type seen in clinical practice, it will be discussed here in some detail.

Anterior dislocation

The most common mode of injury is fall on the outstretched hand with the limb in lateral rotation. In this position, the head of the humerus is thrust against the tightened anterior capsule, which gets torn or avulsed from the anterior rim of the glenoid. Rather than abduction as was thought earlier, lateral rotation of the arm is particularly important in causing this injury. In this type of dislocation, the position of the head of the humerus may slip to one of the following positions (Fig. 5-8A–D):

1. Subcoracoid – Fig. 5-8A, B

2. Subglenoid – Fig. 5-8C

3. Subclavicular – Fig. 5-8D

1. *Subcoracoid:* The dislocated humeral head comes to lie anteriorly below the coracoid process. Since this is the commonest amongst the various types of dislocations of the shoulder, it will be discussed here at length. The patient presents with pain, inability to move the

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affected shoulder, supporting the injured limb by the other hand. On examination, the rounded contour of the shoulder may be lost since the humeral head is not in its normal position. The axillary nerve may be injured and can result in paralysis of the deltoid muscle. Radiograph is done to confirm the diagnosis and also to look for any associated fracture, usually of the proximal humerus.

2. *Subglenoid:* The head of the humerus comes out through the lower part of the capsule and remains beneath the glenoid cavity.

3. *Subclavicular:* Rarely, the head of humerus occupies a position just below the clavicle.

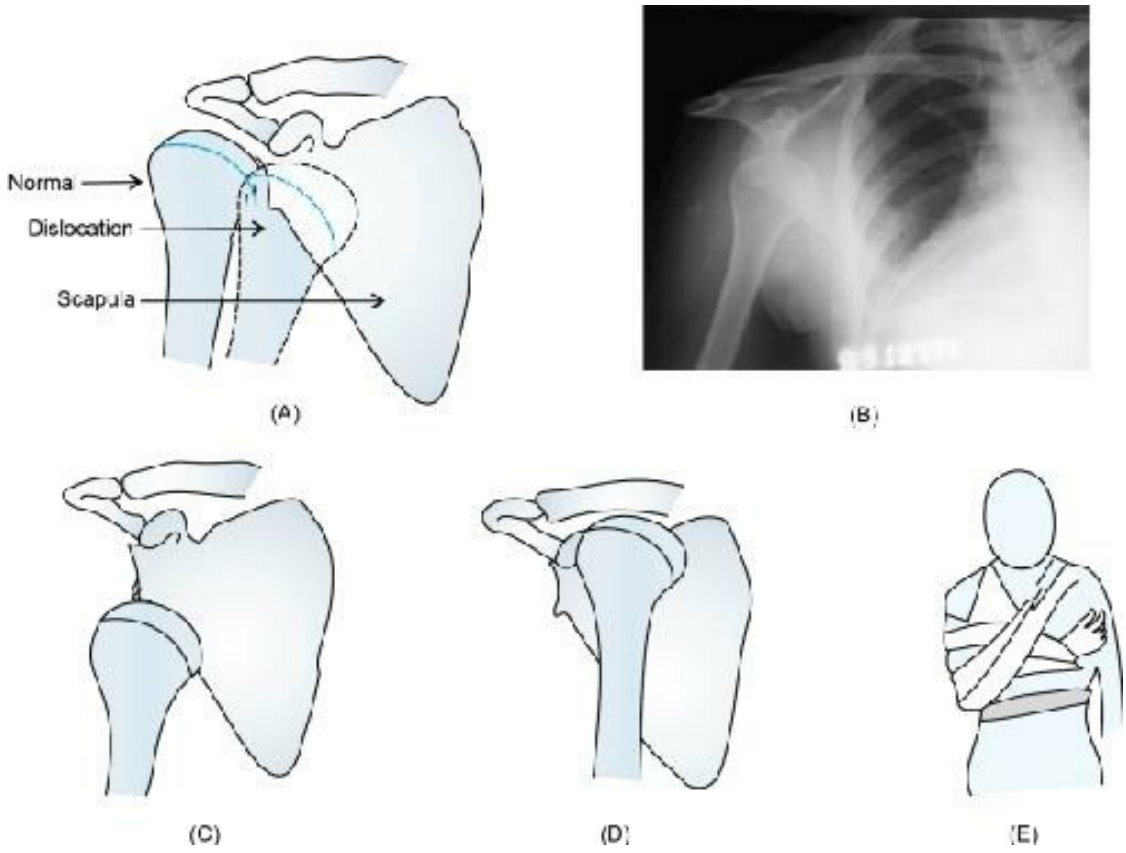

FIG. 5-8 Anterior dislocation of shoulder. **(A)** Subcoracoid. **(B)** Subcoracoid dislocation as seen on a radiograph. **(C)** Subglenoid. **(D)** Subclavicular. **(E)** Immobilization by strapping the arm in adduction and internal rotation.

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Treatment of subcoracoid anterior dislocation of shoulder

The dislocation is reduced by manipulation either under sedation or under general anaesthesia by Kocher's manoeuvre. The reduction is maintained by immobilizing the limb in adduction and internal rotation with the hand of the affected side close to the opposite shoulder (Fig. 5-8E). The immobilization is secured by strapping the arm to the trunk for a period of 3 weeks. This provides adequate healing time for the tear in the anterior capsule of the shoulder joint through which the head had dislocated. Inadequate immobilization increases the chances of recurrent dislocation of the shoulder.

Physiotherapeutic management

Basic objective: To regain full range active movements of the shoulder complex with an emphasis on the early return of movements of abduction and external rotation.

During immobilization (first 3 weeks): As the arm is strapped to the trunk in a position of adduction and internal rotation, only wrist and finger movements are possible. Full range strong resistive movements at these joints should be practised at regular intervals.

Self-resistive: Isometric contractions can be safely instituted to the deltoid, biceps and triceps.

Mobilization (after 3 weeks): After the removal of strapping, the limb is supported in a sling. Elbow should be mobilized to the full extent by removing the sling intermittently.

Mobilization of the shoulder flexion–extension should be initiated as small range pendulum swinging movements in a forward stoop position. These movements should be carried out with the arm within the sling. However, the sling can be loosened to accommodate greater range of motion.

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Initiation of shoulder abduction and external rotation: As these two movements are instrumental in causing redislocation, they have to be initiated with utmost care and adequate stabilization at the glenohumeral joint.

Relaxed passive abduction up to 45 degrees should be the initial aim. It is done with the patient lying supine; the physiotherapist passively performs the arc of abduction with the *arm in internal rotation.*

External rotation should be initiated in the same position and by the same technique. It should be done with the *arm adducted by the side of the body.*

As it is important to avoid secondary adhesive capsulitis, relaxed passive movements to the shoulder should be carried out to the full or near-normal range at the earliest. Self-assisted relaxed movements with wand in supine position are also helpful at this stage.

Once a good passive range is attained, regime of strengthening is begun. Self-resisted isometric and slow isotonic movements should be taught as a home treatment programme. Resistive devices like dumbbells could be used in the department.

The programme should be monitored at regular intervals to ensure that 90% of the full range is achieved by 6–8 weeks following dislocation. Heavy resistive exercise, passive stretching and forced external rotation and abduction are safe after 12 weeks. It may be difficult in some patients to achieve the terminal range of abduction–elevation and external rotation. This could be painful and needs to be facilitated by a suitable thermotherapy adjunct.

Majority of patients regain full function by 12 weeks following the injury.

Caution

The patient needs to be warned against performing movements involving sudden abduction and/or external rotation to avoid recurrence.

Complications

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1. Fracture of the greater tuberosity or surgical neck of the humerus

2. Supraspinatus tendinitis

3. Rotator cuff injury

4. Recurrent anterior dislocation of the shoulder

5. Injury to the axillary nerve during reduction

All these complications should be detected at the earliest by careful examination. For complications 1, 2, 3 and 4, the mode of treatment remains the same as described under each heading.

Lesion of the circumflex nerve is rare and when present, the chances of recovery are good. Early detection as well as early initiation of isometric contractions for the deltoid muscle during immobilization is adequate to avoid deltoid atrophy and augment the recovery.

Posterior dislocation

Posterior dislocation of the shoulder is relatively less common than the anterior dislocation and is caused by a direct blow on the front of the shoulder with arm in internal rotation, e.g., during electroconvulsive therapy or epileptic attack or severe electrical shock (Fig. 5-9).

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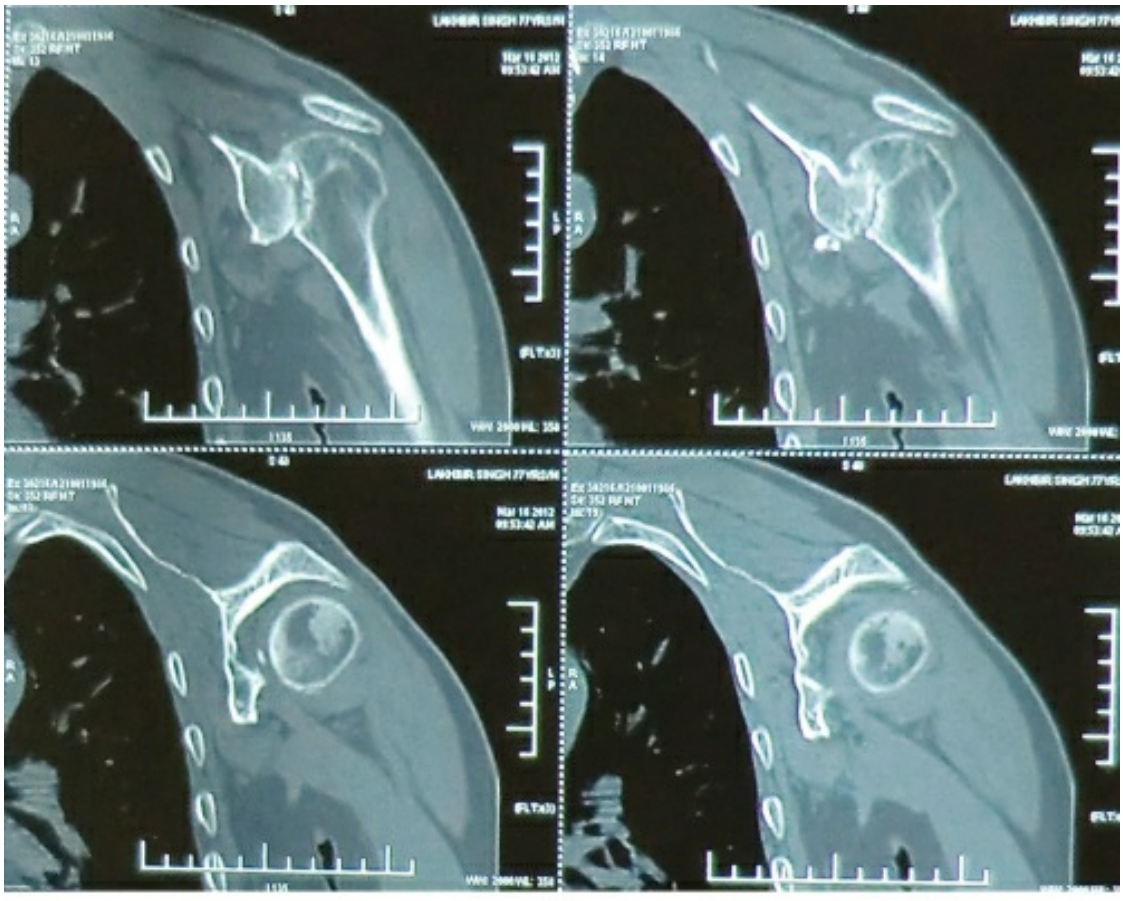

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(C)

FIG. 5-9 **(A)** Plain X-rays showing posterior dislocation of the shoulder. **(B)** CT scan showing the same. **(C)** 3-D reconstruction CT scan.

Treatment

The dislocation is reduced by manipulation and the limb is immobilized in a sling for 2–3 weeks.

Physiotherapeutic management

The major problem is stiff and painful movements of shoulder

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abduction and external rotation. Therefore, slow and graduated mobilization to restore these two movements is to be emphasized. However, other movements should also be handled to prevent adhesive capsulitis.

Precautions

The movement of adduction should be done with the shoulder in external rotation and the movement of internal rotation should be done with the shoulder in abduction. Patients need to be cautioned against performing these movements either simultaneously or separately with jerk.

Fresh dislocation is treated by manipulative reduction.

Luxatio erecta

In rare cases, the limb is strongly abducted, e.g., holding a branch of a tree with the arm in wide abduction while falling down from the tree. As a result of this injury, the head of humerus is pushed down underneath the glenoid and the arm is held fixed in wide abduction–elevation almost by the side of the head. This type of dislocation is therefore termed as *luxatio erecta*.

Recurrent anterior dislocation of shoulder

Recurrent dislocation is characterized by repeated dislocation of the shoulder joint in a person, following one episode of acute dislocation. It occurs due to failure of healing of the torn avulsed capsule anteriorly, maybe because of inadequate treatment (immobilization) during the first episode. Repeated dislocations usually require less violence and therefore, subsequent dislocations occur when the arm is externally rotated and abducted during routine movements of dressing or playing. It is a common phenomenon accounting for more than 80% of dislocations of the upper extremity. This type of traumatic instability of the shoulder is now also termed as *TUBS* (traumatic unidirectional Bankart lesion; surgery is usually required).

There is also another type of recurrent shoulder instability which

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presents without any history of trauma. It is called *AMBRI* (atraumatic multidirectional bilateral; rehabilitation is the treatment where inferior capsular shift may be undertaken occasionally).

Traumatic pathology

Bankart lesion: The avulsion of the glenoid labrum and anterior capsule creates a pouch anterior to the neck of the scapula into which the humeral head slips with every dislocation (Fig. 5-10B).

Hill–Sachs lesion: Hill–Sachs lesion is a defect in the posterolateral quadrant of the head of the humerus. It is caused by the anterior edge of the scapula when the dislocated head impinges against the glenoid (Fig. 5-11).

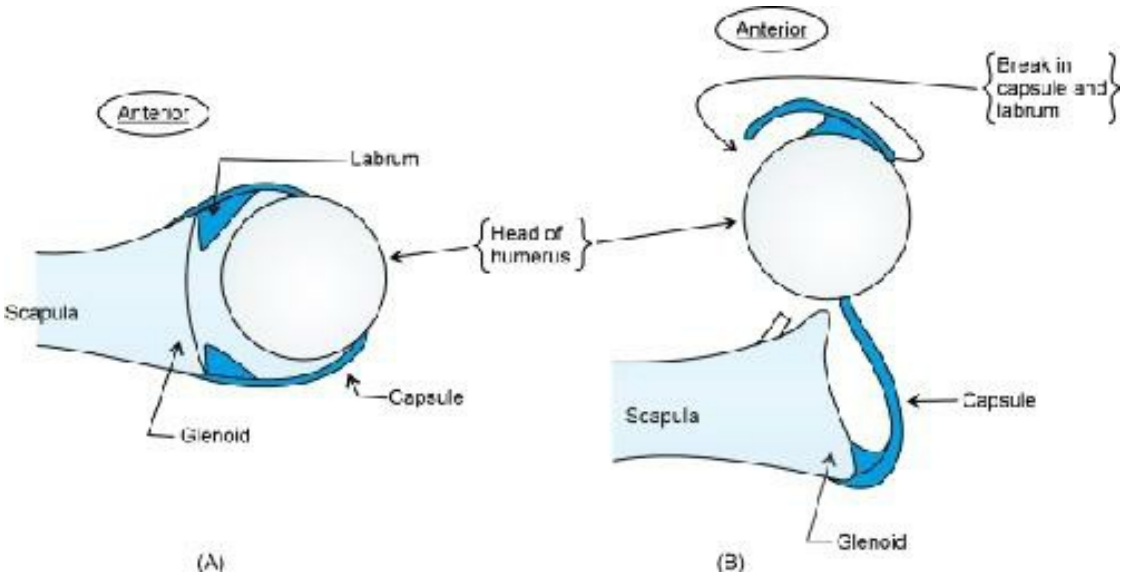

FIG. 5-10 Bankart lesion: **(A)** normal relationship of head of humerus vis-à-vis the labrum, and **(B)** head of humerus dislocated anteriorly, into the capsular pouch causing avulsion of the labrum and capsule.

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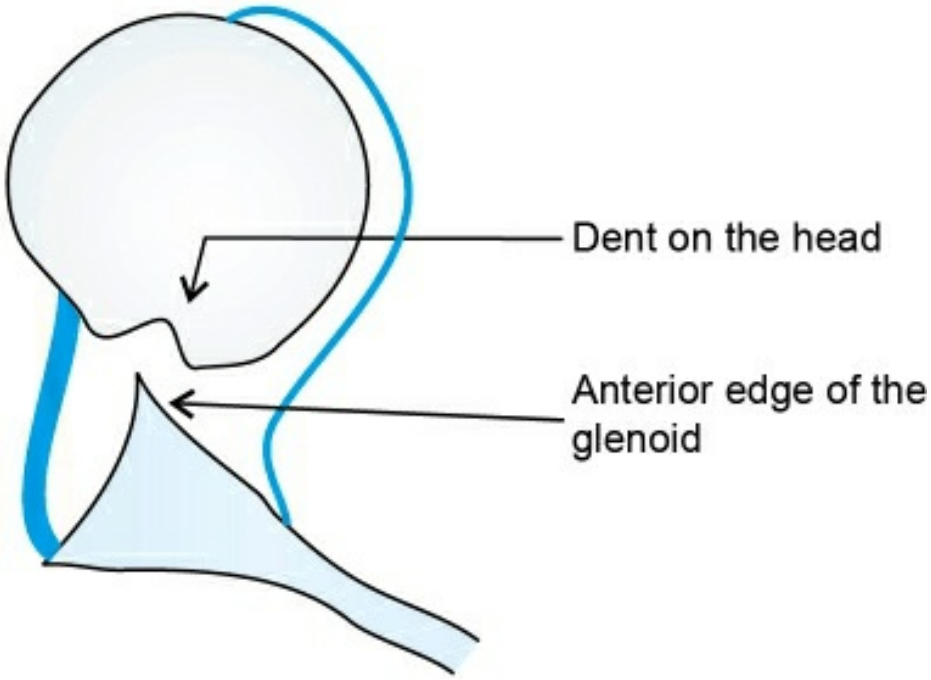

FIG. 5-11 Hill–Sachs lesion, where the dislocated head impinges against the glenoid.

Clinical presentation

The patient presents with a history of repeated dislocations of the shoulder, which occur with less violence and often reduced by the patient himself. On *examination*, the patient resists any attempted movement of abduction and external rotation due to the apprehension of dislocation. This is called *apprehension sign*.

Treatment

The treatment invariably is surgical. Although a large number of surgical operations have been described, the following operations are performed commonly:

1. *Bankart's operation:* The tear in the anterior capsule is repaired and the avulsed part of glenoid labrum is re-attached.

These days, repair of the Bankart lesion is done mostly

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arthroscopically. However, sometimes mini open surgery may be done. Since this is a *minimally invasive surgery*, it has definite advantages. The postoperative morbidity is less and the rehabilitation is faster.

2. *Latarjet procedure*: It is also known as Latarjet–Bristow procedure. This is a surgical operation which is indicated in recurrent dislocation of shoulder where there is bony defect or a fracture of the glenoid. In this procedure, a section of the coracoid process is removed and transferred to the front of the glenoid. This transferred piece of bone will now act as a barrier and prevent the head of humerus from slipping/dislocating anteriorly (Joshi et al., 2013; Lafosse & Boyle, 2010; Young et al., 2011).

3. *Putti–Platt operation:* This procedure is indicated in cases of bony Bankart lesion, i.e., when there is bony avulsion from the anterior glenoid. In such a situation, the labrum cannot be repaired and therefore, the Putti–Platt operation is performed. In this operation, the subscapularis muscle is divided along with the anterior capsule and it is sutured back by overlapping (double-breasting) both the divided edges of the subscapularis muscle along with the capsule. Postoperatively, the limb is immobilized in internal rotation by the side of the trunk for a period of 3 weeks, after which the shoulder is mobilized.

Physiotherapeutic management

Physiotherapy can play a very important role in preventing recurrent anterior dislocation.

Physiotherapy to prevent recurrence: By isometrics and conditioning the muscles of the shoulder girdle and the shoulder joint itself.

Preventive regime of physiotherapy: The principal objectives of physiotherapeutic management:

1. To strengthen the ligaments and muscles crossing the shoulder joint to the optimum level

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2. To regain full passive range of motion (ROM) of all the movements

Strengthening procedure: To be successful, the exercise needs several repetitions. The best approach is to teach the patient self-resisted eccentric, as well as isometric contractions (reversal technique) for all the shoulder movements. The exercises should be taught in standing or sitting position so that they can be conveniently performed several times. Self-resisted small range reversal technique for various agonists and respective antagonist groups is very well accepted by the patient (Fig. 5-12).

In the department, weighted dumbbells, or weight belts may be used so that the progress and the extent of muscular strength can be assessed and monitored at regular intervals.

To achieve and maintain full range passive motion: Initially, it has to be done by a physiotherapist with the patient in supine position. The arc of movements of abduction–elevation, flexion–elevation and external rotation needs to be done gradually and carefully. To assure total relaxation, it is ideal to use some thermotherapy or cryotherapy adjunct before initiating these movements. Once the near-normal or full range is achieved, the patient is taught to carry out these movements. Extra care should be taken during the terminal range of elevation and external rotation. As adequate stabilization of the shoulder girdle facilitates relaxation of the glenohumeral joint, the patient should be advised to get some assistance at home while performing these movements. However, proper guidance to stabilize the shoulder girdle has to be learnt from the

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physiotherapist before carrying it out at home.

For the success of this regime of prevention, long-standing efforts (3–6 months) and skilful education of the patient are essential.

Surgically managed patients: The regime of physiotherapy for patients treated with surgery proceeds on the same lines as described for anterior dislocation. The main difference is the secured safety of performing the movements. The joint is stable as the head of the humerus is enveloped firmly by overlapping of the divided parts of the subscapularis. Therefore, passive sustained stretching is safe. But, it needs hard effort to achieve active terminal range of elevation and external rotation.

Usually, the extreme range of external rotation remains deficient. However, a strong and functional shoulder can be achieved within 10–12 weeks.

On the whole, the results are excellent.

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FIG. 5-12 Self-resisted reversal technique of exercise to strengthen muscles around shoulder.

Fracture dislocation of shoulder

Dislocation of the shoulder may be associated with fracture of the neck of humerus (Fig. 5-13). Closed reduction may be difficult or impossible due to a fracture fragment through the neck of humerus obstructing the reduction.

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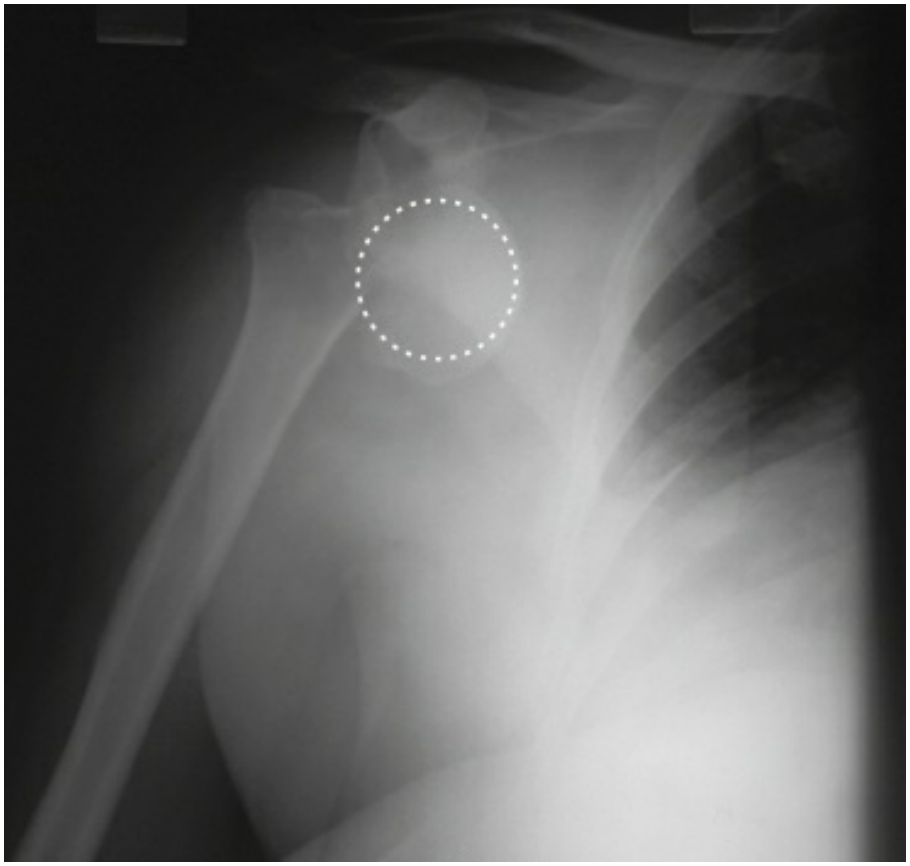

FIG. 5-13 Fracture dislocation of the shoulder joint.

Treatment

1. As mentioned earlier, closed reduction may be difficult and surgery may have to be resorted to.

2. ORIF (Fig. 5-14) may be indicated in younger patients. Although the results, in terms of movements, may be unpredictable.

3. In fractures through the anatomical neck of humerus, prosthetic replacement of the shoulder may be performed (Fig. 5-15). In elderly patients, due to expected osteoporosis, it is not safe to conduct reduction with manipulation. It is rather treated by physiotherapy to restore maximum ROM at the dislocated shoulder after rest in a sling for 2–3 weeks.

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4. In elderly patients, it may be advisable to leave the fracture alone and start mobilization as soon as pain permits. Some functional range or movements may be obtained.

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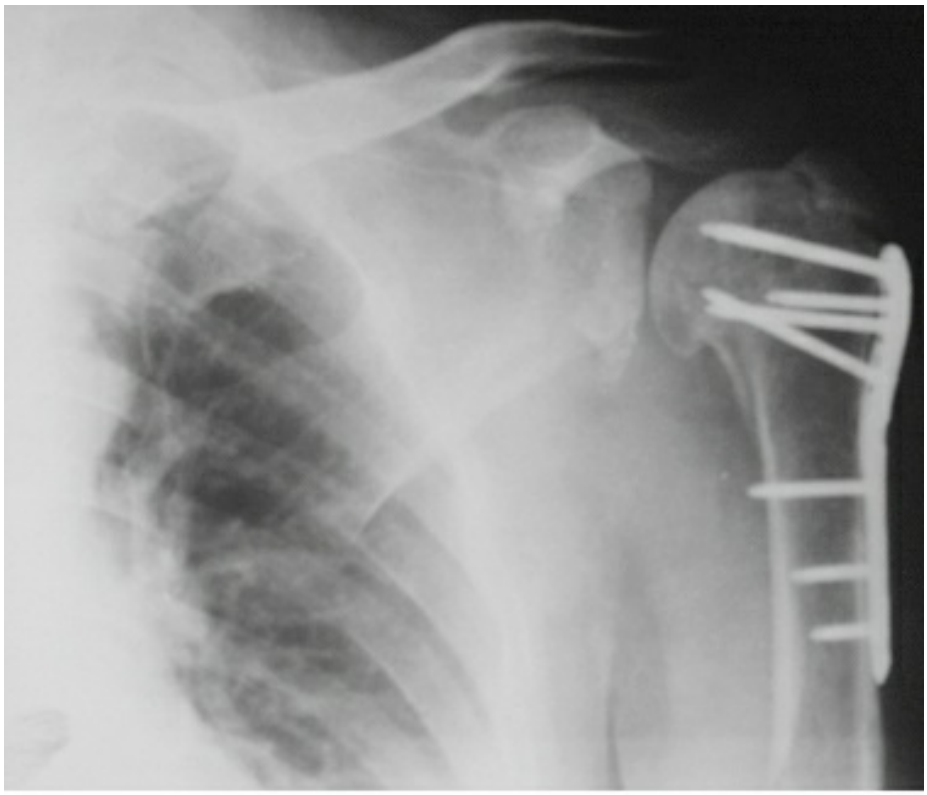

(B)

FIG. 5-14 Treatment of fracture of the proximal humerus by plating. **(A)** Preoperative radiograph. **(B)** Fracture fixed with a plate.

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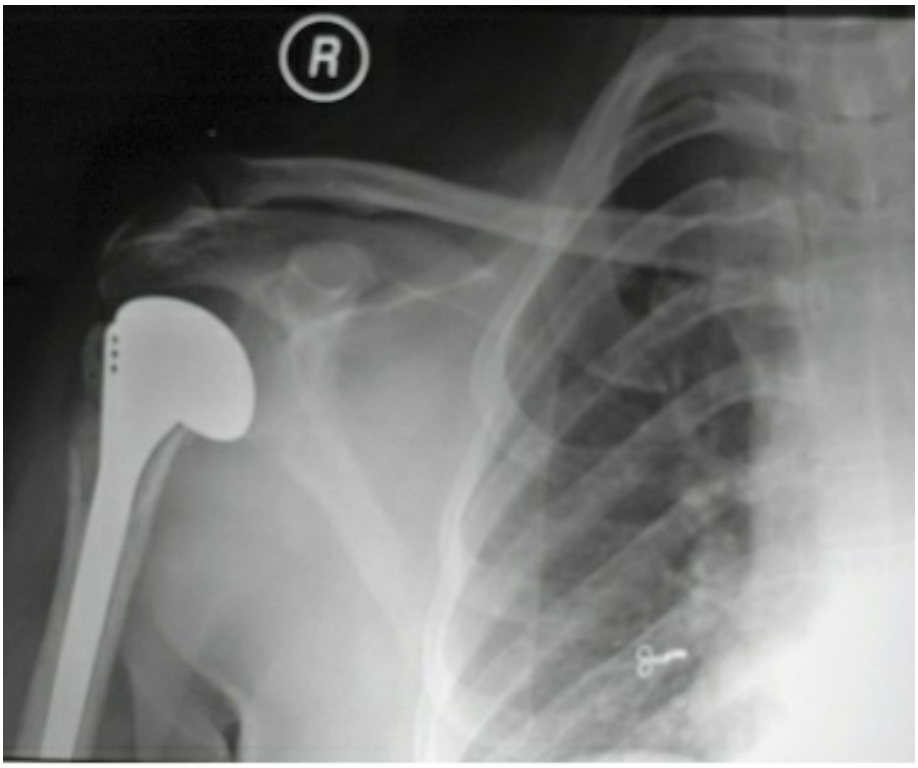
(A)



(B)

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FIG. 5-15 **(A)** Preoperative radiograph of fracture of the proximal humerus. **(B)** Treated by hemi-replacement arthroplasty.

Complications

1. Joint stiffness

2. Avascular necrosis of the humeral head

Fracture of greater tuberosity of humerus

It is of two types.

1. Contusion fracture of the greater tuberosity

A fall on the side of the shoulder results in a comminuted fracture of the greater tuberosity. A direct blow to the side of the shoulder can also cause this injury. Although this is usually a comminuted fracture, the fragments are seldom displaced (Fig. 5-16A).

Treatment: It consists of supporting the limb in a sling for a week or two. Active movements of the fingers, wrist and elbow are encouraged from the beginning while shoulder mobilization is started as soon as the pain diminishes. If passive stretching is avoided, full movements are regained within a few weeks.

2. Avulsion fracture of the greater tuberosity

This injury results from a fall on the outstretched hand. Contraction of the supraspinatus tendon against resistance causes avulsion of a small fragment of the bone which may or may not be displaced from its original position (Fig. 5-

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16B).

Treatment: For an undisplaced fracture, supporting the limb in a sling for a week or two is adequate. If, however, the fragment is completely avulsed, operative treatment is indicated. The avulsed fragment is reduced and fixed with a screw (Fig. 5-17).

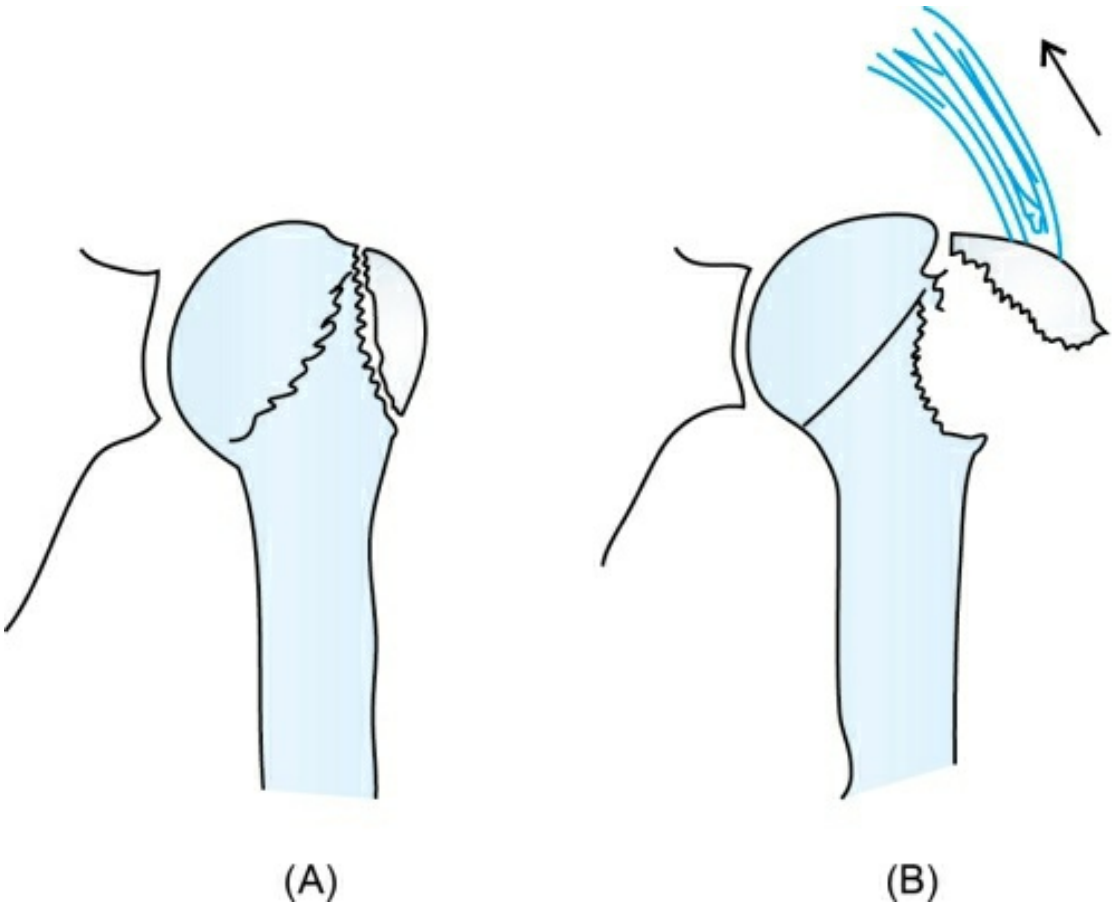

FIG. 5-16 Fracture of the greater tuberosity of humerus. **(A)** Undisplaced contusion fracture. **(B)** Avulsion fracture – avulsion occurs as a result of pull by the contraction of supraspinatus.

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(A)

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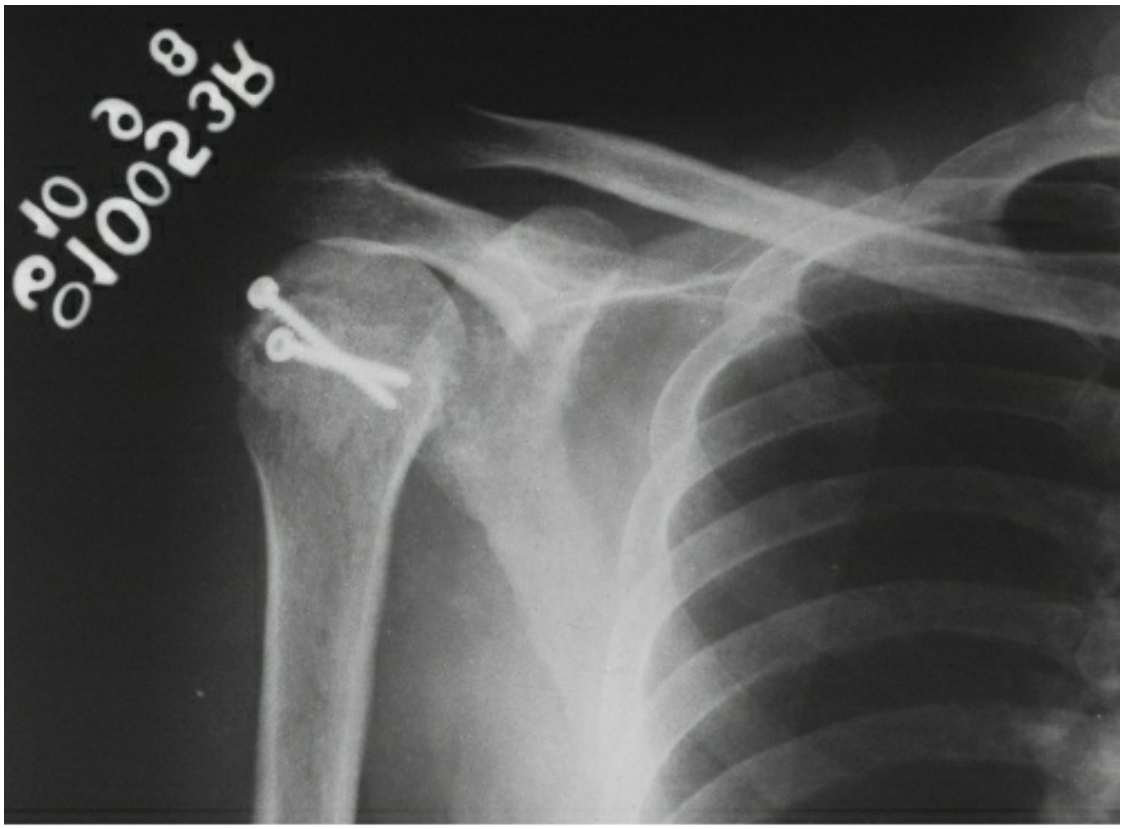

(B)

FIG. 5-17 **(A)** Preoperative radiograph showing displaced fracture of the greater tuberosity associated with dislocation of the shoulder. **(B)** Postoperative radiograph. The dislocation is reduced and the greater tuberosity is fixed with screws.

Physiotherapeutic management

Basic objective: To regain active full range of motion at the shoulder complex.

In both these injuries, unless there is complete avulsion of the greater tuberosity, there exists reasonable stability of the fracture. Therefore, the management is simple.

During immobilization (initial 2 weeks): The physiotherapeutic programme is the same as described for the fractures of clavicle or

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scapula. However, strong isometrics to the deltoid under POP cast need extra emphasis.

On rare occasions, the callus formation may impede the movement of the biceps tendon. This may result in pain and stiffness. To avoid this situation, efforts should be made to achieve full range of movements at the shoulder, with special emphasis on the terminal arc of the movements of abduction–elevation and flexion–elevation.

Friction massage and ultrasonics over the area of the tendon can be helpful to prevent or to treat such adhesions allowing the freedom of movement.

Full function and normal range of motion should be regained by 6–8 weeks after injury.

Fractures of the proximal humerus

Fractures of the proximal humerus occur most commonly in middle-aged or elderly patients (Fig. 5-18). In these patients, it usually occurs following a trivial trauma and the displacements are not so marked. Occasionally, these fractures do occur in young individuals following a severe injury and are associated with considerable displacements of fragments.

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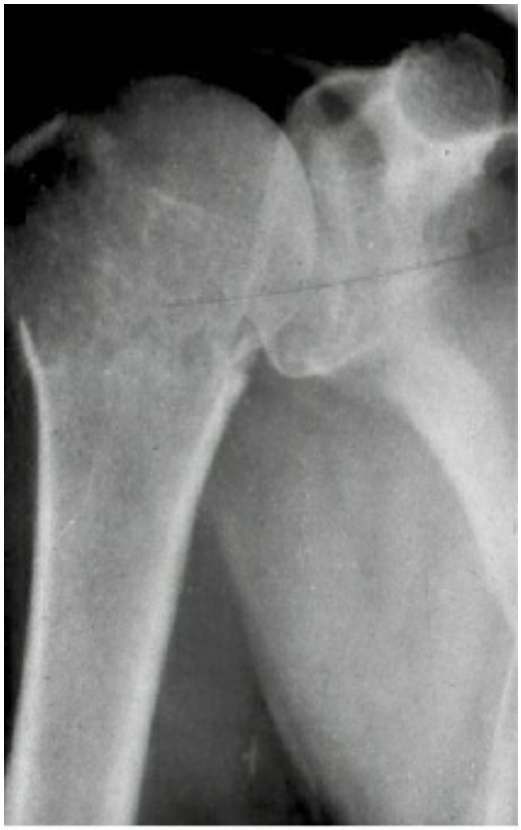

(A)

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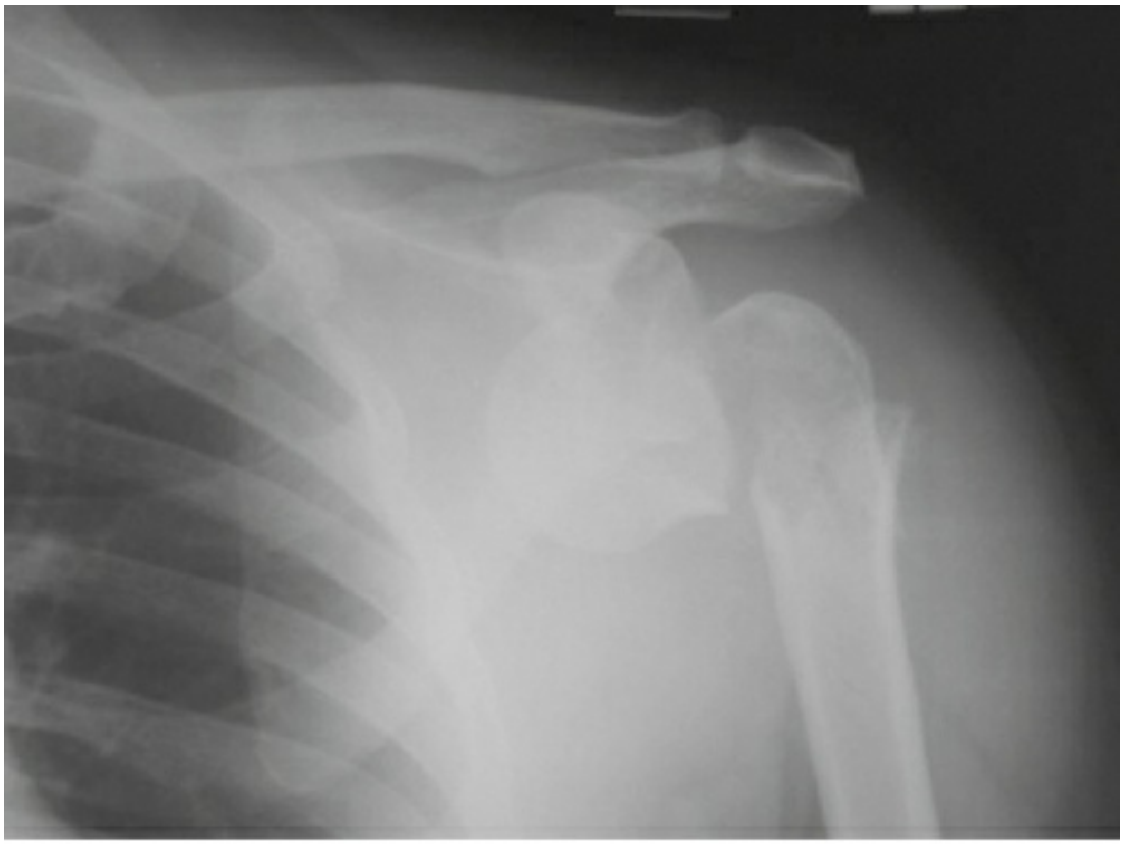

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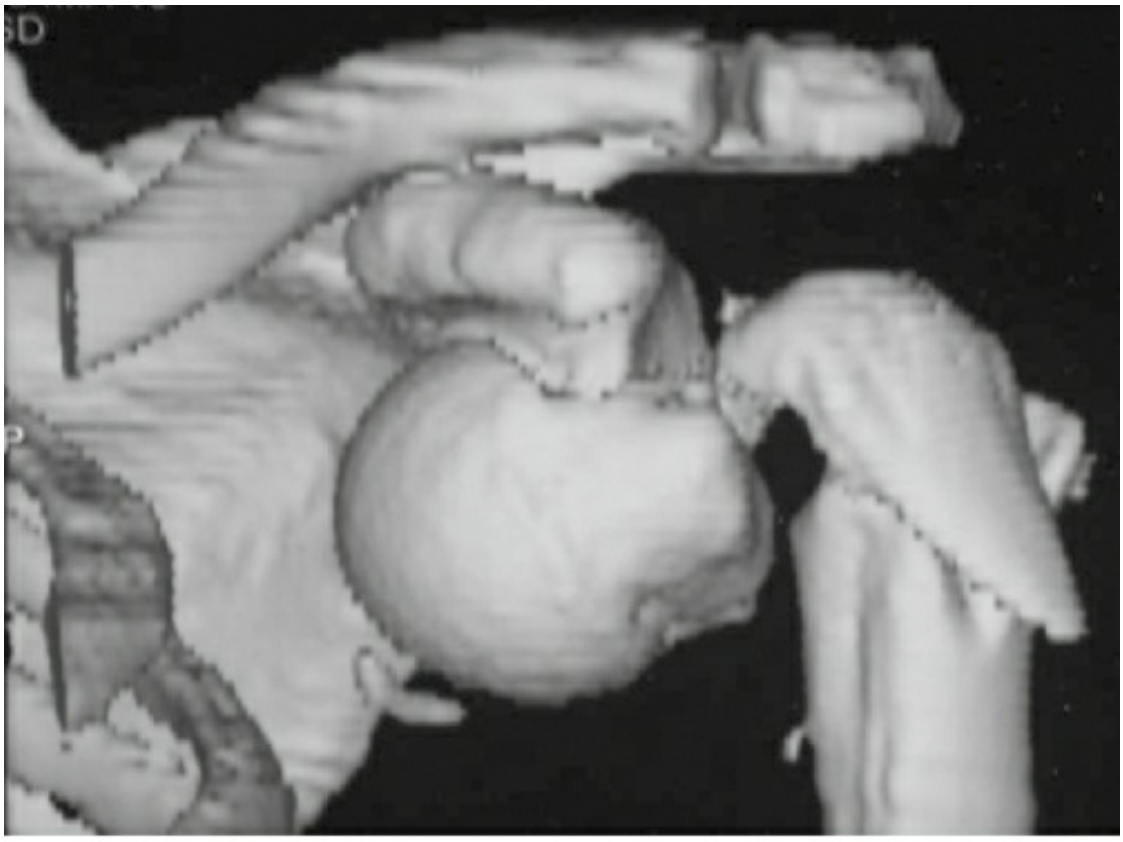

(C)

FIG. 5-18 Fracture of the proximal humerus. **(A)** Undisplaced fracture. **(B)** Displaced fracture with dislocation of head of humerus. **(C)** CT scan with 3-dimensional reconstruction showing the fracture dislocation clearly.

Mechanism of injury

Fractures of the proximal humerus can occur due to any of the following:

1. Fall on the outstretched hand

2. Road traffic accidents (RTAs)

3. During an epileptic fit

Classification

Although many classifications have been proposed, the Neer's four-

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part classification is the most widely accepted classification. This classification involves the four major segments of the proximal humerus, namely, the head, the greater tuberosity, the lesser tuberosity and the shaft. It is also based on the principle that the fracture occurs through the old physical lines among these segments.

One-part fracture: The fragments are undisplaced and hence the results are good.

Two-part fracture: One segment is separated from the others. These fractures can usually be managed by closed manipulation.

Three-part fracture: Two fragments are displaced.

Four-part fracture: All the major fragments are displaced.

Clinical features

Pain and swelling around the shoulder are the presenting symptoms. Ecchymosis may develop within 24–72 h over the shoulder and arm and may extend up to the elbow and chest wall.

Diagnosis

Diagnosis can be confirmed by plain radiographs; however, a CT scan can give a better evaluation of the extent of the comminution of the fracture (Fig. 5-19).

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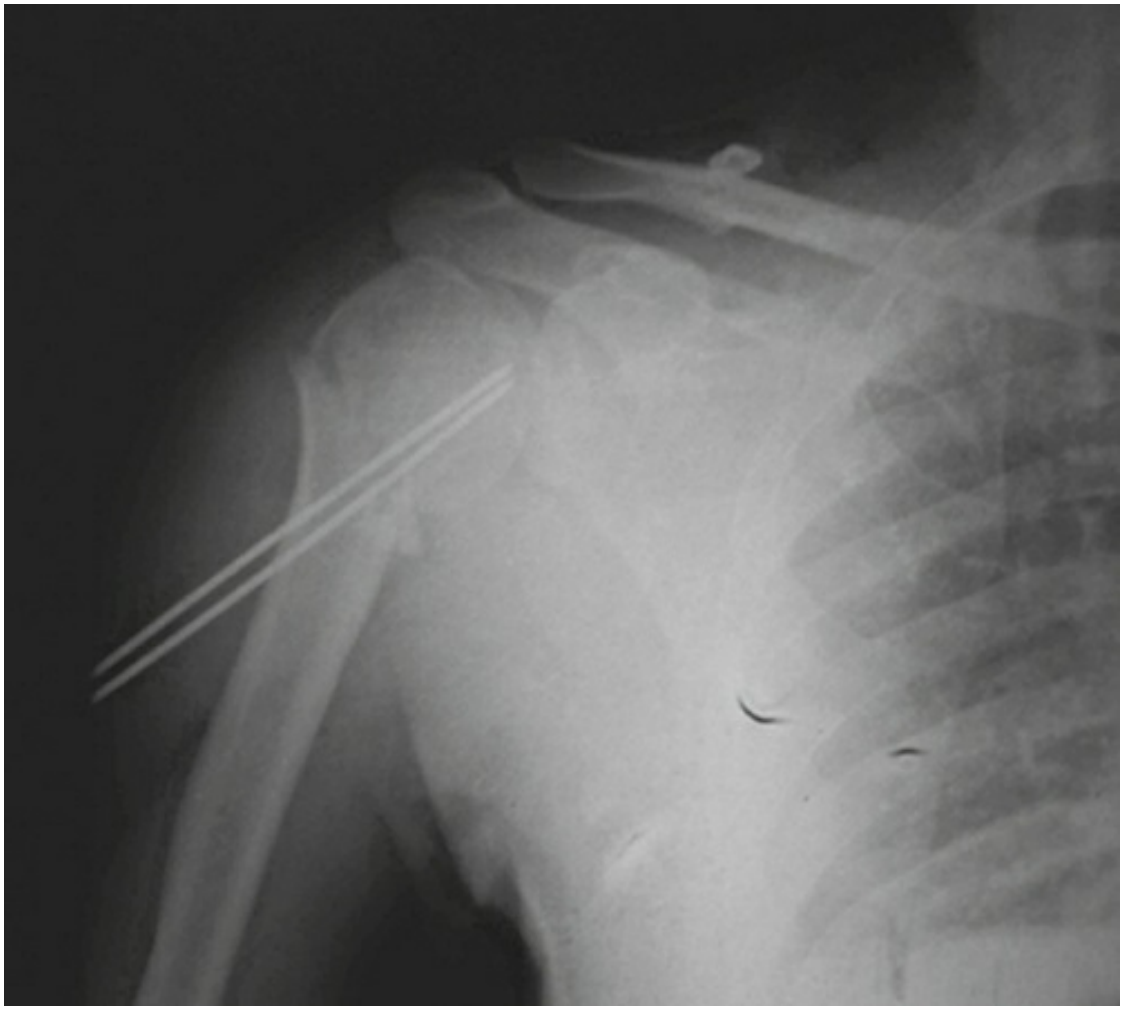

FIG. 5-19 Fracture of neck of humerus treated by Kirschner wires, passed percutaneously.

Treatment

Minimally displaced fractures are treated by a triangular sling for a period of 2–3 weeks, followed by mobilization of the shoulder.

Two- and three-part fractures in young adults can be treated by the following methods:

1. Closed manipulation and immobilization in an arm–chest bandage or a plaster of Paris (POP) U-slab for 3–4 weeks.

2. Closed manipulation and percutaneous K-wire fixation (Fig. 5-20).

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3. Open reduction and internal fixation (ORIF) by special types of plates (Fig. 5-14).

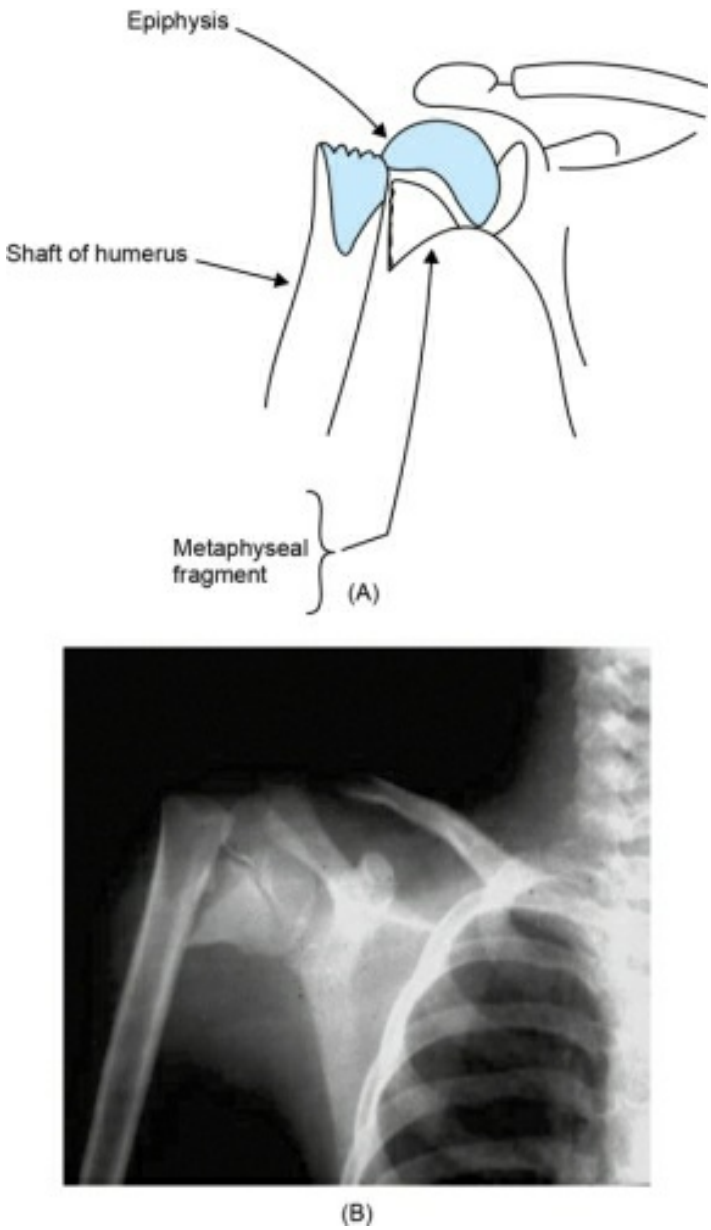

FIG. 5-20 Type II epiphyseal injury of upper end of humerus. **(A)** Diagrammatic representation, **(B)** as seen on a radiograph.

Four-part fractures are best treated by prosthetic replacement of the proximal humerus (Fig. 5-15).

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In children

In children, up to 17 years of age, these injuries are Salter–Harris Grade II epiphyseal injuries (Fig. 5-20). Most of these injuries can be treated conservatively; up to 30 degrees of angulation is acceptable since remodelling leaves little disability.

Complications

1. *Joint stiffness*: Joint stiffness is a common complication which can occur at all ages, except in children. The incidence of joint stiffness may be present in both (conservative as well as operative) methods.

2. *Malunion*: Malunion may lead to restricted movements at the shoulder joint but does not cause much disability.

3. *Avascular necrosis*: In fracture through the anatomical neck of humerus, the proximal fragment may develop avascular necrosis.

4. *Injury to vessels and nerves*: Severe violence with marked displacement of fracture fragments may cause injury to axillary vessels and nerve.

Physiotherapeutic management

The physiotherapeutic management depends upon the type of fracture and the mode of management.

Basic objective: To regain full active range of movements at the shoulder complex.

1. **Impacted fractures of neck of humerus:** Healing of the fracture is no problem, although the fracture is commonly seen in elderly people. The important task for a physiotherapist is to avoid stiff and painful shoulder or shoulder–hand syndrome by starting judicious mobility exercise at the earliest.

Conservative approach: during immobilization

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(a) Initially cryotherapy, TENS or diapulse or ultrasonics can be given for the reduction of pain.

(b) Self-resisted full range elbow, forearm, wrist and hand movements to be encouraged.

Mobilization

(i) Shoulder mobilization: Relaxed pendular movements, in small range with the arm in a sling can be started as early as after 1 week, (ii) relaxed passive movement working up gradually to overhead abduction as well as rotation should be attempted as soon as the sling is removed, progressing from supine to sitting to standing position. The result depends upon the skill of the physiotherapist to teach the patient the proper techniques of self-mobilization. Usually, functionally acceptable results can be achieved in the majority of patients within 6–8 weeks.

2. Unimpacted fractures of neck of humerus: Both types of fractures, i.e., unimpacted adduction fractures or abduction fractures, are either treated conservatively or by ORIF.

Conservative approach – during immobilization: When treated conservatively, a sling is given for a period of up to 3 weeks. The treatment is on the same lines as described for impacted fractures.

Care should be taken to ensure adequate relaxation and least discomfort by adequately supporting the site of fracture and the weight of the arm while initiating early mobilization.

The best way is to start rhythmic pendular movements in a small range, beginning with extension and swinging of the arm forwards.

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After attaining relaxed flexion–extension swing, adduction–abduction and rotation may be initiated in a small range (Fig. 5-21).

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FIG. 5-21 Rhythmic relaxed pendular abduction–adduction exercise.

In the conservative approach, when closed reduction and manipulation is done, shoulder is immobilized in an 'axillary muff and collar and cuff'. No movement at the shoulder is permissible up to 3 weeks.

Therefore, the chances of developing a painful stiff shoulder are quite high and need early attention.

Deep heating thermotherapy procedures like short-wave diathermy, ultrasonics or relaxing thermotherapy, e.g., hot packs and relaxed passive movements are important.

Maximum emphasis has to be given to educating the patient for repeated relaxed auto-assisted shoulder movements with due stress on abduction, starting with pendular movements.

A regular watch needs to be kept to assure improvement in the range of abduction.

Once the active range is achieved, resisted exercises can be started.

Good functional results can be achieved by 6–8 weeks.

Fractures managed surgically: ORIF is done for younger patients. Keeping in view the functional requirements and the possibility of early healing, the approach of treatment has to be more vigorous. Full advantage needs to be taken of the shorter period of immobilization, i.e., 2 weeks. Emphasis should be laid on isometric exercises to the deltoid and strengthening exercises at the earliest.

Relaxed passive as well as auto-assisted exercises by the use of contralateral, normal upper extremity should be taught to the patient immediately after the sling is removed, to regain strength as well as full range of all movements.

Quicker rate of progression from active to active resisted movements and functional use to be ascertained. Excellent results can be obtained by 6–8 weeks.

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CHAPTER
6

Injuries of the arm

OUTLINE

■ Fractures of shaft of humerus

Fractures of shaft of humerus

Fracture of the shaft of humerus can be transverse, oblique, spiral, comminuted or segmental (Fig. 6-1).

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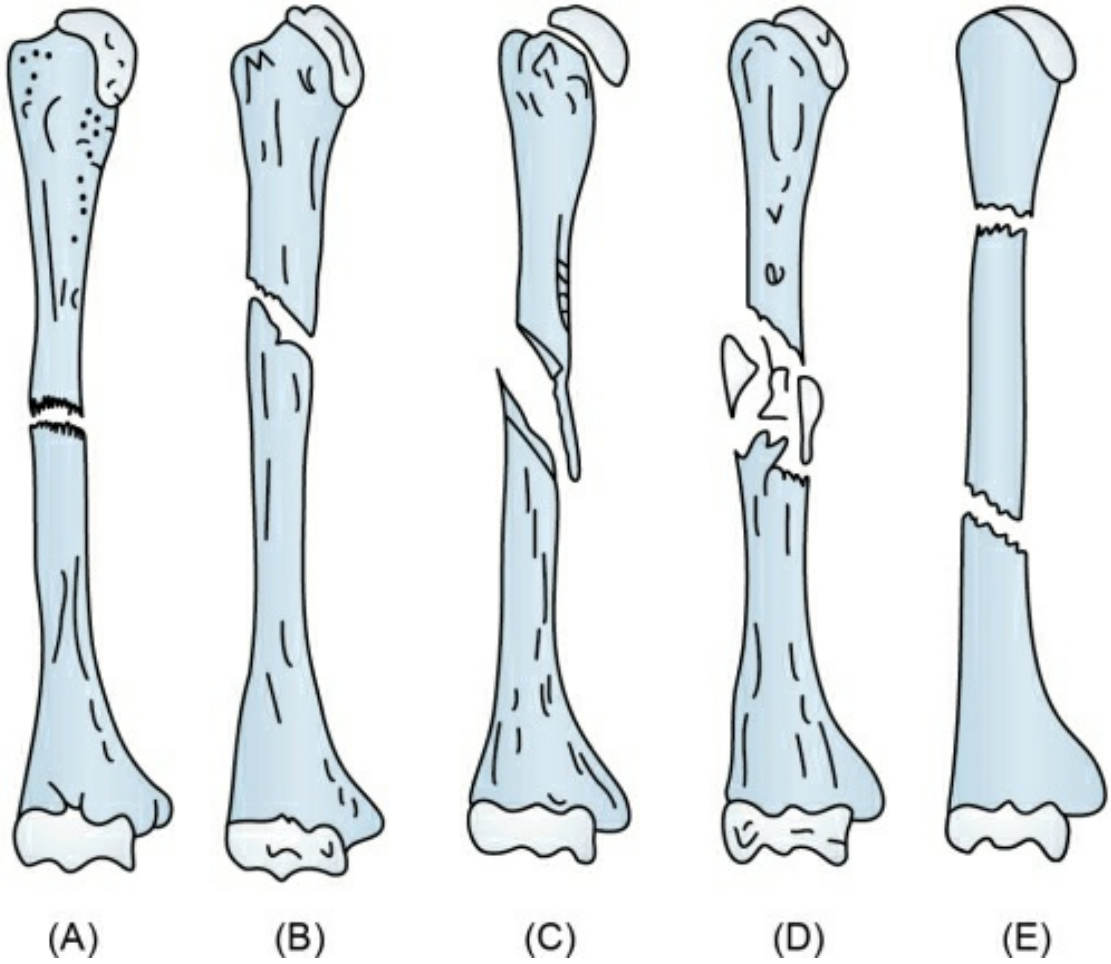

FIG. 6-1 Fractures of the shaft of humerus. **(A)** Transverse. **(B)** Oblique. **(C)** Spiral. **(D)** Comminuted. **(E)** Segmental.

The mode of injury may be (a) direct or (b) indirect trauma.

Direct injury will cause either a comminuted or a transverse fracture while an indirect trauma will result in a spiral or oblique fracture. A pathological fracture is also seen in the humerus since it is a common site for a bone cyst in children and metastases in adults.

The fracture in the mid-shaft of the humerus has a tendency to lateral angulation; the proximal fragment being abducted by the strong pull of the deltoid muscle.

Clinical features

The patient presents with pain, swelling, deformity and abnormal mobility in the arm following an injury.

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In the clinical examination, it is important to test for the function of the radial nerve. The radial nerve supplies the extensors of the elbow, wrist, fingers and thumb. It lies close to the middle of the humerus in the spiral groove and therefore may be injured in the fractures in this region resulting into wrist drop.

X-ray: An X-ray (AP and lateral views) of the arm will show the type of fracture of humerus and its displacements (Fig. 6-2A and B).

(A)

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(B)

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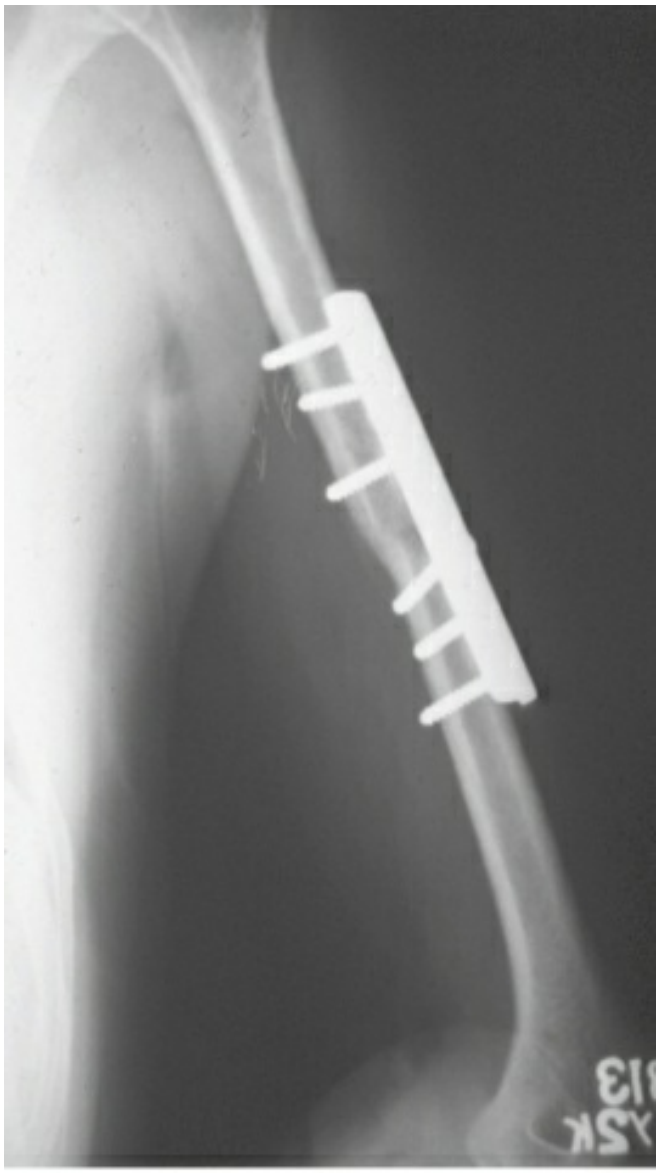

(C)

FIG. 6-2 Fractures of the shaft of humerus. **(A)** AP view and **(B)** lateral view. **(C)** Plating of the humerus. Fracture united.

Treatment

The fracture of the shaft of humerus may be treated by the following methods:

1. *POP-U-slab:* The fracture is manipulated with the patient in sitting position. The elbow is held in 90 degrees flexion and the downward

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pull to the distal fragments corrects the overriding of the fragments. The arm is immobilized in a POP-U-slab with the arm by the side of the trunk and the elbow in 90 degrees flexion (Fig. 6-3). The limb is supported in a sling. The fracture usually takes about 6–8 weeks to unite. In spiral fractures, however, it may unite in 3–4 weeks.

2. *Open reduction and internal fixation:* This may be undertaken in the following circumstances:

(a) Unacceptable reduction following closed manipulation, which may be due to the interposition of soft tissues between the fractured fragments

(b) Nonunion

(c) Injury to the radial nerve in an open fracture

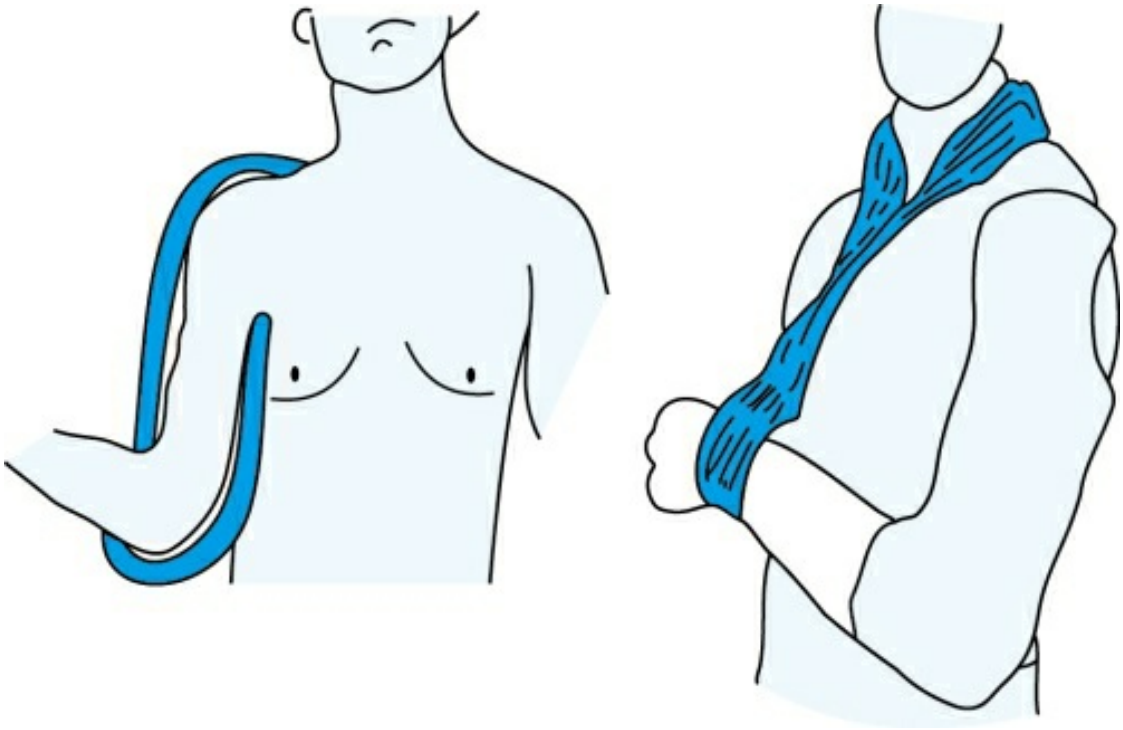

FIG. 6-3 Immobilization by POP-U-slab.

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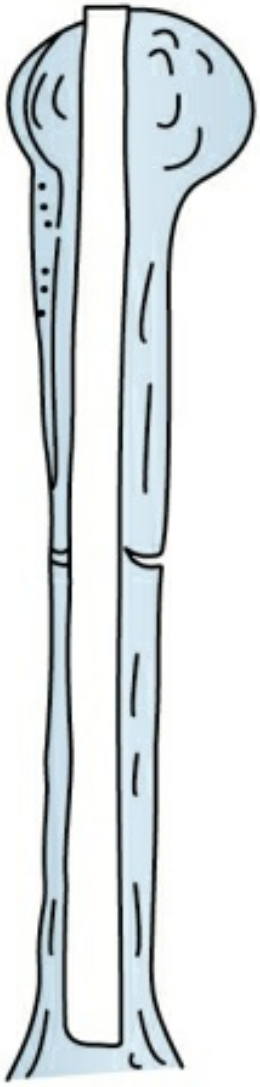
Internal fixation may be achieved by: (a) intramedullary nailing (Fig. 6-4); it can be a conventional Kuntscher's nail or an interlocking nail, the latter is preferred (Fig. 6-4B), and (b) plating of the humerus (Fig. 6-2). Postoperatively, the limb is immobilized in a POP-slab for 4–6 weeks. The shoulder is then mobilized.



(A)

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(B)

FIG. 6-4 **(A)** Internal fixation by Kuntscher's intramedullary nail. **(B)** Internal fixation by interlocking nail.

External fixator: External fixator (Fig. 6-5) is a good alternative in the treatment of open or infected fractures.

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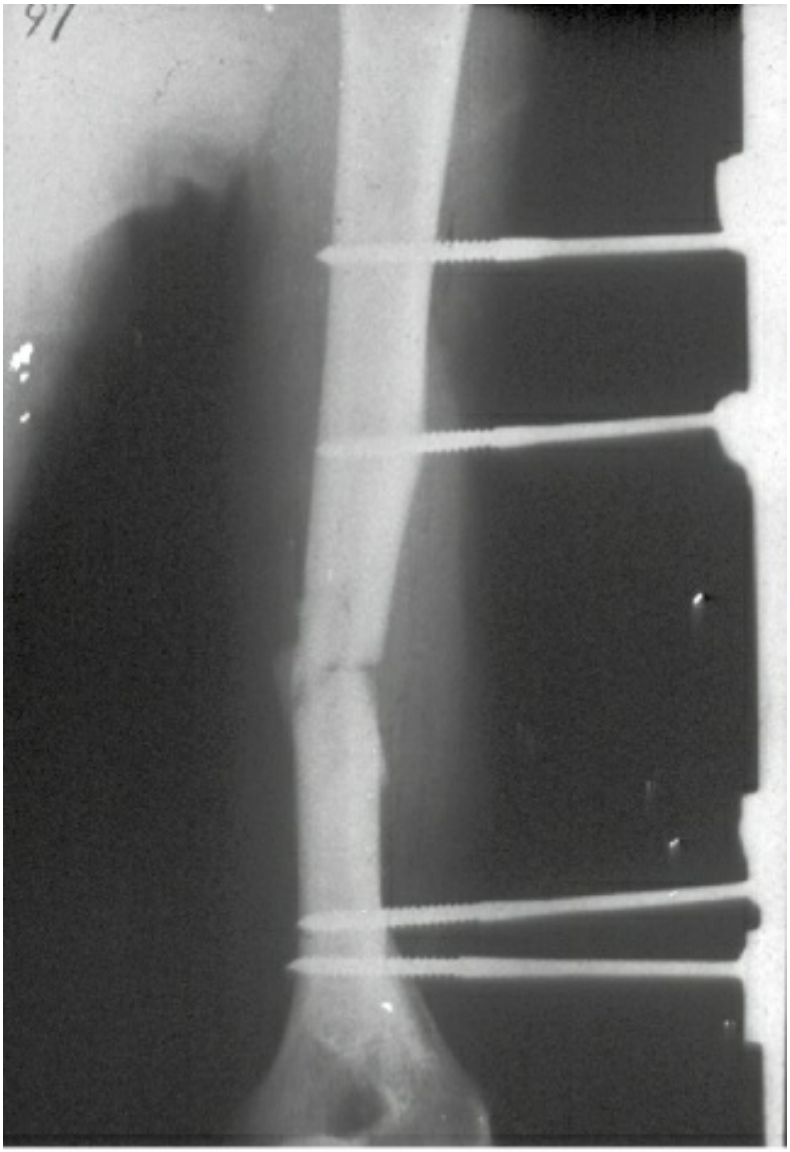

(A)

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(B)

FIG. 6-5 Fracture shaft of humerus treated by external fixator: **(A)** Postoperative radiograph. **(B)** Patient using the limb with the fixator in position.

Complications

1. *Injury to the radial nerve:* The radial nerve is in close proximity to the humerus in its middle third region where the nerve lies in the spiral groove. A fracture in the middle third of the humerus may, therefore, be associated with injury to the radial nerve.

2. *Nonunion:* Nonunion of the humerus is treated by internal fixation along with bone grafting. Postoperatively, the limb is immobilized in a POP-U-slab and sling for a longer period, i.e., 6–8 weeks.

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Physiotherapeutic management

Basic objective: Return of full range active movements at the shoulder complex.

1. **Transverse fractures treated by conservative approach**

During immobilization (first 6–8 weeks): Check the limb for the presence of radial nerve injury. Strong wrist and finger movements working in full range of joint motion are started immediately.

As the POP-U-slab with a sling is given, isometric exercises for the deltoid, triceps and biceps to be initiated, but no other active physiotherapy is possible.

It is very important to check for the involvement of the radial nerve for a few weeks. Many a times the radial nerve gets involved in the callus that is forming around the fracture site.

Mobilization (from 6–8 weeks onwards): Longer period of immobilization results in stiff and painful shoulder.

Before initiating shoulder movements a suitable pain relieving modality like hot packs (HP), transcutaneous electrical nerve stimulation (TENS), ultrasonics or short wave diathermy (SWD) is necessary.

Mobilization on the first day should begin as a self-assisted or even as a relaxed passive movement in a small range. The patient holds the arm in sling position by the other hand with the elbow of the fractured arm in 90 degrees of flexion. The patient then supports the fractured limb with

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the other hand and moves it as a rhythmical relaxed passive movement (Fig. 6-6).

This eliminates the effect of gravity and prevents stretching and pain. Easy movements of small range of flexion–extension or abduction–adduction are well accepted by patients in the initial stage. Later on, all the other movements including circumduction can be started.

Then, progress to Codman's pendular regime in standing, and relaxed passive self-stretching of abduction–elevation and flexion–elevation in supine.

Progress to active and gradually to resisted regime by self-resistive technique, using weighted dumbbell, weight belts, or pulley and weights.

Use of wand, shoulder wheel and skates can be helpful as an assisted exercise modality.

Terminal range of elevation and rotation should always be emphasized to avoid lingering pain and stiffness.

The period of recovery to full function varies from 3 to 4 months.

Spiral fracture: It is also treated conservatively. Union occurs early and the period of immobilization in U-slab and sling is only 3–4 weeks. Therefore, it is treated on the same lines as a transverse fracture. Since the period of immobilization is about one-half that of a transverse fracture, good results are expected in just half the time.

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2. **Fractures treated by surgery**: Plating of the humerus which involves immobilization with POP-U-slab and sling for 4–6 weeks is to be treated on the same lines as in the conservative approach. The difference is proper evaluation of the extent of injury to the radial nerve if present and its management by appropriate methods. In addition, the inspection of the surgical scar and its management may be necessary.

In the presence of nonunion, postoperative immobilization is extended to 6–8 weeks due to internal fixation and bone grafting. Since, in these cases, the extent of stiffness and pain are more, it takes longer time for resolution of these problems. Physiotherapeutic programme needs to be progressed gradually. Recovery of function may take even longer time, anywhere between 4 to 5 months.

FIG. 6-6 Self-assisted relaxed passive mobilization with the sling on.

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CHAPTER 7

Injuries of the elbow

OUTLINE

- Fracture of the capitulum
- Supracondylar fracture of the humerus
- Intercondylar fracture of the humerus
- Fracture of single condyles of the humerus
- Pulled elbow
- Dislocation of the elbow
- Fracture of the olecranon
- Fracture of the head and neck of the radius
- Sideswipe injury of the elbow

Fracture of the capitulum

This fracture occurs in adults as a result of fall on the outstretched hand. The injuring force is transmitted through the radial head to the capitulum resulting in a fracture of the latter. It is, therefore, also usually associated with fracture of the radial head. The size of the fractured fragment may vary from a flake of bone to the entire anterior half of the capitulum (Fig. 7-1A and B). A fracture with a small fragment may be missed on radiograph; it may result in stiffness of the elbow subsequently. A CT scan may be required occasionally to

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delineate the fracture anatomy better and also to detect any other fracture, particularly that of the radial head.

FIG. 7-1 Fracture of the capitulum. **(A)** Diagrammatic representation of a displaced fracture of the capitulum (F). **(B)** As seen on a radiograph. **(C, D)** A case treated by internal fixation by two special types of screws.

Treatment

1. *Manipulative reduction and plaster:* Manipulation is possible in fresh fractures. Accurate reduction of the fracture is essential to obtain a smooth articular surface. The elbow is immobilized in a plaster cast for 3 weeks.

2. *Open reduction:* It is indicated in displaced fracture of the cases where closed reduction fails. The fragment is fixed with the help of screw(s) (Fig. 7-1C and D). After surgery, the elbow is immobilized in a plaster cast for 3 weeks.

3. *Excision of the fragment:* In late neglected cases, if the displaced bony fragment blocks the flexion movement, it may be excised (Fig. 7-2). Postoperatively, the elbow is supported in a sling for about 1 week.

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FIG. 7-2 X-ray showing excision of the radial head.

Physiotherapeutic management

Basic objective: Return of the full range of active elbow and forearm movements

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A. **Cases managed with closed or open reduction**

During immobilization (first 3 weeks)

1. Checking the cast immobilization

2. Strong and full-range movement of shoulder complex, fingers and thumb

Mobilization (from 3 weeks onwards): As soon as the plaster cast is removed, the following should be done:

1. Accurately evaluate the active range of motion (ROM).

2. Initiate full-range movements for the wrist.

3. For the stiff and painful elbow, mobilization should follow the application of paraffin wax bath or steam packs.

   (a) Assisted mobilization by using roller skates: Begin with relaxed rhythmical movements in a small range followed by an objective increase of flexion as well as extension range with emphasis on the extreme arc of the range.

   (b) Relaxed active movements can be initiated with the patient in prone position with elbow over the edge of the treatment table. During this movement the shoulder is placed in 90 degrees of abduction (Fig. 7-3A).

   (c) Relaxed active free flexion can be further progressed by the modified use of knee ratchet (Fig. 7-3B). Use of roller skates on a powdered sun mica board is ideal (Fig. 7-3C). The same method can be used to improve the range of

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elbow extension.

(d) The forearm pronation and supination should be initiated as rhythmic active assistive or free active movement by keeping the forearm fully supported on the thigh with elbow in flexion (Fig. 7-4).

(A)

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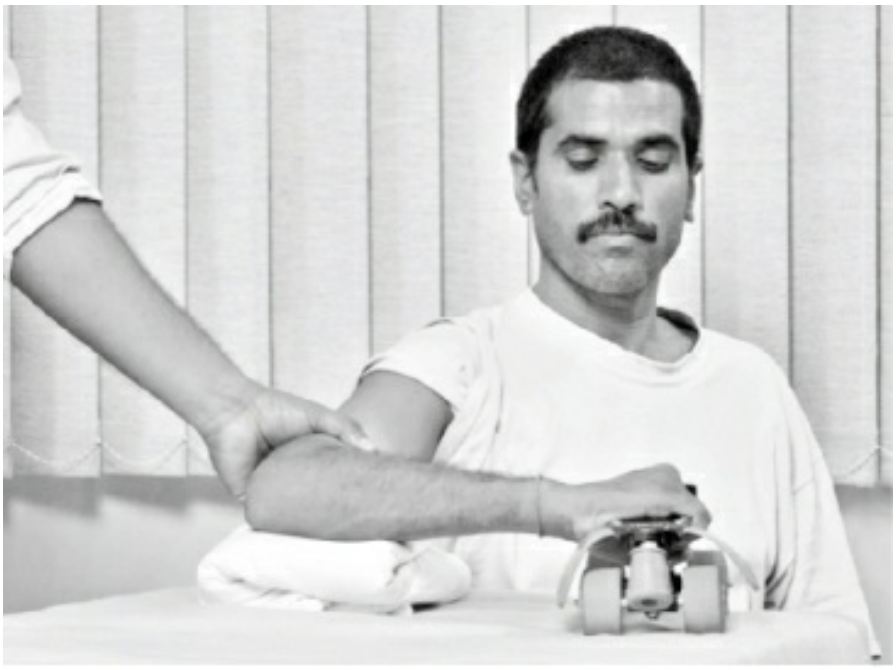
(B)



(C)

FIG. 7-3 **(A)** Relaxed active free elbow flexion and extension in prone. **(B)** On knee ratchet. **(C)** With roller skates.

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FIG. 7-4 Relaxed free pronation and supination with the forearm fully supported on the thigh.

When the pain is substantially reduced, a wand could be used to begin active movement. It can apply gentle stretch to regain the extreme range of all the four movements (Fig. 7-5) by contralateral hand.

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FIG. 7-5 Active elbow mobilization with wand. Gentle self-assistive stretch may be applied to further the range of motion after assuring pain-free relaxation.

Functional use of elbow and forearm has to be emphasized except lifting heavy objects.

Caution

By 5 weeks following the injury or 2 weeks following mobilization, if there is no appreciable improvement of elbow ROM, elbow should

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be carefully examined for suspected bony block. This may need surgical intervention.

B. **Fractures managed by excision of the displaced fragment**

The regime of physiotherapeutic management, in the event of excision of the bony fragment, follows the same pattern as outlined for conservative management.

The patients treated surgically may have persistent pain for a longer time. Home treatment with exercises in warm water and use of whirlpool or steam pack in the department may be useful.

An acceptable range of all the four movements should be regained by 5–6 weeks following injury.

Supracondylar fracture of the humerus

It is one of the most common fractures in children. This fracture results from a direct injury, e.g., fall on the point of elbow, or an indirect injury, e.g., fall on the outstretched hand. The distal fragment may be displaced posteriorly (extension type of fracture) or anteriorly (flexion type of fracture). The former is the most common type (Fig. 7-6).

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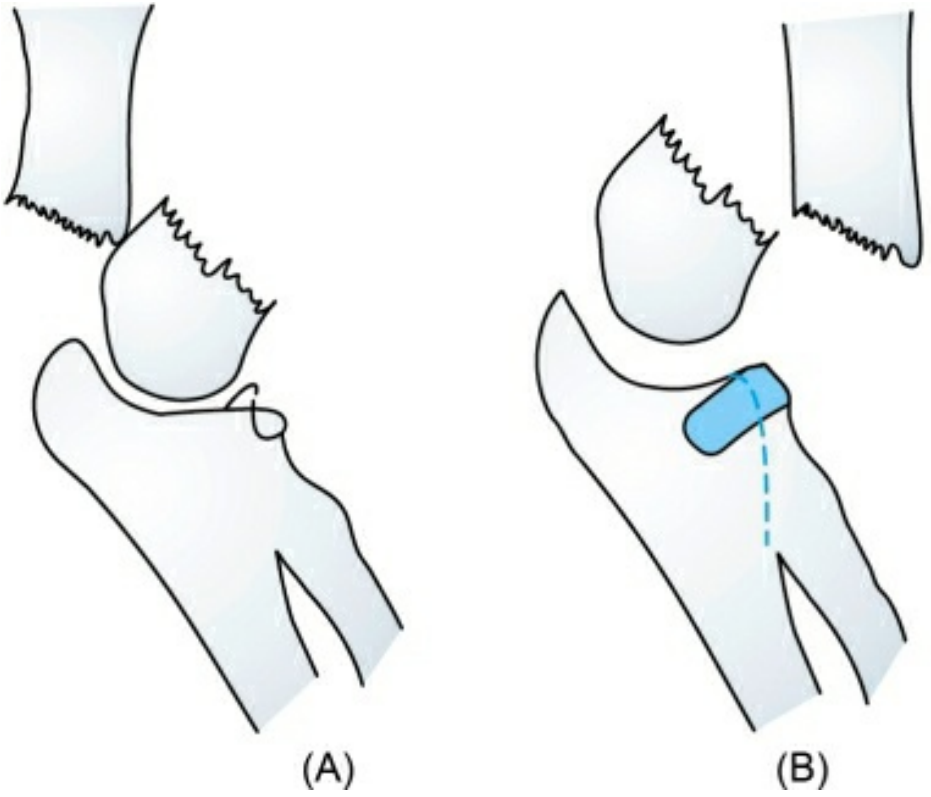

FIG. 7-6 Supracondylar fracture of the humerus. **(A)** Flexion type. **(B)** Extension type.

The brachial artery and the median nerve may be injured by the sharp distal end of the proximal fragment (Fig. 7-7). It is therefore important to test for the neurovascular status distally.

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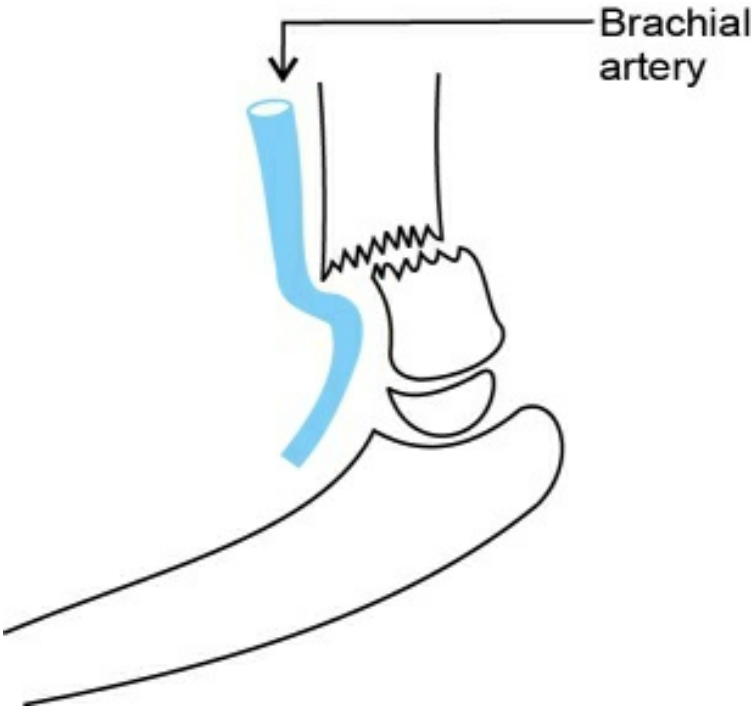

FIG. 7-7 The brachial artery may be injured by the sharp edge of the proximal fragment.

X-ray: An X-ray (AP and lateral views) is essential to study the type of fracture and the displacements (Fig. 7-8 A and B).

FIG. 7-8 Internal fixation of supracondylar fracture by Kirschner wires. **(A, B)** Preoperative and **(C, D)** postoperative radiographs.

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Treatment

1. *Closed reduction:* The fracture is reduced by closed manipulation under general anaesthesia. After reduction, the extension type of fracture is immobilized in an above-elbow plaster slab with the elbow in flexion, whereas the flexion type (less common) of fracture is immobilized with the elbow in extension. In either case the plaster is removed after 3 weeks.

2. *Traction:* In cases where closed reduction has failed or in late (more than a week old) cases, the fracture is treated by Dunlop traction (Fig. 7-9). The traction is maintained for 3 weeks.

3. *Open reduction:* Open reduction of fracture is indicated when (a) the closed manipulation fails, (b) the brachial artery is injured and needs exploration and (c) there is an associated nerve palsy which needs exploration.

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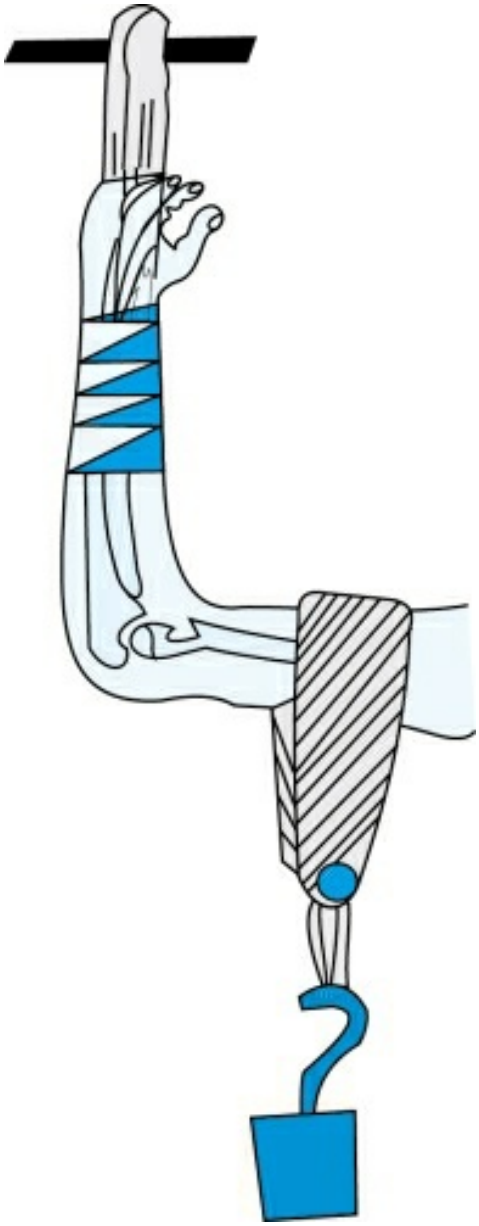

FIG. 7-9 Treatment of supracondylar fracture by Dunlop traction.

The fracture fragments are fixed internally with Kirschner (K-) wires (Fig. 7-8). Postoperatively, the limb is immobilized in a posterior slab with the elbow in flexion for 3 weeks. The K-wires are also removed after 3 weeks and the elbow is mobilized.

Complications: The complications of supracondylar fractures can be divided into the following two groups:

(a) Early complications

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(b) Late complications

Early complications

These complications occur at the time of injury or immediately thereafter.

1. *Injury to the brachial artery*: This is the most serious complication in which the radial artery is injured by the sharp edge of the proximal fragment (Fig. 7-7). The artery may actually be lacerated or may just go into spasm. This jeopardizes the blood supply to the flexor muscles of the forearm resulting into Volkmann ischaemia. This condition should be diagnosed early and treated immediately.

Diagnosis: There is a *sudden increase in pain* in the forearm and *stretch pain*. *Stretch pain* is elicited on the flexor aspect of the forearm when the fingers are passively extended.

Treatment: A suspected case of Volkmann ischaemia should be treated as an emergency to prevent irreversible changes. The treatment consists of the following:

- Removal of the tight bandage/plaster/splint immediately
- Elevation of the forearm
- If no improvement is seen within 2 h, surgical operation of decompression of the tight flexor compartment (fasciotomy)
- Surgical exploration and repair of injury to the brachial

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artery

2. *Injury to the peripheral nerves*: Median, radial and ulnar nerves may be injured, in that order. In the majority of cases the nerves may recover spontaneously.

Late complications

1. ***Malunion:*** Malunion is the most common complication of supracondylar fracture of the humerus, resulting in a cubitus varus deformity (Fig. 7-10).

Treatment: If the deformity is unacceptable cosmetically, it needs corrective osteotomy in the supracondylar area of the humerus.

2. ***Myositis ossificans***: Myositis ossificans is ectopic new bone formation around the elbow (Fig. 7-11). This is a common complication, which occurs following massage to the elbow after injury and results in stiffness of the elbow.

Treatment: In the acute painful stage, the elbow is immobilized in an above-elbow plaster slab for about 3 weeks. Otherwise, the treatment is mobilization. Occasionally, an attempt may be made towards surgical excision of the myositis mass followed by mobilization of the elbow, after the myositis mass has consolidated. However, recurrence is common.

3. ***Volkmann ischaemic contracture (VIC):*** Volkmann ischaemia, if not treated in time, gradually progresses to VIC. The ischaemic muscles are gradually replaced by

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fibrous tissue, which contracts and draws the wrist and finger into flexion. If the peripheral nerves (commonly the median nerve) are also damaged by ischaemia, there will be sensory and motor paralysis in the forearm and hand.

Diagnosis:

(i) There is marked wasting of the forearm muscles and the characteristic deformity of flexion of the wrist and fingers (Fig. 7-12).

(ii) *Volkmann sign*: In this sign, the finger cannot be fully extended passively with the wrist extended; but fingers can be fully extended passively when the wrist is flexed (Fig. 7-13). This sign is pathognomonic of VIC.

Treatment: In *established cases*, restoration to normalcy is impossible because irreversible damage has occurred to the important muscles and nerves. However, reconstructive surgery can improve some function in the hand.

Mild cases can be treated by (i) stretching exercises and (ii) use of a turnbuckle splint (Fig. 7-14), which gradually stretches the contracted muscles.

Moderate cases require a muscle slide surgical operation (also called *Maxpage operation*) where the flexor group of muscles are released from their origin.

Severe cases can be treated by proximal row carpectomy and wrist arthrodesis.

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FIG. 7-10 Cubitus varus deformity of the left elbow.

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FIG. 7-11 Myositis ossificans on the anterior aspect of the elbow.

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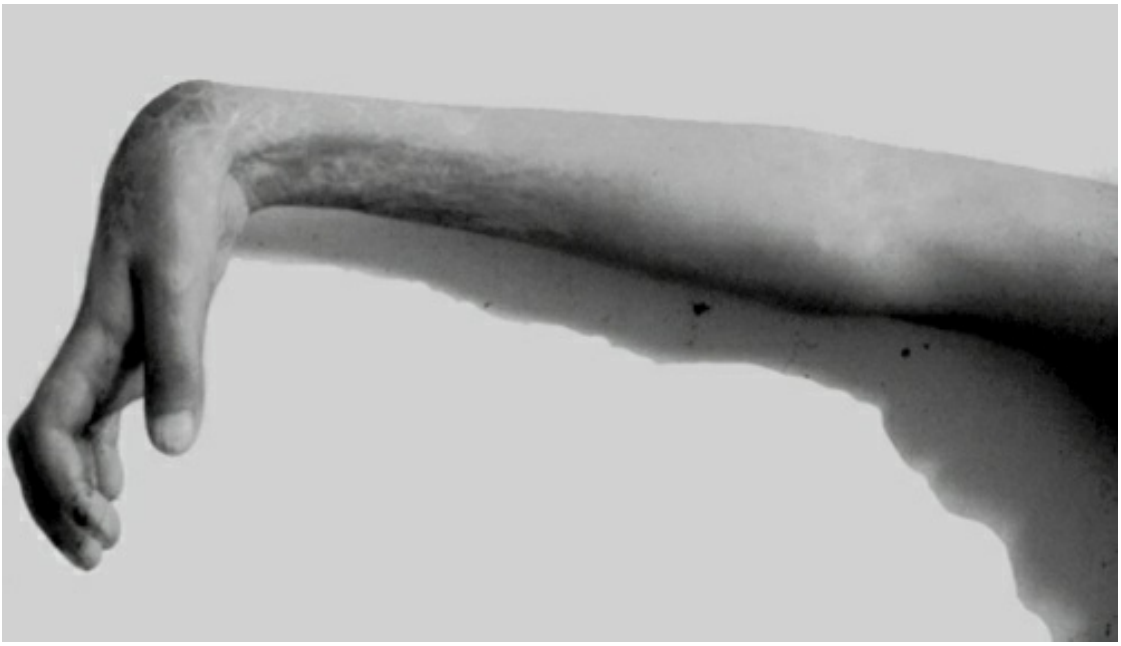

FIG. 7-12 Volkmann ischaemic contracture (VIC) with typical posture of the wrist in flexion, metacarpophalangeal (MCP) joints in hyperextension, and proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints in flexion.

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(A)

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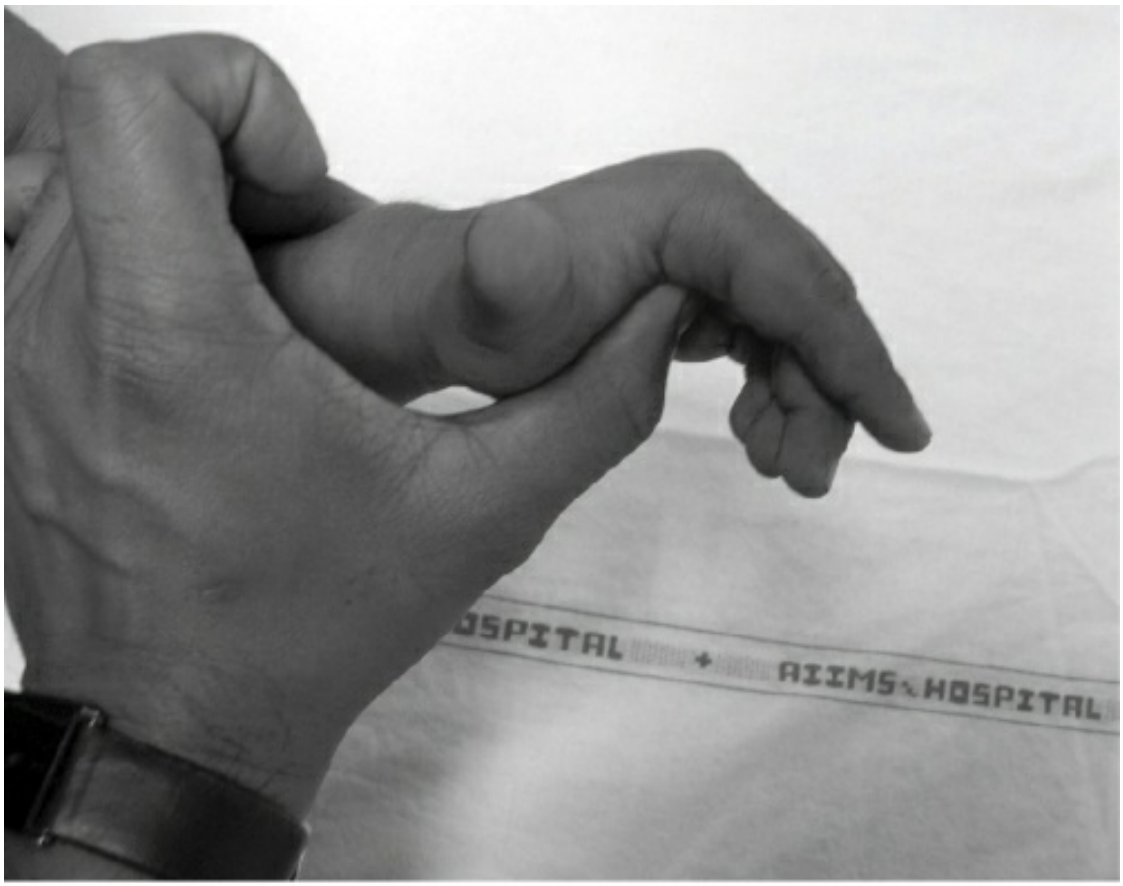

(B)

FIG. 7-13 Volkmann sign: **(A)** The fingers can be fully extended with the wrist in flexion. **(B)** When the wrist is extended, the fingers go into flexion and full extension of the fingers is not possible.

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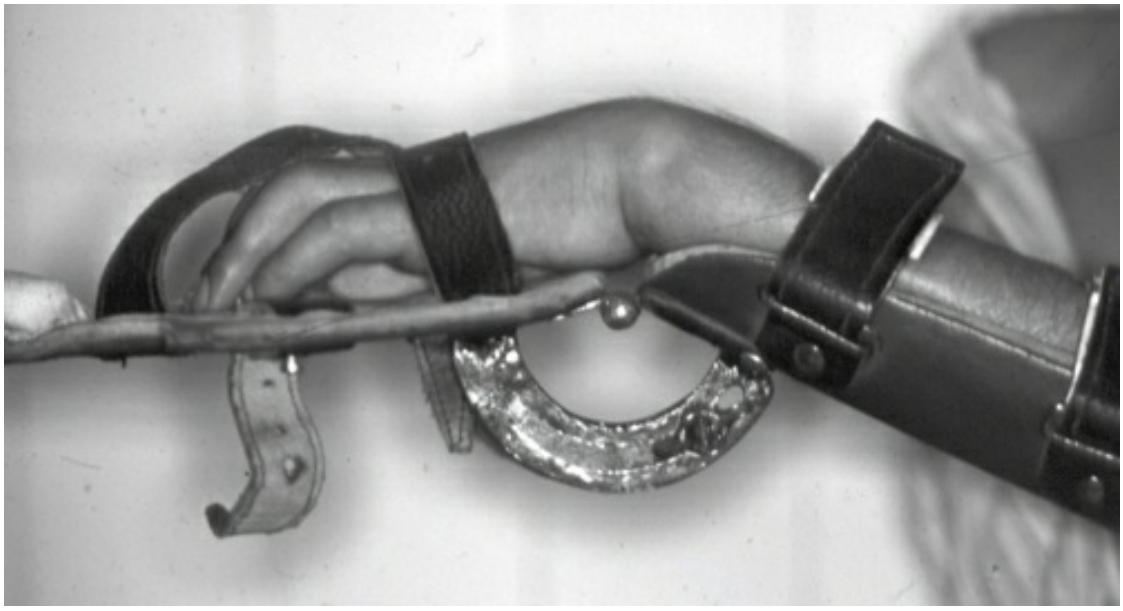

FIG. 7-14 Turnbuckle splint used for correction of Volkmann ischaemic contracture.

Physiotherapeutic management

Basic objective: The basic objective is to achieve active full-range movement of the elbow and forearm.
Supracondylar fractures in children: The most common fracture in children is the extension type where the lower end of humerus is displaced posteriorly.
The physiotherapeutic programme depends upon the type of initial management of the fracture.

Conservatively managed fractures

During immobilization (first 3 weeks): The fracture is managed either by (a) manipulation with closed reduction, or by (b) Dunlop traction.

(i) Proper checking of plaster slab/traction to ensure proper immobilization and freedom of the thumb and fingers

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(ii) Vigorous, strong full-range movement for free joints to reduce inflammation and augment healing

Mobilization (after 3 weeks)

(i) Evaluation of the ROM at the elbow and the forearm should be accurate.

(ii) Before initiation of mobilization, adjuncts of thermotherapy like paraffin wax bath and hydro collator packs should be applied. They induce relaxation, reduce pain and augment local circulation providing comfort and encouragement for exercise.

(iii) Movements at the elbow should be initiated in the form of active assisted rhythmic movements in a gravity-eliminated position. Use of roller skates provides excellent means at this stage. It can be carried out several times at home on a dining table. However, alignment of the elbow joint and proper stabilization of the arm, leaving the elbow joint free to move (avoiding friction of elbow with the top of the table), has to be ensured.

(iv) Flexion is an important component of the elbow movements. It should be initiated and emphasized as described earlier in prone position (Fig. 7-3A), or by modified use of the knee ratchet (Fig. 7-3B) or by roller skates (Fig. 7-3C).

Extension at the elbow also needs to be emphasized. Tendency for cubitus varus or valgus needs to be checked at the extreme range of extension and recorded.

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(v) Relaxed swinging of elbow flexion with supination and elbow extension with pronation are ideal. It not only induces relaxation at the elbow, but also promotes the range of supination and pronation.

(vi) After a brief session of relaxed rhythmical free active mobilization, further range should be attempted by sustained stretching beyond the existing limitation for both the movements.

The progress of the movement needs to be monitored at regular intervals. The results in children are usually good and full range of movement should be expected within 6–8 weeks.

Caution

Vigorous passive movements or passive stretching at the end of the limitation or any kind of massage should be forbidden to prevent myositis ossificans.

Fractures treated surgically

For fractures treated by K-wire stabilization following open reduction, the physiotherapeutic management remains the same as described for conservative management.

Adequate protection and care for the area of incision, and extra encouragement are necessary in the process of mobilization.

If the fracture is associated with nerve injury, proper protective and re-educative procedures are necessary along with other mobility procedures.

Intercondylar fracture of the humerus

Adults following a fall on the point of elbow usually sustain this fracture. The olecranon process is driven between the condyles, which are fractured from each other and from the shaft by a **T**- or **Y**-shaped fracture line (Fig. 7-15A). Comminution is commonly seen in these

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fractures.

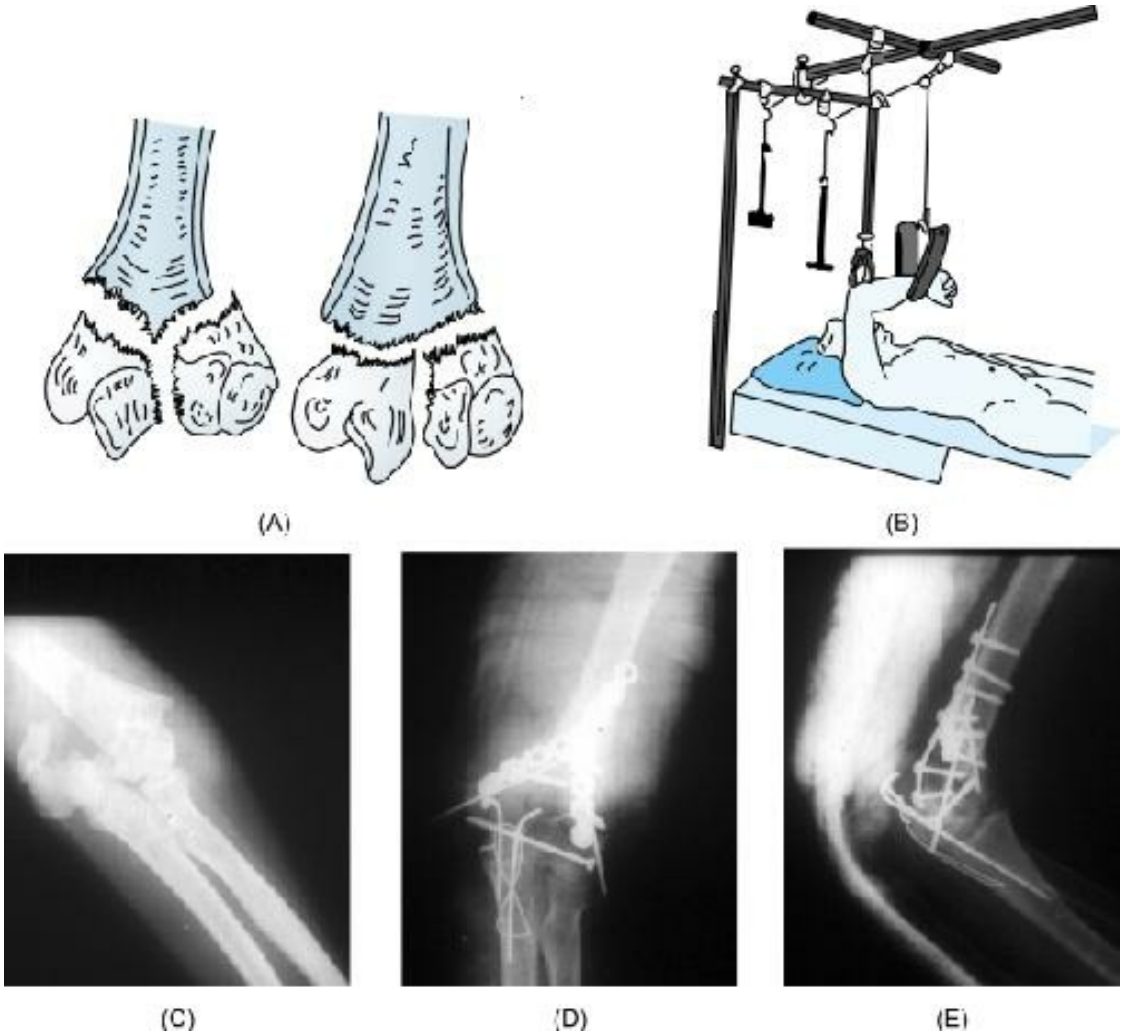

FIG. 7-15 Intercondylar fracture of the humerus. **(A)** Y-shaped and T-shaped fractures. **(B)** Overhead traction immobilization. **(C–E)** Pre- and postoperative radiographs of intercondylar fracture of humerus as treated by internal fixation by plate and screws.

Diagnosis

The elbow joint is swollen and painful. The movements are grossly restricted.

A radiograph of the elbow shows the diagnosis of the fracture. The intercondylar fracture of the humerus is usually comminuted and

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therefore a CT scan is often required to delineate the exact anatomy of the fracture – this usually helps in planning the treatment.

Treatment

1. *Plaster cast*: An undisplaced or a minimally displaced fracture can be treated using an above-elbow POP cast for 3–4 weeks.

2. *Traction:* Skin or skeletal overhead traction is applied to the forearm (Fig. 7-15B). It is maintained for 3 weeks.

3. *Open reduction and internal fixation:* Open reduction is indicated in fractures where the comminution is not severe. The fragments are fixed internally with screws and/or plates (Fig. 7-15C–E). Postoperatively, the elbow is immobilized in a plaster slab for about a week. The elbow is mobilized early.

Physiotherapeutic management

In this fracture, both the condyles of the humerus are separated from the humeral shaft in the shape of a T or Y. The fracture not only results in a gross injury to the soft tissues around the elbow joint but also disorganizes the joint. Therefore, the results are usually poor. The degree of stiffness is severe, when the fracture is comminuted.

Fractures treated by a conservative approach

Immobilization (First 3 Weeks)

1. Vigorous strong movements for the joints which are free; wrist to be moved with assistance by temporarily removing hand support sling in traction, besides finger and thumb movements

2. Carefully monitored isometrics to be initiated for deltoid without disturbing the immobilization

Mobilization (After 3 Weeks):
Mobilization needs to be taken as an important priority and

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maximum efforts are needed to achieve it.

Initially, suitable thermotherapy adjunct should be given for an extended period to obtain maximum relaxation. Techniques of mobilization described earlier for supracondylar fracture (Figs 7-1, 7-3 and 7-4) should be used.

However, considering the poor prognosis, periods of sustained gentle stretches by using modified knee ratchet techniques for improving the range of flexion and extension are ideal (Figs 7-1 and 7-5). At the same time, efforts should be made to achieve early the maximum range of pronation and supination. In the absence of the acceptable range of flexion and extension, good return of the movements of forearm rotation assists in the functional use of hand and is therefore important.

Tying a cuff and collar sling in the maximally attained flexion exerts continuous gentle traction facilitating flexion for the functional use of hand (Fig. 7-16). Although this technique facilitates flexion, it has the disadvantage of restricting the range of extension at the elbow and, therefore, needs to be used judiciously.

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FIG. 7-16 Maintenance of extreme flexion achieved following mobility exercise to offer continuous light stretching effect by cuff and collar sling.

A careful and controlled passive stretching technique can be used after 6 months to regain further ROM (Stoddard, 1971).

Fractures treated by a surgical approach

Open reduction and internal fixation (ORIF) by multiple screws or plating has two distinct advantages:

1. Stabilization of the fracture

2. Initiation of active physiotherapy immediately following healing of the soft tissue in 8–10 days

The chances of regaining the functional range of movement are better.

The method of management is the same as described for the conservative approach. However, care should be taken of the surgical incision.

Fracture of single condyles of the humerus

Isolated fractures of the lateral condyle of the humerus and medial epicondyle of the humerus are seen in children. Fracture of the lateral condyle of the humerus is more common and seen in the age group of 3–6 years (Fig. 7-17). Displacement in these fractures is common due to the strong pull of common origins of the flexor and extensor groups of muscles in the medial epicondyle and lateral condylar fractures respectively. Undisplaced fractures are treated by a plaster slab for 2–3 weeks.

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FIG. 7-17 **(A)** Line diagram showing a displaced fracture of the lateral condyle of humerus. **(B)** As seen on a radiograph. **(C)** Normal radiograph of the elbow for comparison. **(D)** Fracture of the lateral condyle of the humerus fixed by K-wires.

Displaced fractures need ORIF by K-wires (Fig. 7-17D). Fracture of the medial condyle of the humerus in adults needs internal fixation with plate and screws (Fig. 7-18). Postoperatively, the elbow is immobilized in 90 degrees of flexion for 3 weeks.

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(A)

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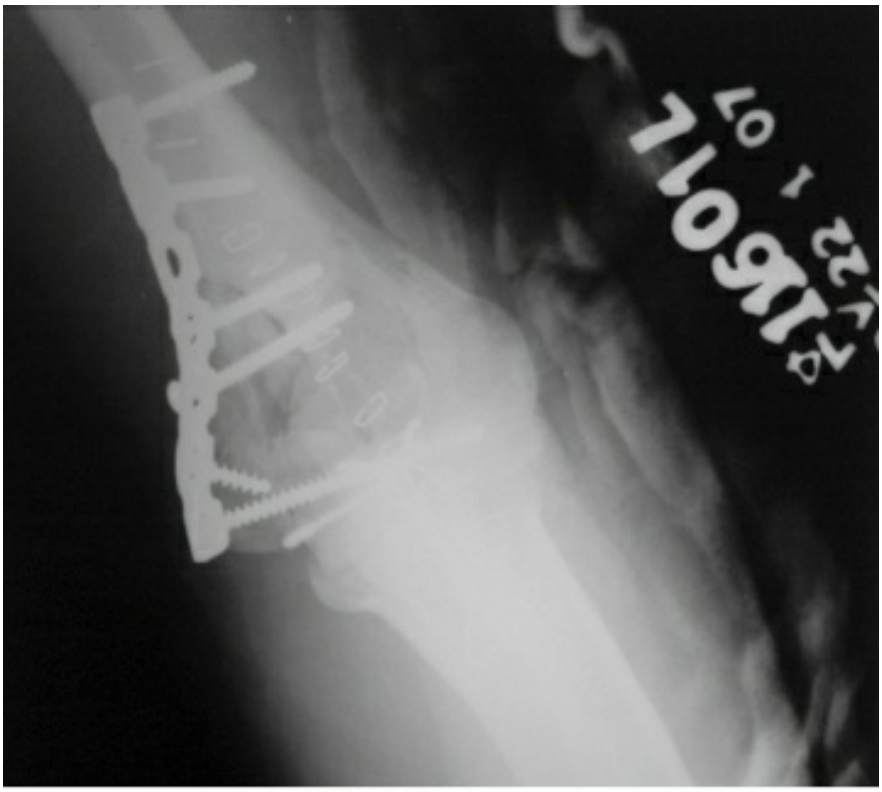

(B)

FIG. 7-18 **(A)** Comminuted fracture of the medial condyle of the humerus in an adult. **(B)** Treated by plating.

Complications

1. *Nonunion* of the fracture is usually seen in untreated displaced fractures.

2. There is *tardy ulnar nerve palsy.*

3. Nonunion of the lateral condylar fracture can cause cubitus valgus deformity in growing children. The cubitus valgus deformity can in turn be a cause of tardy (late) ulnar nerve palsy (Fig. 7-19).

4. Injury to the ulnar nerve may be associated with fracture of the medial epicondyle of the humerus.

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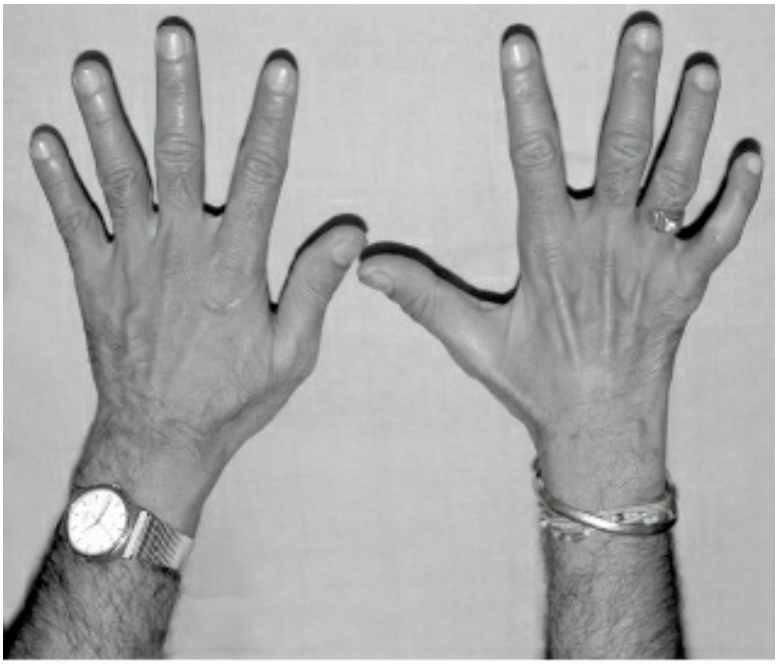
(A)



(B)

FIG. 7-19 **(A)** Cubitus valgus deformity of the right elbow following nonunion of the fracture of the lateral condyle of the humerus and **(B)** ulnar nerve palsy on the right side in the same patient. The wasting of the interossei is conspicuous on the dorsum of the hand.

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Physiotherapeutic management

These fractures are treated conservatively or by reduction and K-wire stabilization. In both the approaches of management, active physiotherapy for the elbow is begun after 3 weeks of immobilization.

It is to be carried out in the same phases as described for the supracondylar fracture. The following measures will also be needed.:

1. The parents need to be educated to watch for any signs of ulnar nerve compression in patients with fractures of the medial epicondyle.

2. Possible weakness of flexor muscles in case of isolated fracture of the medial epicondyle needs to be watched.

3. The extensor group of muscles in fracture of the lateral condyle need to be watched critically. If weakness is present, appropriate strengthening techniques for the affected muscle group should be incorporated in the mobilization programme.

Pulled elbow

When a child, younger than 4 years, is lifted with a jerk by his/her hand, the radial head can slip partly out of the annular ligament or the annular ligament can slip over the radial head and cause severe pain. The child does not use the hand and even resists examination. The radiograph is normal.

Treatment

The forearm is gently pulled, with the elbow flexed, supinated and pronated. This manoeuvre reduces the radial head back into the annular ligament with instant relief from pain.

Dislocation of the elbow

Posterior dislocation of the elbow is commonly seen following a fall on the outstretched hand with the elbow slightly flexed (Fig. 7-20). The radius and ulna are pushed backwards resulting in rupture of the

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periosteum from the lower end of the humerus and injury to the brachialis muscle from the coronoid process.

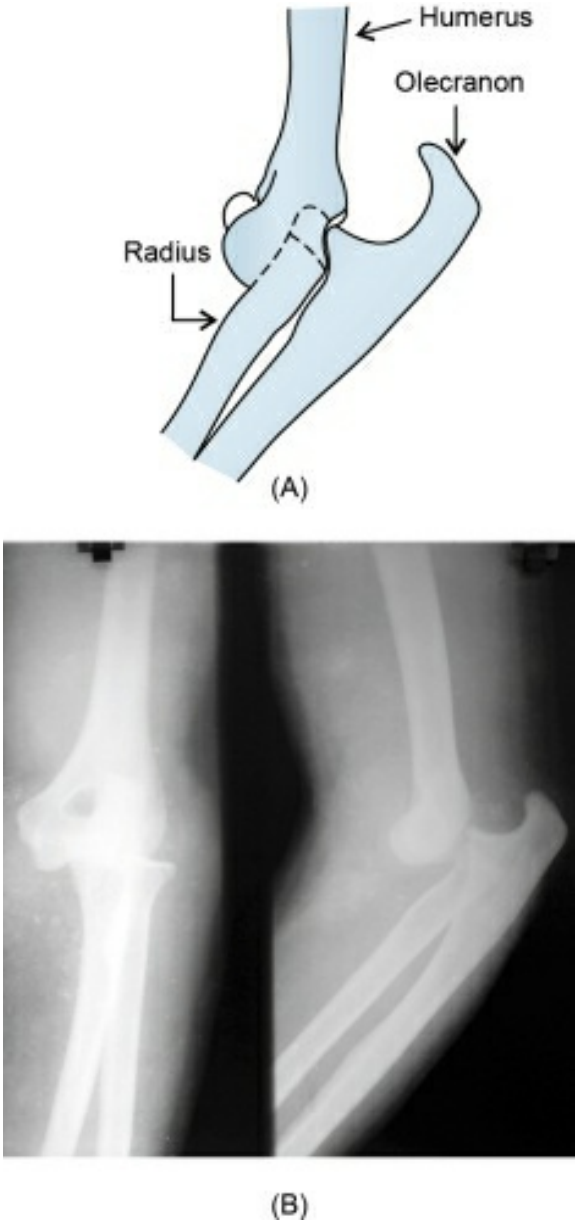

FIG. 7-20 Posterior dislocation of the elbow: **(A)** Diagrammatic representation. **(B)** Radiographic representation.

Rarely, anterior, lateral, medial or divergent dislocations of the elbow may be seen.

The dislocation of the elbow may quite commonly be associated

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with fracture of the coronoid process of ulna. Less commonly, fractures of the condyles of the humerus, head and neck of radius may also be present.

The ulnar nerve may get injured in a dislocation of the elbow and, therefore, the clinical examination/evaluation must include tests for ulnar nerve function.

Treatment

1. Closed manipulation, done under general anaesthesia, is often successful. The limb is immobilized in an above-elbow plaster slab with the elbow in flexion and the forearm in supination for 3 weeks.

2. Open reduction may be necessary:

(i) Where closed manipulation fails

(ii) In late cases

Complications

1. *Stiffness of the elbow*: It is usually seen if the dislocation is reduced after 2–3 weeks of injury.

2. *Myositis ossificans*: Painful passive stretching, massage and haematoma in the brachialis muscle can result in myositis ossificans which, in turn, causes stiffness of the elbow.

3. *Injury to the ulnar nerve*

Results: The results are generally good in fresh cases treated adequately in time.

Physiotherapeutic management

The results of this type of injury largely depend upon three basic

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factors:

1. Time of reporting

2. Adequacy of the initial management

3. Associated injury

In the first two approaches of closed manipulation and open reduction, acceptable return of function is expected.

During the Period of Immobilization (First 3 Weeks)

1. Check the plaster cast to ensure freedom of movement of the free joints.

2. Provide vigorous and strong exercises to all the free joints, especially full-range shoulder abduction in elevation and rotation. Finger and thumb exercises in elevated position with arm resting on the tabletop are important. All these reduce swelling, and also the process of inflammation.

3. This period should also be gainfully utilized to explain and guide the total exercise regime on the normal side. This facilitates the exercise programme on the affected side during mobilization.

Mobilization After 3 Weeks

1. Careful evaluation of the ROM of flexion and extension at the elbow and pronation and supination at the forearm is done.

2. Evaluation of the degree of pain and swelling is also done.

3. Suitable thermotherapy modality may be used as an adjunct before starting mobilization. Paraffin wax bath and warm saline water can be used in the department and home, respectively.

4. Relaxed and rhythmical active assisted mobilization of the elbow

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and forearm to be initiated as described previously.

5. To initiate mobilization, roller skates, wand or whirlpool bath, if available, could be used.

6. Pronation and supination should be initiated in forearm lap position.

7. Maintain the extreme range of elbow flexion and extension achieved after exercises by properly tying sling in that position of flexion (Fig. 7-16) and by the assistance of a normal hand for extension. Valgus stress at the elbow must be avoided while exercising.

During the process of mobilization, proper watch has to be kept for the possible complication of myositis ossificans. Excessive tenderness and inflammation around the brachialis insertion and reduction in the ROM may be early signs of myositis ossificans. These, therefore, need to be carefully monitored at each visit of the patient. Vigorous passive movements, passive stretching and massage are strictly contraindicated for the same reason.

The regime of exercises is progressed further emphasizing full-range active movements and functional use of the whole upper extremity.

By the end of 6–8 weeks, functionally acceptable results can be achieved.

Fracture of the olecranon

This fracture occurs in adults following a direct injury due to fall on the point of elbow; or an indirect injury due to fall on the hand with elbow in slight flexion. Direct injury results in a transverse fracture. The proximal fragment is displaced proximally by the pull of the triceps muscle (Fig. 7-21).

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FIG. 7-21 Fracture of the olecranon. **(A)** A fracture without displacement – treated by an above-elbow POP cast. **(B)** A displaced fracture – treated by internal fixation by screw or tension band wiring. **(C)** Comminuted fracture – treated by excision of the fragments and reattachment of the triceps.

Diagnosis

There is pain and swelling on the posterior aspect of the elbow joint. The patient will not be able to actively extend the elbow.

Radiograph: An X-ray (especially a lateral view) gives the diagnosis

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of the fracture as well as the displacements of the fracture fragments. The X-ray also gives information about the comminution of the fracture, if present – this helps in deciding the exact method of treatment.

Treatment

1. A fracture without displacement is treated with an above-elbow POP cast (Fig. 7-21A).

2. ORIF with screws or tension band wiring is done for transverse fractures (Fig. 7-21B).

3. ORIF by plating: A special olecranon plate is used in comminuted fractures of the olecranon, which cannot be fixed by tension band wiring (Fig. 7-22). Plating is also indicated in fractures of the olecranon where the fracture extends into the shaft of the ulna.

4. In severely comminuted fractures, where reduction and internal fixation is not feasible, excision of the proximal fragment of the olecranon is done and the triceps is repaired (Fig. 7-21C).

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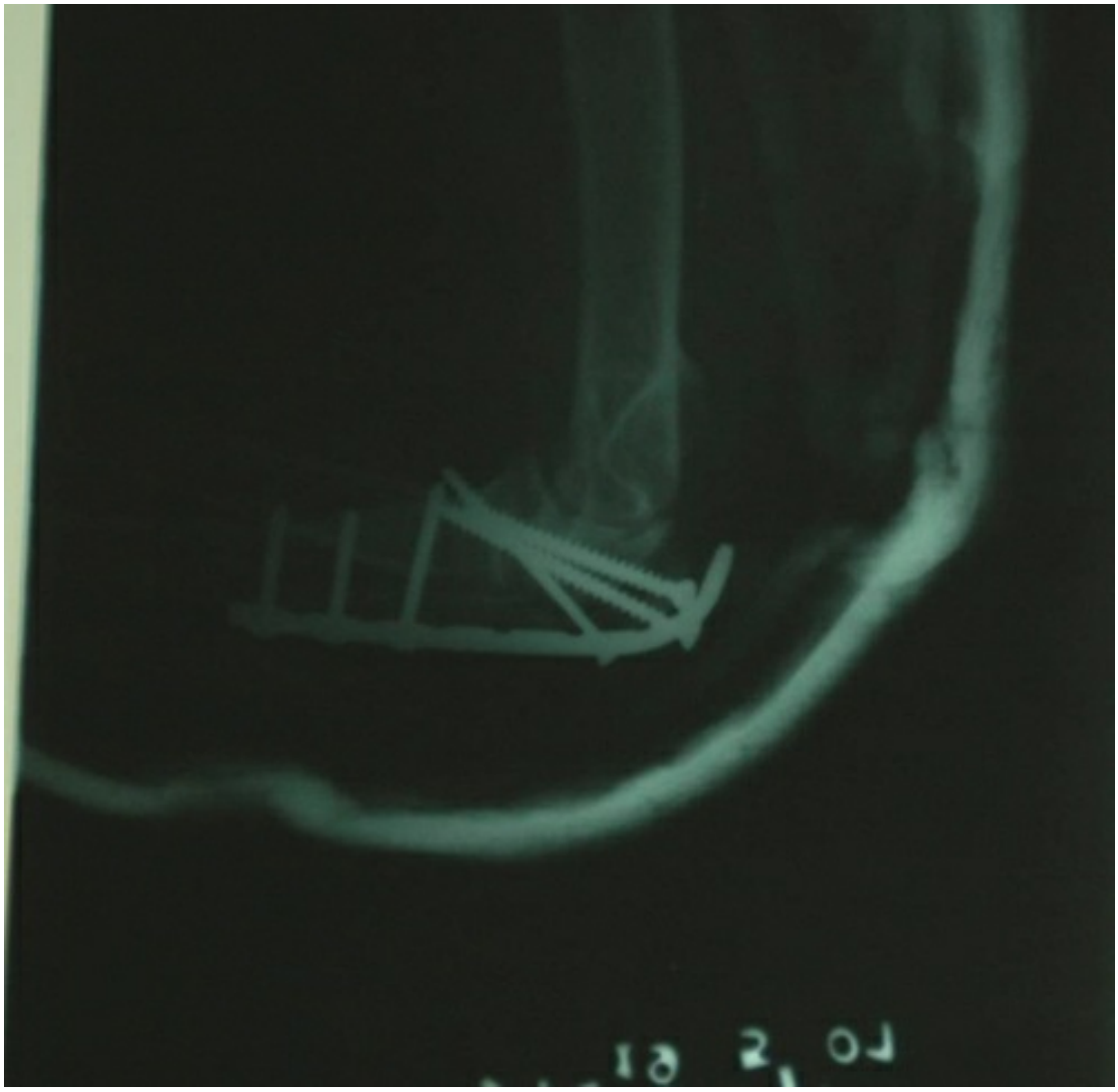

FIG. 7-22 Special plate used for fixation of fracture of the olecranon.

In these methods, the elbow is immobilized in a POP slab for a period of 2 weeks.

Physiotherapeutic management

The physiotherapeutic management basically remains the same as for supracondylar fractures.

Early return of terminal range of flexion and extension

Relaxed elongation of triceps is necessary for the terminal range of flexion and that of biceps brachii for the terminal range of extension.

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Therefore, gravity-assisted relaxed swinging in the terminal range of flexion needs to be encouraged at the earliest. This should be followed by terminal active stretch and hold. This will maintain the achieved range of flexion. Repeat the same procedure for extension also.

Similarly, stretching and strengthening exercises to triceps need to be instituted early to regain full function of surgically repaired triceps in case of comminuted fractures.

Fracture of the head and neck of the radius

Fracture of the head of the radius is common in adults (Fig. 7-23), while the fracture of the neck of the radius is usually seen in children (Fig. 7-24). Both these fractures result when the elbow is subjected to valgus strain during a fall.

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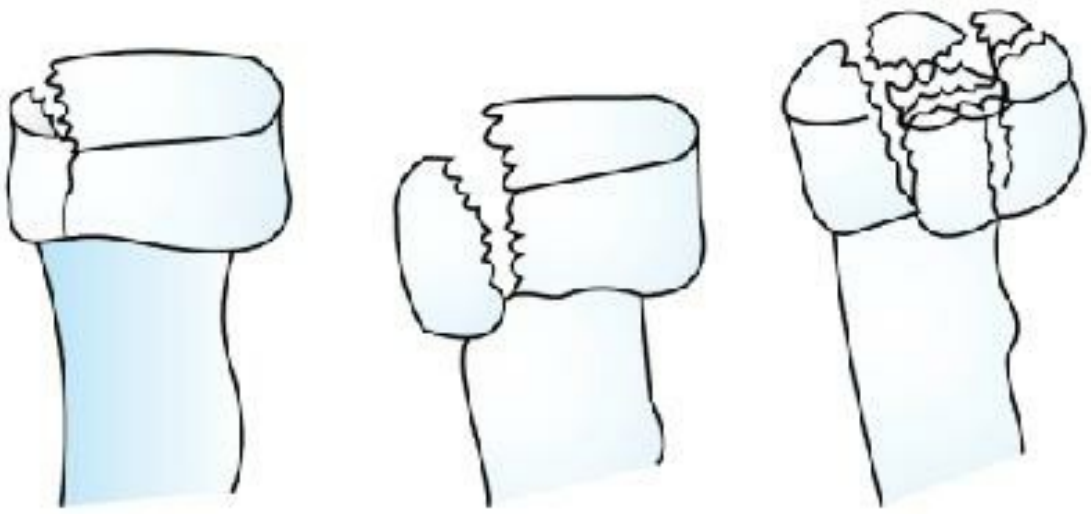

(A) (B) (C)

(D)

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FIG. 7-23 Fracture of the head of the radius. **(A)** Minimally displaced. **(B)** Displaced fracture. **(C)** Comminuted fracture. **(D)** Fracture of the head of the radius, as seen on radiograph.

FIG. 7-24 Fracture of the neck of the radius in a child.

The patient presents with pain and mild swelling over the lateral aspect of the elbow following a fall on the outstretched hand.

On examination, there is tenderness over the head of the radius and

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restriction of supination and pronation movements.

Radiograph: An X-ray can confirm the diagnosis and show the fracture which can either be an incomplete fracture, a displaced fracture or a comminuted fracture (Fig. 7-25).

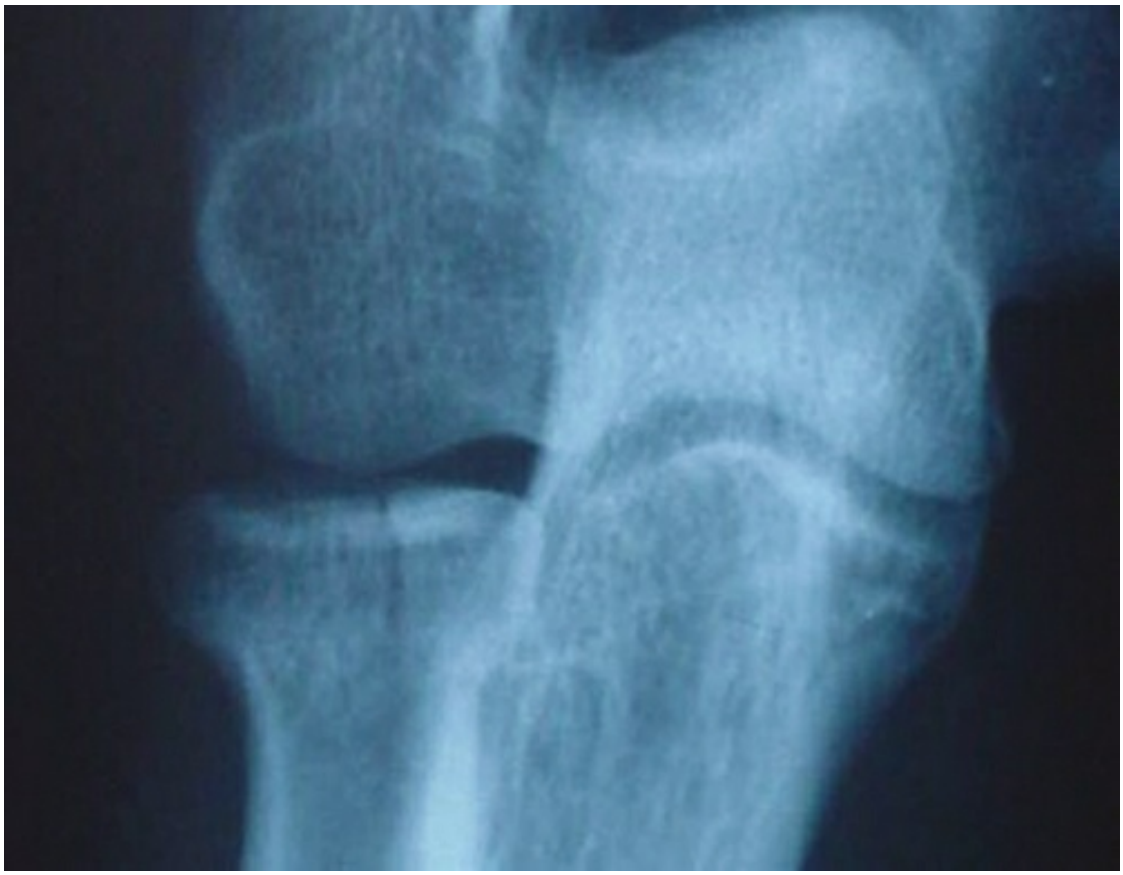

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FIG. 7-25 Mason classification.

Treatment

Fracture of the head of the radius

1. Conservative treatment: Undisplaced fractures are treated by a posterior plaster slab for 2–3 weeks.

2. Surgical treatment:

(a) *ORIF:* Displaced fractures of the radius are treated by ORIF with the help of special plates and screws (Fig. 7-26).

(b) *Excision of the radical head:* A comminuted fracture in an

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elderly person with low functional demands is treated by excision of the head of the radius. The elbow is immobilized, postoperatively, in a POP slab for a week and then mobilized (Fig. 7-27).

(c) *Replacement of the radial head:* Comminuted fractures of the head of the radius can also be treated by excision and replacement of the radial head by a prosthesis (Fig. 7-28).

(A) (B)

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(C)

FIG. 7-26 Fracture of the head of the radius. **(A and B)** Preoperative and **(C)** postoperative radiographs showing fracture of the head of the radius treated by internal fixation using special plates.

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FIG. 7-27 X-ray shows excision of the radial head.

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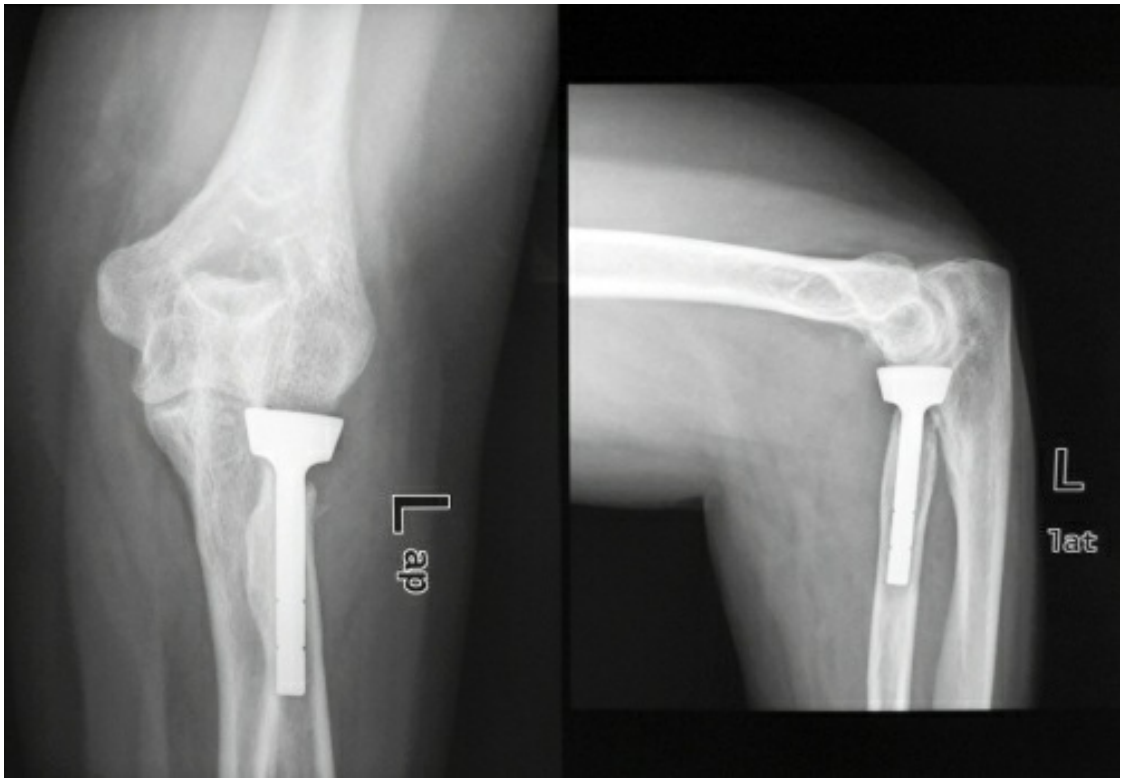

FIG. 7-28 Replacement of the radial head by a prosthesis.

Fracture of the neck of the radius

Since this fracture occurs in children, the fracture fragments are never excised for fear of impairment of growth. The fracture is reduced either by closed manipulation or by ORIF using K-wires. The elbow is immobilized in a plaster slab for 2 weeks. It is then mobilized after removal of the K-wires.

In adults, the fracture of the neck of the radius can also be treated by open reduction and internal fixation.

Physiotherapeutic management

The programme of management is based on the same lines as for supracondylar fracture.

The rotational movements of the forearm, i.e., pronation and supination, need extra attention. As the movements are painful, the forearm should be well supported on the thigh while sitting, and active relaxed repeated rotation in both the directions needs to be

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initiated early. The progress of rotation should be monitored at regular intervals.

Complications following fractures around the elbow joint: The complications following immobilization are more disabling then the fracture itself. Therefore, prevention of the following expected complications is of primary importance.

Common Complications

A. VIC

B. Injury to the peripheral nerves

C. Malunion

D. Myositis ossificans

E. Osteoarthritis

A. ***VIC***: VIC occurs as a result of occlusion of the arterial circulation. If not detected early, it may progress to muscular ischaemia (muscles on the flexor aspect) which may progress to fibrosis, resulting in typical Volkmann sign and the deformity of flexion of the wrist and fingers. If not stretched, the progressive fibrosis of the flexors results in fibrous ankylosis of the wrist and finger joints – giving rise to a typical VIC deformity with wrist in flexion, metacarpophalangeal (MCP) joint in hyperextension and flexion at the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints (see Fig. 7-12). Ischaemia of median and ulnar nerve results in sensory loss making the patient prone to injury. Ultimately, it may result in a totally nonfunctional hand.

REMEMBER

Be extremely watchful for this dreaded VIC following fractures around the elbow forearm and hand.

Signs and symptoms: Within 3–4 h following immobilization:

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1. Severe intractable continuous pain all along the area distal to the site of occlusion. Pain increases in intensity on passive finger extension.

2. The fingers and toes become swollen and discoloured, first pale and then blue, resulting in difficulty in performing movements. Even blisters may appear.

3. Radial pulse is absent.

4. Muscular spasm develops with a hard and woody feel on touching.

5. Loss of muscle extensibility – there is a feeling of stiffness in the distal joints.

6. There is gradual loss of sensory status and motor functions.

7. A typical diagnostic sign – the Volkmann sign – develops (Figs 7-12 and 7-13).

If not attended immediately, it may progress to an irreversible typical VIC deformity. The fibrosis of the flexor group of muscles leads to flexion deformity at the elbow, wrist, fingers and thumb. The forearm remains in pronation and MCP joints in hyperextension. If not noticed even at this stage, an increase in the compartmental pressure may cut off the circulation completely leading to gangrene. The median and ulnar nerves may also get involved. The probable causes are as follows: (i) sustained pressure on blood vessels due to tight POP, bandage or splint applied for immobilization, (ii) injury to the brachial

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artery, and (iii) latent disease of the vessel.

Preventive measures

1. The most important aspect of prevention is the education of the patient or the parents regarding the expected signs and symptoms of VIC. They must keep a close watch on these and should report to the casualty at the earliest indication. They may themselves remove the cast, bandage or splint, causing pressure, in case they expect delay in reaching the hospital. Ideally, the patient should be properly checked daily for the symptoms of VIC for a week.

2. Thorough examination of the POP splint or bandage to confirm that it is not causing any undue pressure.

3. Check the radial pulse bilaterally, if feasible, to compare and ensure that the radial pulse on the affected side is not weaker compared to its counterpart.

4. Check the nail bed circulation by applying pressure on the nail beds. The pressure causes whitening of the area pressed, but it returns to normal as soon as the pressure is released. It is an alarming sign if it remains white for a longer period indicating that the circulation is slow.

5. Check the motor power and sensory status of the fingers free from immobilization.

6. Check the distal free limb joints for the feeling of coldness in comparison to the normal contralateral area.

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Treatment (suspected cases): In case any of these signs appear, perform the following:

1. Immediate removal or discontinuation of pressure causing factors, e.g., splint, POP cast, bandage

2. Limb elevation and passive as well as active vigorous movements of segments distal and proximal to the affected area

3. Heat to be applied to the other limbs and the trunk to promote general vasodilation (Adams, 1981)

4. Contrast bath, steam packs, massage and stimulation to be used to augment local circulation and nerve excitation, provided the sensory status of the affected area is intact

Established cases: The prognosis depends upon the degree of permanent damage to the muscle and nerves.

The prognosis is poor if there is total loss of sensation, feeble motor function, stiffness in the joints and fibrosis of the muscles.

However, functionally useful status can be achieved through constant efforts by the patient and the team of specialized personnel.

The first objective of the management is to stretch the contracted and fibrosed soft tissues on the flexor aspect of the forearm, wrist and hand to the maximum possible extent. This is done by proper stabilization and carefully

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graded relaxed passive stretching.

It is equally important to retain the stretch and elongation of the soft tissues, achieved by relaxed passive stretching, by using a turnbuckle splint.

The therapeutic approach depends upon the type of VIC.

1. *Mild type:* There is ischaemia of the flexor digitorum profundus. It can be managed by exercises and dynamic splinting to maintain finger extension.

2. *Moderate type:* It involves superficial as well as deep finger flexors, and flexors of the wrist and thumb. If these muscles are still functional, the conservative approach of graded splinting and exercises are useful. Muscle lengthening operation may be necessary in nonresponding cases.

3. *Severe type:* Invariably needs surgery as the contractures are progressed beyond the scope of conservative management. However, preoperative passive relaxed stretching and dynamic splinting facilitate surgery. Serial splinting, as advocated by Sir Robert Jones in three positions or stages, is ideal:

Stage I: The maximum extension is achieved and held at the interphalangeal joints, wrist and MCP joints in full flexion and the fingers are separately splinted.

Stage II: Maintaining extension at the interphalangeal joints, gradual extension is achieved at the MCP joints by a splint extending to the wrist.

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Stage III: Maintaining extension at the interphalangeal and MCP joints, graduated extension is achieved at the wrist. Dynamic splint which provides graduated extension at the wrist joint (extending from finger tips to elbow) is incorporated with the previous two splints (Fig. 7-14).

The ultimate aim is to achieve maximum extension at the wrist, which is a functional requirement. This needs careful fabrication, fitting, use and maintenance of the splint, which is the responsibility of an orthotist and physiotherapist. The splint has joints at the wrist, MCP and interphalangeal joints that can be easily adjusted at desired angles. For increasing the extensibility of the contracted soft tissues on the flexor aspect, effective adjuncts like massage, ultrasonics and axial traction can be used, besides relaxed passive movements. If the swelling persists, strong voluntary movements with the limb in elevation should be given. As and when the condition improves, the exercise programme should be modified to achieve optimal function.

Surgical treatment: In severe cases, recovery of normal function is impossible. However, the following surgical procedures may be done in selected cases:

(i) *Shortening of forearm bones:* It is done to overcome contracture of the flexor group of muscles.

(ii) *Muscle sliding operation:* The contracted common flexor groups of muscles are detached from their origin and are allowed to slide distally. Also called Max Page operation, this allows correction of the flexion contractures at the

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wrist and finger joints.

(iii) *Excision of the dead muscles:* The necrotic muscle mass is excised and replaced by a healthy muscle obtained from the neighbourhood or from a distant site using microvascular techniques in the latter case.

(iv) *Nerve grafting:* If the median nerve is damaged beyond repair, nerve grafting may sometimes be helpful.

Physiotherapeutic management following surgery: In all the four surgical procedures, the objective of physiotherapy is the re-education of the muscle action. It depends upon the extent of paralysis.

The muscle power, the joint range and the sensory status are assessed preoperatively.

Postoperative management: The most important aspect is to provide a corrective splint, incorporated with immobilization. This is to maintain the corrected position of the contractures, and assists, in movements.

Measures like diapulse, hand elevation and active resistive movements of the related joints are carried out to reduce inflammation and pain.

During mobilization: The basic therapeutic principles are as follows:

1. Care of the anaesthetic areas

2. Re-education of the muscle action

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3. Sensory re-education

4. Improvement of the functional efficiency

5. Modifications in the splint to further improve the function

All these will proceed on the same lines as described for peripheral nerve injuries.

During immobilization (4–6 weeks): Routine physiotherapeutic measures are taken to reduce pain, inflammation and swelling.

During mobilization: Emphasis is placed on early mobilization of the elbow joint and strengthening of the elbow and forearm muscles.

Regime of physiotherapy is the same as described for the fractures in the region of the elbow joint.

B. ***Injury to the peripheral nerves***: Median and ulnar nerves may be involved. However, shortening and fibrosis of flexor muscles may lead to ineffectiveness of the muscles supplied by the radial nerve.

If the sensory status is not adversely affected, electrodiagnostic testing should be done to assess the degree of nerve damage. The critical interpretation of these diagnostic procedures forms the basis of treatment.

Principles of treatment

1. *Prevention of contractures*: It is achieved best by relaxed

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passive full-range movements which should be self-assisted and taught, to be practised slowly with proper proximal stabilization and low-intensity sustained stretching procedures.

Secondly, splints which can maintain constant small stretch should be fabricated. The patient should be taught how to apply and maintain them. Intermittent removal of the splints is necessary.

2. *Maintenance of circulation to the denervated muscles*: It is achieved by measures like limb elevation, crepe bandage and passive ROM. Thermotherapy and electrical stimulation can be given only if there is no sensory deficit.

3. *Strengthening of muscles and movements*: There is a close, interdependent relationship between the conducting power of peripheral nerves and the strength of voluntary contraction. Therefore, while planning an exercise programme, maximum importance needs to be given to this aspect. Meticulously planned and executed strengthening exercises balanced with stretching techniques form the most effective aspect of improvement.

4. *Concentration of functional movements*: Graduated resistive functional movements, as they are performed in daily routine, need to be stressed. They contribute significantly to improving the strength of activities and the conducting capacity of the peripheral nerve fibres. In the absence of true recovery, such attempted functional

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movements with correct splints promote the activity by compensatory mechanism. Therefore, care must be taken to encourage such movements only when further chances for nerve muscle recovery are extremely limited.

C. ***Malunion***: Malunion or union of a fracture in malposition may result in a deformity.

Following conservative management: The deformity is treated conservatively if it is not severe and not causing any pressure on vital structures like the peripheral nerve.

In this situation, the job of a physiotherapist is to improve the functional performance, strengthen the muscle power and educate for better performance of the whole extremity. Functional splint can be given to minimize the effects of deformity.

Following surgical management: The malunited supracondylar fracture of the humerus causes either cubitus varus or valgus deformity. The former is more common. This deformity is corrected surgically by performing corrective osteotomy. Postoperatively, the limb is immobilized in a POP slab with flexion at the elbow for a period of 4–6 weeks. The elbow is then mobilized.

D. ***Myositis ossificans***: This is the most common and yet the most difficult complication of injuries around the elbow joint (see Fig. 7-11).

Considering the degree of disability it causes, maximum efforts should be made towards its prevention.

Preventive measures

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1. A fracture should be fixed with proper alignment of the elbow joint.

2. Proper immobilization of the elbow joint following injury: Discourage early passive mobilization of the elbow, so that the haematoma around the joint is allowed to get absorbed rather than to dissipate into the surrounding muscles and get ossified.

3. Signs and symptoms like local oedema, tenderness, pain and decrease in mobility should be watched carefully. If any of these is present, rest with total immobilization is a must for 14–21 days.

4. Early vigorous movements, massage and passive movements should be strictly avoided. These are reported to be the causative factors of myositis ossificans.

In suspected cases: Rest with immobilization has to be continued further. Regular check-up of ROM and radiographs is done till the ossification progresses to the third and final stage of dense shrunken mass.

In confirmed cases: Once the progress is arrested, a vigorous exercise programme including graduated, sustained but gentle passive stretching can be started to regain maximum possible ROM.

The patient needs to be educated and guided on the process of these exercises to make the home treatment programme effective.

Vigorous active exercises by using aids like roller skates help

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in improving the mobility in the available ROM, which is required in the functions of daily routine.

Surgical treatment: Surgery is rarely indicated in myositis ossificans. Surgical excision of the myositis mass is undertaken only after the radiographic evidence of its consolidation. It may take 6–9 months for the myositis mass to consolidate. Since there is a high incidence of recurrence following surgery, the role of surgery is controversial. It is done only if the elbow is ankylosed in a functionally unacceptable position.

Postoperatively, the limb is immobilized in a plaster slab for a period of 1 week, following which movements are started.

Physiotherapeutic management: The basic objective of physiotherapy is to restore maximal ROM and strength at elbow.

During immobilization

1. To control pain and inflammation, diapulse can be effective

2. Resistive full ROM to shoulder and hand

3. Light isometrics to muscle groups around elbow

Mobilization (2–3 weeks)

Gradual mobilization should be started after removal of the slab.

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1. It should be started as an assisted active free movement by using roller skates, sling suspension or hydrotherapy.

2. Carefully monitored relaxed passive movements can be started avoiding passive stretch.

3. Accurate measurement of ROM should be done at regular intervals.

4. Gentle isometrics should be provided to the flexors as well as extensors.

5. Gravity-assisted elbow flexion and extension should be started on the knee ratchet maintaining low-intensity long gentle stretch for further increase in the ROM.

6. Free self-assisted forearm pronation and supination should be initiated by placing forearms on the thighs.

7. It is important to maintain the ROM of flexion by adjusting the angle of the sling.

8. Gentle stretching sessions may be preceded by superficial heating procedures like hydropacks.

After 3 weeks

If inflammation, swelling as well as pain have reduced, the methods of mobilization and stress are made progressive. The range of forearm rotation should be full by this time.

Vigorous active free movements are encouraged by using skates. They can be made resistive by putting weight (e.g.,

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sandbag) over the roller skates and performing them slowly.

By 6 weeks, a good functional range and strength should be regained.

But, on many occasions, a stiff or flail elbow may be encountered. The former may be considered for manipulation under general anaesthesia and intensive muscle strengthening procedures for the latter.

Sideswipe injury of the elbow

This injury results when, for example, the flexed elbow, sticking out of a car or bus window, is hit by another passing vehicle. It is often an open injury (Fig. 7-29) and consists of fractures of the lower end of the humerus, upper end of the ulna and the radius with anterior dislocation of the elbow (Fig. 7-30).

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FIG. 7-29 Radiograph showing various fractures around the elbow and clinical photograph showing the associated open injury.

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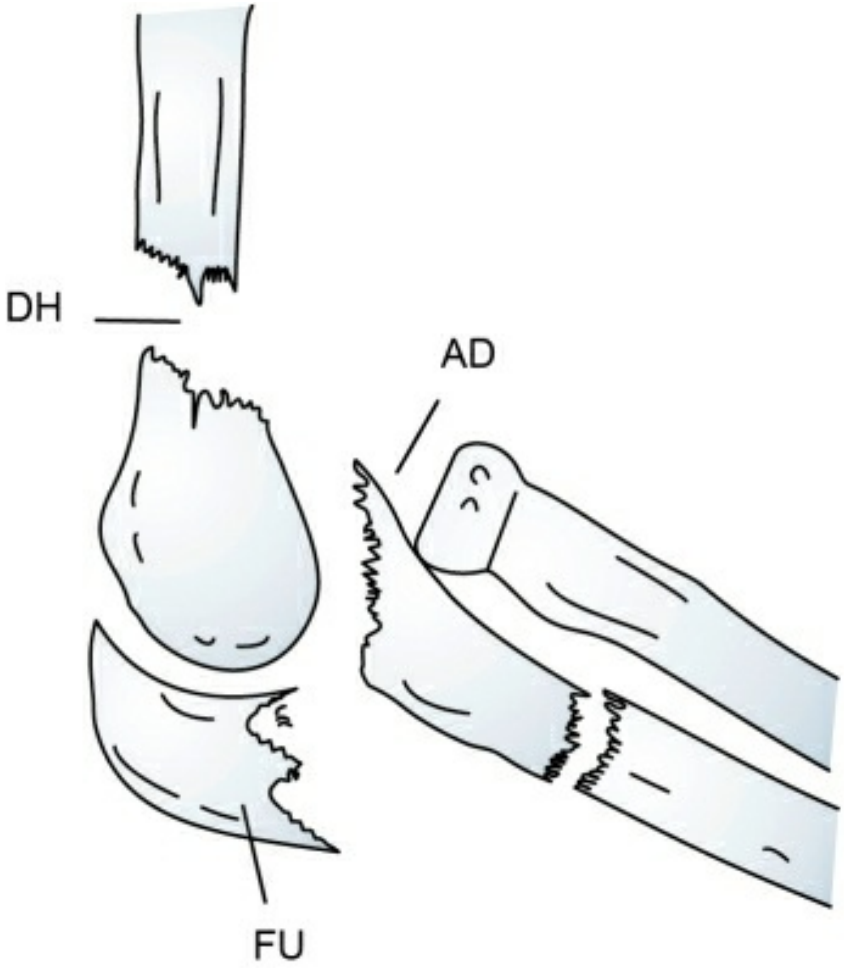

FIG. 7-30 Sideswipe injury to the elbow. DH: fracture of the distal end of the humerus, FU: fracture of the upper end of the ulna, AD: anterior dislocation of the elbow.

Treatment

It is a difficult injury to treat. The problems are too many: open wound, dislocation of elbow and multiple fractures (Fig. 7-31). Treatment of dislocation gets priority over the fractures. The trend is to immobilize the limb in an external fixator for a period of 6–8 weeks because of the open wounds.

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FIG. 7-31 Fractures of both bones of the forearm. AP and lateral radiographs showing transverse fracture of the radius and oblique fracture of the ulna.

However, occasionally the fractures in the humerus or ulna can be fixed internally by a plate or nail (Fig. 7-32).

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FIG. 7-32 Fractures of the humerus and ulna fixed internally by plates and screws; dislocation of the radial head reduced.

Results: The results are poor as stiffness invariably results.

Physiotherapeutic management

Basic objective: To regain maximum functional range of movements of elbow and hand.

As the extent of damage and the management of this injury is complex, the results are poor as regards ROM.

Physiotherapeutic treatment is the same as for posterior dislocation of the elbow. In spite of the poor prognosis, efforts should be made to regain the maximum possible range of movements.

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Encouragement is given to early functional use of the elbow and forearm rather than repeatedly attempting for the anatomically correct groove of movement.

If the affected limb is nondominant, return of rotation movements of the forearm gives the patient an acceptable functional range as the stability of the elbow is not a problem. Therefore, whenever it is not possible to regain the functional range of elbow flexion and extension, efforts are concentrated on improving the range of pronation and supination. Strengthening of the wrist and fingers, shoulder and forearm should be initiated from the initial phase of treatment to provide maximum compensation for the stiff elbow joint.

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CHAPTER 8

Injuries of the forearm

OUTLINE

- Fractures of the radius and ulna
- Isolated fractures of the radius and ulna
- Fracture and dislocation of the forearm

Fractures of the radius and ulna

Fractures of the shaft of both the forearm bones (radius and ulna) are seen at all ages. A direct injury results in a transverse (see Fig. 7-31) or a comminuted fracture which may be an open fracture. An indirect injury, e.g., fall on the outstretched hand, causes oblique or spiral fractures. Displacements of the bone fragments commonly occur due to the pull of supinator and pronator group of muscles (Fig. 8-1). In the forearm, there is a predominance of supinators (biceps and supinator) on the proximal fragment which produce an unopposed supination of the proximal radius fragment. Similarly, in the distal half of the forearm, there is dominance of pronators (pronator teres and pronator quadratus, which produce pronation of the distal radial fragment. Fractures in children are usually of a greenstick variety (Fig. 8-2).

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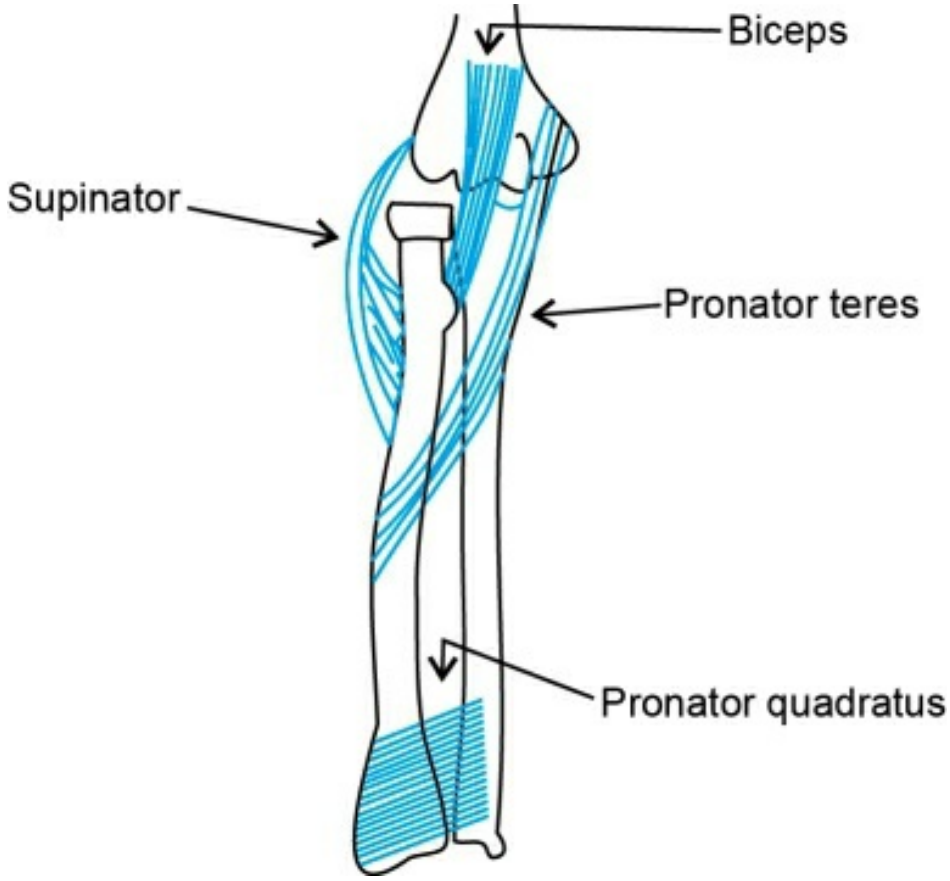

FIG. 8-1 Preponderance of supinators in the proximal part of the forearm, and pronators in the distal half.

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FIG. 8-2 Greenstick fracture of the lower end of radius.

Treatment

The treatment of these fractures can be conservative or operative.

1. ***Conservative treatment***

An undisplaced fracture does not need manipulation. For displaced fractures, closed manipulation under anaesthesia is carried out. In children, closed reduction alone is often

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successful. While in adults an attempt is always made to reduce the fracture by closed manipulation. If the fracture pattern is of an unstable variety or the reduction is unsatisfactory, open reduction becomes necessary.

After reduction, the limb is immobilized in an above-elbow plaster cast with the elbow in flexion. Some surgeons prefer to keep the forearm in supination for upper one-third fractures, in mid-prone position for mid one-third fractures and in full pronation for the lower third fractures. The rationale for these positions of immobilization is that there is preponderance of supinator muscles in the proximal third of the forearm while pronators are dominant in the distal third. Others prefer to immobilize in mid-prone position only to facilitate the functional performance in the event of stiffness. The plaster is maintained for 3–6 weeks in children and 8–10 weeks in adults.

2. ***Operative treatment***

It is indicated where closed manipulation has failed or a good initial reduction has been lost subsequently in the plaster. The bone fragments get displaced because the swelling subsides after some time and the plaster becomes loose.

Operative treatment is also carried out in fresh open fractures. Stabilization of these fractures by external fixators facilitates wound care.

The commonly used method of internal fixation is by plates

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and screws (Fig. 8-3A). Another method of internal fixation by intramedullary nails (Fig. 8-3B) is also employed occasionally.

After internal fixation, the limb is immobilized in an above-elbow plaster cast for a period of 4–6 weeks, with the elbow in flexion and forearm in mid-prone position.

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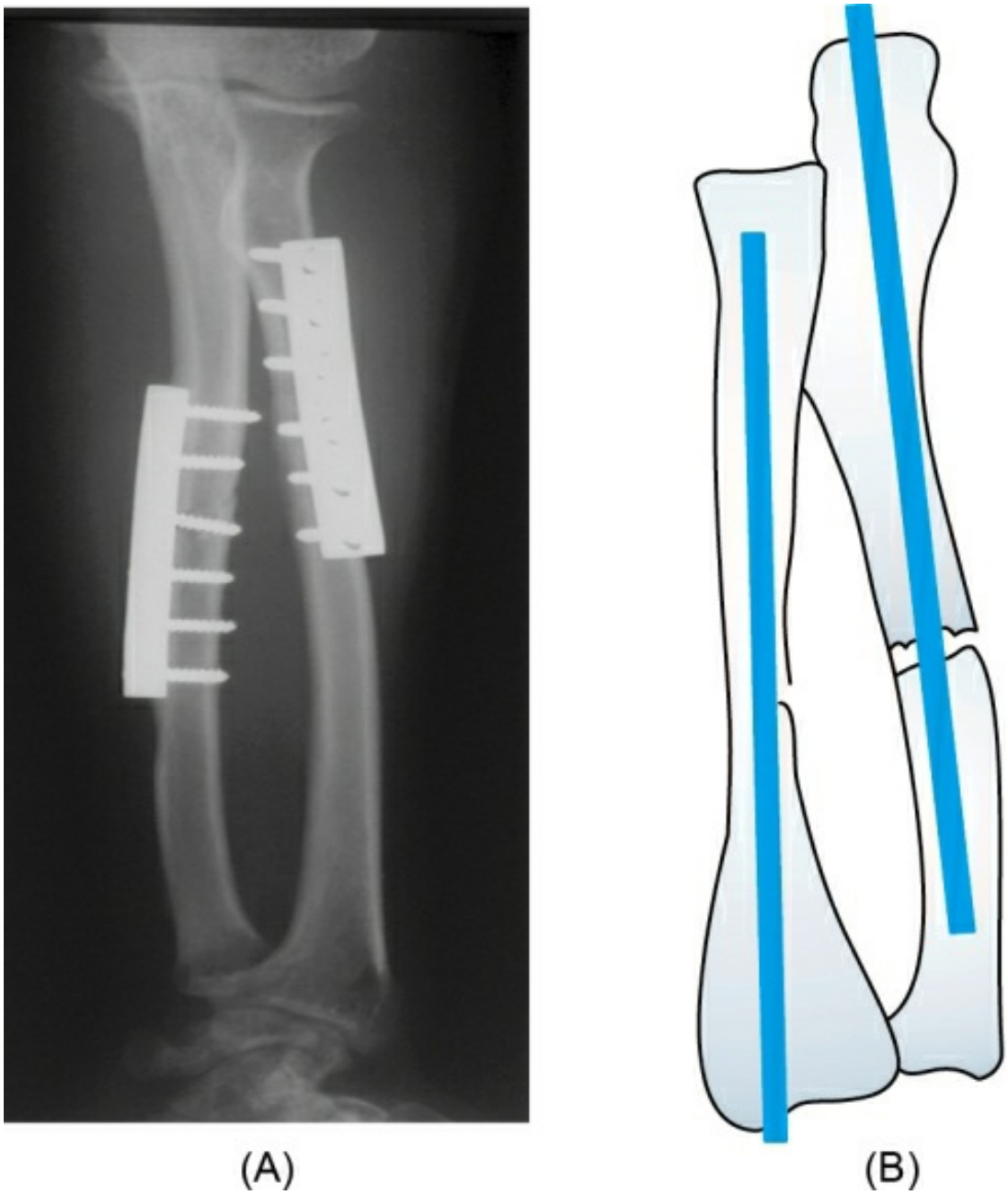

FIG. 8-3 Internal fixation by **(A)** plating, **(B)** intramedullary nailing.

Complications

1. *Nonunion:* When the fracture fails to unite, open reduction and internal fixation along with bone grafting are indicated. Postoperatively an above-elbow plaster cast is maintained for a period

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of 6–8 weeks.

2. *Malunion:* Angulatory deformity of the forearm results when the fracture unites in a malposition. It not only results in an ugly deformity but also leads to restriction of rotation of the forearm.

If the angulation/deformity is severe, surgical correction of the deformity with internal fixation and bone grafting is undertaken. The period of immobilization after surgery is 6–8 weeks.

3. Cross-union: When the fractures of radius and ulna are at the same level, the chances of cross-union due to fibrous or bony bridging (Fig. 8-4) are high. Cross-union causes restriction of pronation and supination of the forearm. In such fractures, the forearm is preferably immobilized in mid-prone position. Should cross-union occur, the forearm would still be in a functional position.

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FIG. 8-4 Cross-union between radius and ulna.

Physiotherapeutic management

Fractures treated by conservative approach

During immobilization (first 3–6 weeks in children and 8–10 weeks in adults): Initially, all the measures to control the process of inflammation are adopted.

As soon as the fracture is reduced and the patient is in a position to

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do exercises, active full range strong movements should be initiated to the muscles and joints which are not immobilized (e.g., shoulder, fingers and thumb). Shoulder movements should be emphasized to the full range, especially in adult patients to avoid secondary stiffness and pain and to improve circulation to the whole limb. At the outset, the physiotherapist must check that a full range of passive flexion at the metacarpophalangeal (MP) joints is possible and that the plaster is not hindering the terminal range of flexion at these joints. While encouraging and emphasizing the movements of digits to improve circulation and oedema, the movements should be fast, strong and forceful to dissipate the lymphatic fluid effectively (Basley, 1981). Somehow the tendency is to be gentle and to accept the patient's reluctance.

The patient should be taught to do isometrics for elbow flexors and extensors while the limb is in the cast.

Mobilization (after 3–6 weeks in children and 8–10 weeks in adults): Vigorous active relaxed movements of the elbow and wrist should be initiated. One has to be careful in initiating and emphasizing the movements of pronation and supination. It is carried out as relaxed free movements with the forearm fully supported over the thigh with the patient in sitting position (see Fig. 7-4). As the pain becomes less, self-assisted stretching by the contralateral hand should be started (Fig. 8-5).

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(B)

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(A)

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FIG. 8-5 Self-assisted passive stretching pronation and supination. **(A)** By using contralateral hand and **(B)** by wand.

The patient is made to sit on a stool with his back against a wall. The elbow is kept at 90 degrees with its posterior aspect touching the wall. The active relaxed stretching of pronation and supination are facilitated by holding a wand. Supination and pronation combined with relaxed active elbow flexion and extension, respectively, facilitate early return of these movements. We have found this method very effective.

Gradual progression may be made to full range resistive pronation and supination.

Children generally get full function within 8–10 weeks, while adults require 14–16 weeks and yet may not get full range of rotation. However, functionally adequate range is usually regained.

Fractures treated surgically: In fractures treated by external fixator or by internal fixation, the period of immobilization is usually short (4–6 weeks). Moreover, the stability of the fracture is assured. These two factors contribute towards an early mobilization and better recovery.

Vigorous exercise programme can be initiated after removal of the external fixator or plaster cast.

The physiotherapeutic treatment is the same as described for the fractures treated by conservative methods.

A near normal range of motion including strong rotation can be achieved by 8–12 weeks.

Complications: When surgery is performed for nonunion or malunion, the regime of postoperative physiotherapeutic management remains the same as described earlier.

Restricted movements: Passive stretching to regain maximum possible range of pronation and supination has to be initiated immediately after removal of the plaster.

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In case of *cross-union*, the movements of pronation and supination are invariably restricted. The patient has to be trained to perform the activities of daily living (ADLs) by adopting compensatory techniques, e.g., abduction of the shoulder joint to compensate for forearm pronation and shoulder adduction to compensate for forearm supination.

Isolated fractures of the radius and ulna

Isolated fracture of the radius in the lower fourth region commonly occurs in children due to a fall. It is a greenstick fracture which needs a below-elbow plaster cast for only 3 weeks. Results are good.

Isolated fracture of the ulnar shaft occurs in adults following a direct blow (Fig. 8-6). By natural reflex, it is the forearm (ulnar aspect) that is brought forward to protect the face from a blow or an injury. It is also called *nightstick fracture*.

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FIG. 8-6 Isolated fracture of the lower end of ulna.

Treatment

It is treated by an above-elbow plaster cast for about 6 weeks. Displaced fractures may need open reduction and internal fixation. Occasionally, nonunion may occur. However, overall results are excellent.

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Physiotherapeutic management

Fracture of radius in the lower fourth region: No specific techniques in physiotherapy are needed. The patient may be guided on simple techniques of mobilization of the elbow and forearm.

Isolated fracture of the shaft of ulna: The physiotherapeutic management remains the same as described for fractures of both bones of forearm. Regaining full range of pronation and supination does not pose any problems as radius is not affected.

Full range of motion (ROM) is regained within 8–12 weeks.

Fracture and dislocation of the forearm

There are two types of injuries where fracture of one forearm bone is associated with dislocation of the radio-ulnar joint. These injuries are as follows:

Monteggia fracture

In this injury, fracture of the upper half of the ulna is associated with anterior dislocation of the radial head (Fig. 8-7).

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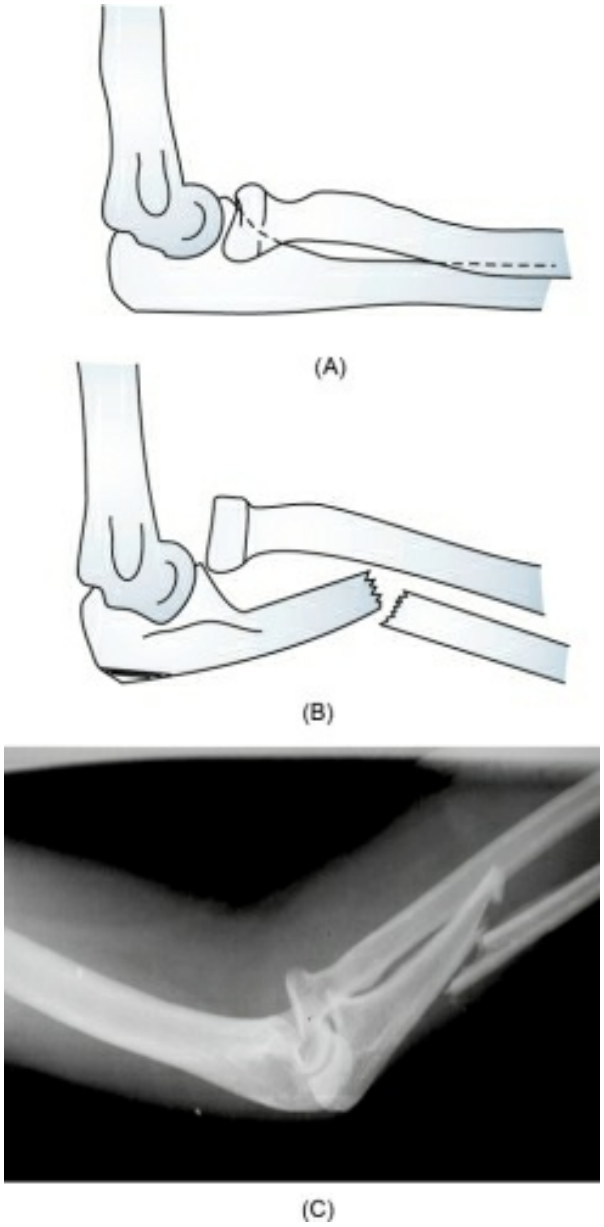

FIG. 8-7 Monteggia fracture. **(A)** Normal relationship of ulna and radius at the elbow, **(B)** fracture of the upper half of the ulna with dislocation of the head of radius and **(C)** as seen on a radiograph.

Treatment

In children, the fracture dislocation is reduced by closed manipulation. Immobilization is carried out in an above-elbow plaster cast with the elbow in flexion and the forearm in supination for a period of 4–6 weeks.

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In adults, in fresh cases, closed manipulation is often successful in reducing both the radial head dislocation as well as the fracture of ulna. The limb is immobilized in an above-elbow plaster of Paris (POP) cast for 4–6 weeks. Sometimes the fracture of ulna may be fixed internally by a plate which can reduce the period of immobilization to about 4 weeks. Late reported cases may need internal fixation of the ulna and excision of the head of radius. The results are not good in the latter.

Physiotherapeutic management

1. *Treated conservatively:* In children, the physiotherapeutic management does not pose any problems and full function is possible in 8–10 weeks with simple guidance on elbow and forearm movements.

In adults, initial measures are taken to control inflammation, pain and swelling. Strong and full range movements, especially to the metacarpophalangeal joints, need to be emphasized.

After removal of the plaster cast, a vigorous exercise programme for elbow flexion–extension and forearm pronation–supination has to be concentrated and progressed as outlined earlier for fractures of both bones. The only difference being the persistence of elbow stiffness for a long period due to anterior dislocation of the radial head.

2. *Treated surgically:* The physiotherapeutic management basically follows the same stages as outlined for conservatively treated Monteggia fractures.

If reduction of the head of radius is achieved and

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maintained, then the results are good and effectively functional range can be achieved by 8–12 weeks. However, in late reported cases, even after surgical procedures, the results are unpredicted as regards ROM.

Galeazzi fracture

Fracture of the lower third of the radial shaft is associated with dislocation of the inferior radio-ulnar joint (Fig. 8-8).

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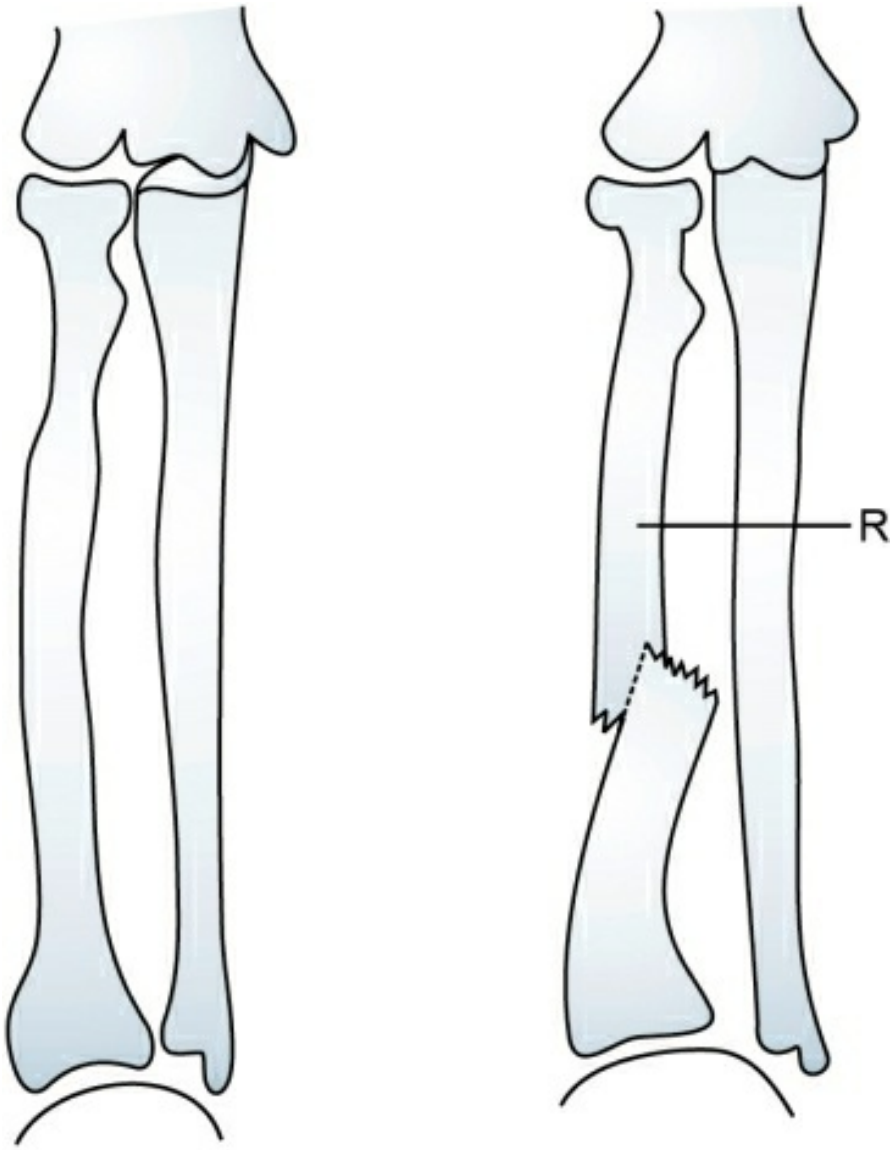

(A) (B)

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(D)

FIG. 8-8 Galeazzi fracture dislocations: **(A)** normal anatomy of radius, ulna and inferior radio-ulnar joint and **(B)** Galeazzi fracture dislocation. Note the fracture of the lower half of the radius (R) with dislocation of the inferior radio-ulnar joint. **(C)** Galeazzi fracture: fracture of the lower third of the radius with dislocation of the inferior radio-ulnar joint as seen on radiograph. **(D)** Fracture of the radius fixed internally by a plate. Note that the inferior radio-ulnar joint is also reduced.

Treatment

Closed reduction of the fracture rarely succeeds; even after a good

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reduction, the fragments get redisplaced after a week or two in the plaster. The treatment of choice, therefore, is ORIF of the fracture. Plate and screws are used for internal fixation of the fractures (Fig. 8-8D). Postoperatively an above-elbow plaster cast is given for 4–6 weeks.

Physiotherapeutic management

It proceeds almost on the same lines as described for Monteggia fracture.

It differs from Monteggia fracture in that the injury is away from the elbow joint and as such, return of the range of elbow joint movement is faster and better. But dislocation of the inferior radio-ulnar joint delays the return of pronation and supination of forearm. Therefore, these movements need special emphasis. Acceptable range of pronation and supination as well as wrist flexion–extension can be achieved by 8–12 weeks in almost all patients.

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CHAPTER 9

Injuries of the wrist

OUTLINE

- Colles' fracture
- Smith's fracture
- Barton's fracture
- Fracture of the distal radius: current status
- Fracture of the scaphoid
- Injuries of the lunate

Colles' fracture

Fracture of the lower end of radius within 1 inch of the distal articular surface of radius is called *Colles' fracture*. This fracture occurs at the cortico-cancellous junction of the bone and hence, it almost always unites. It is the commonest fracture seen in middle-aged and elderly patients, particularly women, following a fall on the outstretched hand with the wrist in extended position. Amongst the important displacements of this fracture, the distal fragment is displaced and tilted dorsally (Fig. 9-1) which gives the hand and wrist a typical deformity called 'dinner fork' deformity. The other displacements are proximal impaction, radial deviation and supination of the distal fragment.

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FIG. 9-1 Colles' fracture. **(A)** Extra-articular fracture with dorsal displacement and tilt of the distal fragment resulting in a deformity which resembles a **(B)** dinner fork. **(C)** Colles' fracture as seen on radiographs.

Treatment

Manipulation: Closed manipulation is performed under anaesthesia and the limb is immobilized in a below-elbow plaster cast for 4–6 weeks.

Displaced fractures can be treated by any of the following methods:

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1. *External fixator:* Stabilization of the fracture by an external fixator is indicated if the fracture is grossly comminuted (Fig. 9-2).

2. *Internal fixation:* In markedly displaced fractures, open reduction and internal fixation is done by a buttress plate (Fig. 9-3) or by special plates (Fig. 9-4).

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FIG. 9-2 External fixator for distal radius.

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FIG. 9-3 Fracture of the distal radius fixed by buttress plate.

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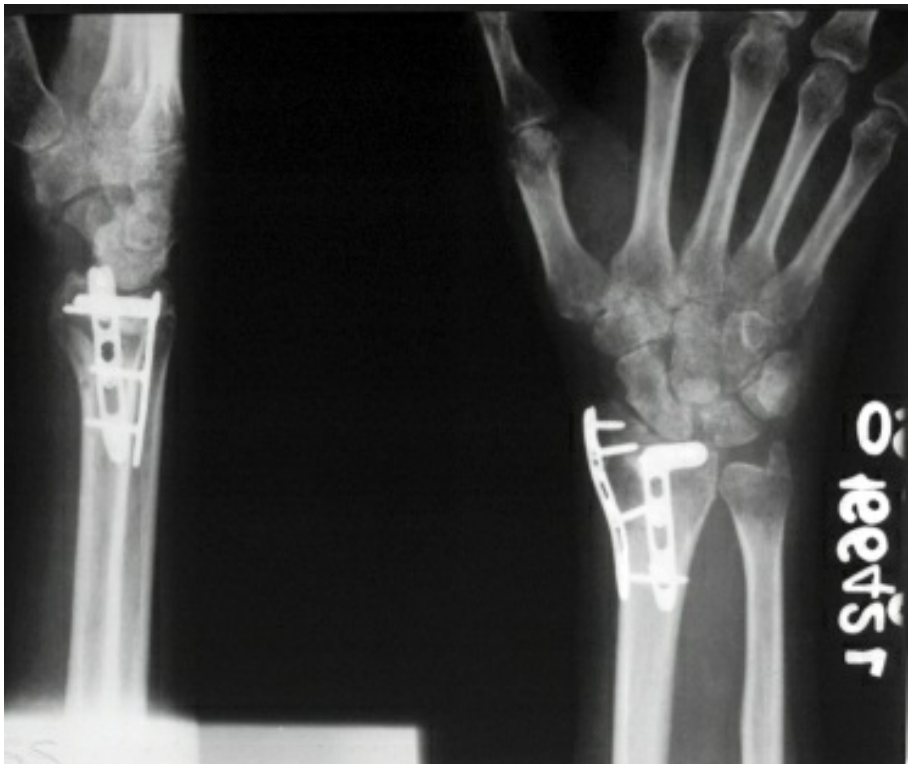

FIG. 9-4 Fracture distal radius fixed by special plates.

Complications

1. *Stiffness:* Stiffness of the fingers and shoulder are the most common avoidable complications of Colles' fracture. The patient should be encouraged to move the fingers, elbow and shoulder joints right from the second day of injury.

2. *Malunion:* It is quite common in the event of total neglect of the injury or by seeking the advice of quacks. It may also result if the reduction had been inadequate or had slipped inside the plaster. Severe comminution causes collapse of the multiple bony fragments leading to malunion. A malunited fracture leaves an unsightly deformity and there is restriction of palmar flexion, ulnar deviation and supination.

3. *Sudeck's osteodystrophy:* It is characterized by pain and stiffness in the wrist and fingers, red shiny skin and osteoporosis of the bones of

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the wrist and hand. The main problem is the stiffness of finger joints, pain and oedema of hand (Fig. 9-5). The treatment consists of maintaining finger joint mobility despite pain.

4. *Carpal tunnel compression:* The median nerve may get compressed in the carpal tunnel following a Colles' fracture. Though rare, early decompression of the carpal tunnel is indicated for better results.

5. *Rupture of the extensor pollicis longus tendon:* The tendon of the extensor pollicis longus may get ruptured in rare instances by attrition over the rough area at the site of fracture. The treatment is repair of the tendon or extensor indicis tendon transfer.

6. *Nonunion:* It is extremely rare but may require open reduction, internal fixation and bone grafting.

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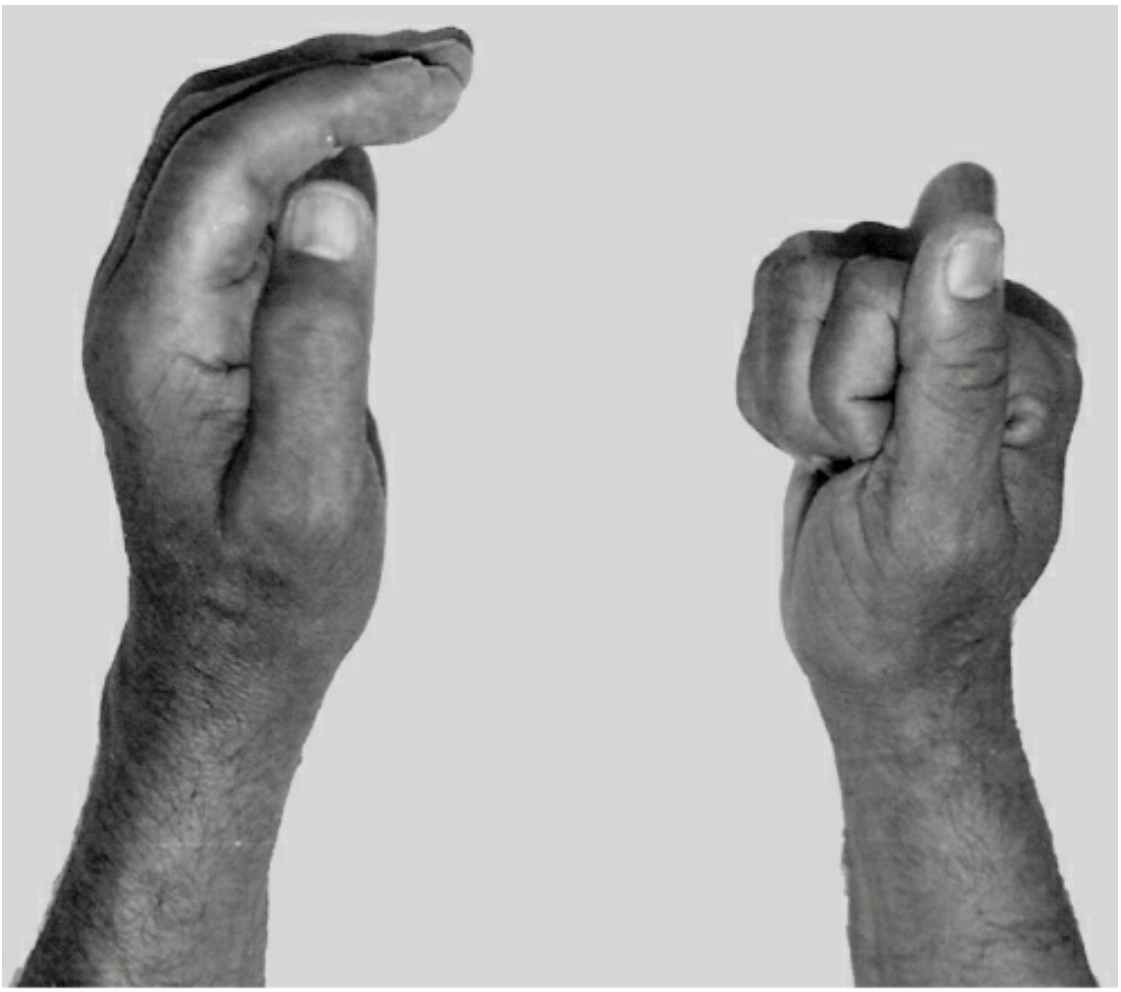

(C)

FIG. 9-5 Sudeck's osteodystrophy of the left hand: **(A)** Osteoporosis. **(B)** Shiny skin and swollen hand. **(C)** Stiffness of the finger joints.

Physiotherapeutic management

Giving due importance to the high incidence of the injury and also the complications, the management programme needs extra attention and proper guidance.

During immobilization: After reduction and immobilization, proper guidance is needed to reduce oedema by the following methods:

(a) Elevation of hand above the elbow, and elbow above the shoulder

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(Boyes, 1964).

(b) Alons in his monogram advocated the use of electrical stimulation on a sensory excitation level. He proposed that the electrical field created in the tissues may trigger the lymphatic system to absorb excessive fluid.

(c) Sorenson (1983) advocated the use of pulsed galvanic stimulation to reduce oedema. His technique was to place the negative pole over the oedema area and the positive pole at a proximal point, usually over median or ulnar nerve distribution on the upper arm, to stimulate good muscle pump action.

(d) Jobst (1983) devised an intermittent pressure glove to reduce swelling in the exposed fingers and thumb. The pressure should be at a point that is well tolerated and not more than 66–70 mm Hg. This is usually done for 45 min to 1 h.

(e) A technique involving string wrapping the individual finger as well as the exposed metacarpal volar pads also helps in reducing oedema. Objective circumferential measurements before and after treatment will determine the success of the technique.

(f) Checking the plaster cast to see that it is not hampering the full range of metacarpophalangeal joints of the fingers and thumb.

(g) Full range passive as well as strong forceful active movements of fingers effectively drain the excess lymphatic fluid from the digits in the hand (Basely, 1981).

(h) Full excursion of all the movements at elbow as well as shoulder.

(i) Intermittent use of sling with elbow in at least 70 degrees of flexion, as it maintains the elevated position of hand.

(j) Adjuncts like moist hot pack, infrared, warm soaks; cryotherapy with ice massage and TENS could also be used.

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All these procedures are helpful in improving circulation and decreasing pain and oedema. They also alter the elasticity of tissues and the viscosity of the synovial fluid. This further helps in preventing joint stiffness besides augmenting bone healing.

On removing the plaster (3–6 weeks): If earlier programme is carried out effectively, the only job that remains now is to concentrate on the wrist and forearm movements.

A soothing heat therapy using hydrocollator pack or paraffin wax bath induces relaxation, improves local circulation and puts wrist and forearm in an ideal situation for exercises.

Wrist mobilization is initiated with a small range of relaxed speedy flexion–extension with forearm in mid-prone position. The patient is taught to stabilize the forearm just above the wrist joint. This eliminates the force of gravity during flexion and extension at the wrist (Fig. 9-6).

FIG. 9-6 Relaxed free active wrist mobilization.

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As the wrist is immobilized in ulnar deviation, the movement of radial deviation needs to be emphasized in the initial stages.

To initiate pronation and supination, the exercise described on the lap is ideal.

If swelling and pain persist even after a session of exercise, use of an intermittent sling may be necessary. After 1 week of discontinuing the immobilization, the exercise regime should be made vigorous to regain further range of motion at the wrist and forearm. A variety of exercises using various aids like wand can be given. However, a simple but effective regime, which can be done without aids, is as follows:

1. *Exercises to improve flexion–extension at the wrist:* The patient, sitting with palm over the edge of table, stabilizes hand by putting palm of the other hand over it. The patient then gradually lowers the forearm downwards for wrist flexion or upwards to improve wrist extension. Initially, the relaxed speedy movements are done in a small range and then slow stretch is applied to improve the range further (Fig. 9-7).

2. Exercise to improve pronation and supination: Wand or the good hand can be used (as described for fracture of both bones of forearm).

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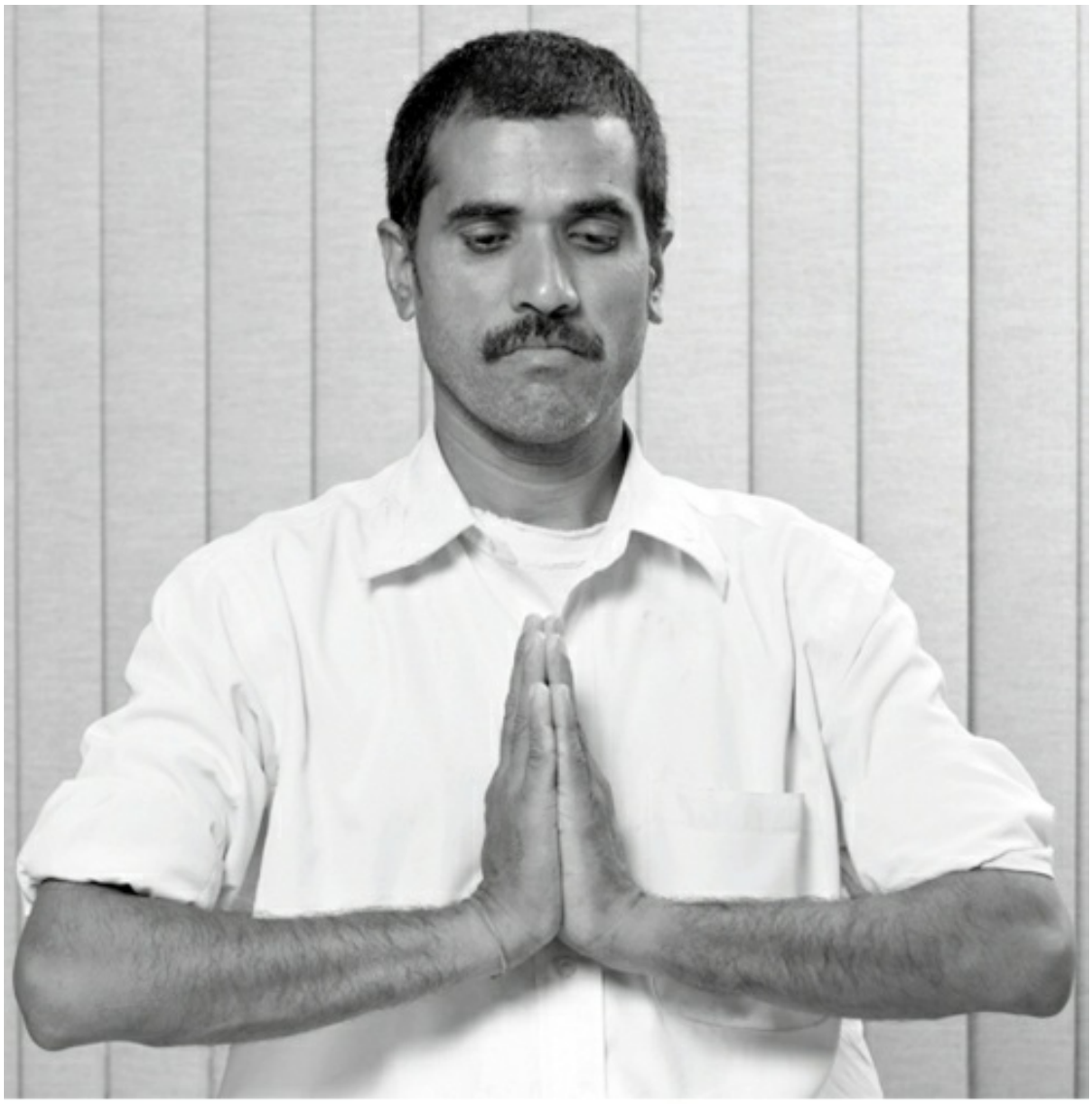

(C)

FIG. 9-7 (A) Self-assisted passive stretching with palm over the edge of a table. (B) and (C) Self-assisted wrist flexion and extension.

As the range improves, the movements can be made strong by teaching isometric as well as isotonic self-resistive exercises or using weights. Very often, passive range exceeds the active range of motion, where adhesions of the tendons or weakness of the muscles is predominant. The former needs measures like ultrasound, friction massage or dynamic stretching splints and the latter needs resistive exercises.

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Functional use of the whole upper extremity and especially the forearm, wrist and hand has to be encouraged and progressed right from the initial stage.

The results are good by 8–10 weeks. However, if palmar angulation of the articular surface is not achieved perfectly, there is a bony obstruction to the range of flexion. These patients have limitation of palmar flexion. Patients who are too sensitive to pain and do not allow the terminal stretching of rotation usually have lack of full range of pronation and supination.

In the majority of patients, adequate amount of motion and strength are possible (Riggs & Conney, 1982).

Management of complications

1. ***Stiffness of fingers and shoulder:*** This is an avoidable complication if the patient is referred for physiotherapeutic guidance on the second or third day after plaster application. The best way is to demonstrate to the patient full range movements on the normal side. The patient should then be made to practise them on the fractured side under supervision of the attending physiotherapist.

2. ***Malunion:*** As the union has already taken place, the physiotherapist can attempt to seek further improvement of the range of motion by using the technique of relaxed sustained stretch. If it fails, compensatory tricky movements by manoeuvring shoulder movement of abduction and adduction to facilitate apparent pronation and supination, respectively, remain the only alternative.

3. ***Sudeck's osteodystrophy:*** When present, physiotherapy is directed to relieve pain, oedema and to check further development of stiffness at the wrist, fingers and thumb. Proper positioning of the limb with frequent elevation and a modality like ultrasound or TENS can be used as an adjunct to reduce oedema and pain. However, major emphasis has to be on the range of motion by active exercises. Maximum possible use of these joints should be promoted by encouraging functional movements of daily routine.

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As the process of recovery is extremely slow in the majority of patients, proper education on the home treatment programme is important. The development of flexion deformities of fingers should be checked by teaching self-stretching exercises. This is done by teaching the patient to keep the hand on the table with the palmar surface in contact with the top of the table. Then the patient gradually puts the normal hand over the dorsum of the affected hand and exerts gradual pressure. This can be made effective by putting a small sandbag to maintain sustained stretch or by using a splint.

Residual flexion deformity of the metacarpophalangeal and interphalangeal joints of fingers may persist even after prolonged physiotherapy. The functional status of the hand can be greatly facilitated by early control of pain and use of the hand in day-to-day activities.

In some patients, the full functional recovery of hand may take up to 3 years.

4. ***Carpal tunnel syndrome:*** see Chapter 27

5. ***Rupture of the extensor pollicis longus tendon***

Early detection of this complication and surgical repair are essential for obtaining good results.

After surgical repair of the tendon, measures for control of pain and swelling are instituted. The emphasis should be on (i) mobilization of the interphalangeal (IP) joint of thumb and (ii) re-education of the repaired tendon to effectively flex and extend the thumb at the

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interphalangeal joint. Graduated self-resistive exercise with proper stabilization of the thumb proximal to the IP joint further improves range of motion (ROM) and strength at the interphalangeal joint.

Smith's fracture

It is a reverse Colles' fracture where the distal fragment is displaced volarwards (Fig. 9-8).

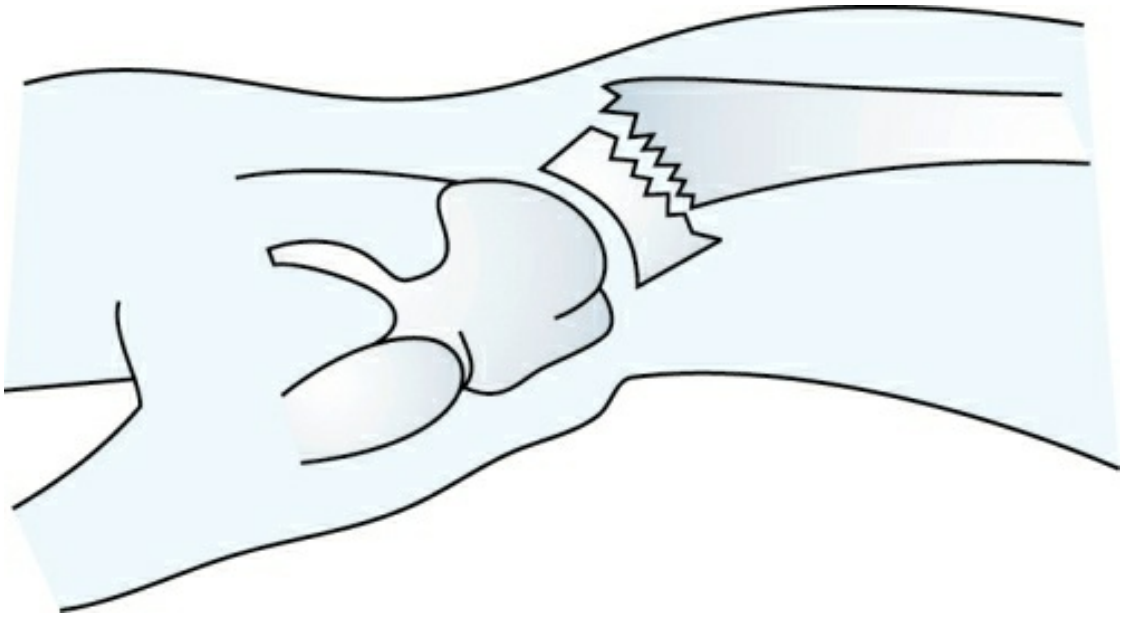

FIG. 9-8 Smith's fracture – the distal fragment is displaced volarwards.

Treatment

Closed manipulation is performed under anaesthesia followed by an above-elbow plaster cast for 4–6 weeks with elbow in flexion and forearm in full supination. Open reduction and internal fixation by buttress plate and screws may be necessary if closed reduction fails.

Barton's fracture

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It is an intra-articular fracture of the lower end of radius. The fracture line is placed obliquely, separating either a large volar fragment (volar Barton fracture) or a dorsal fragment (dorsal Barton fracture – Fig. 9-9).

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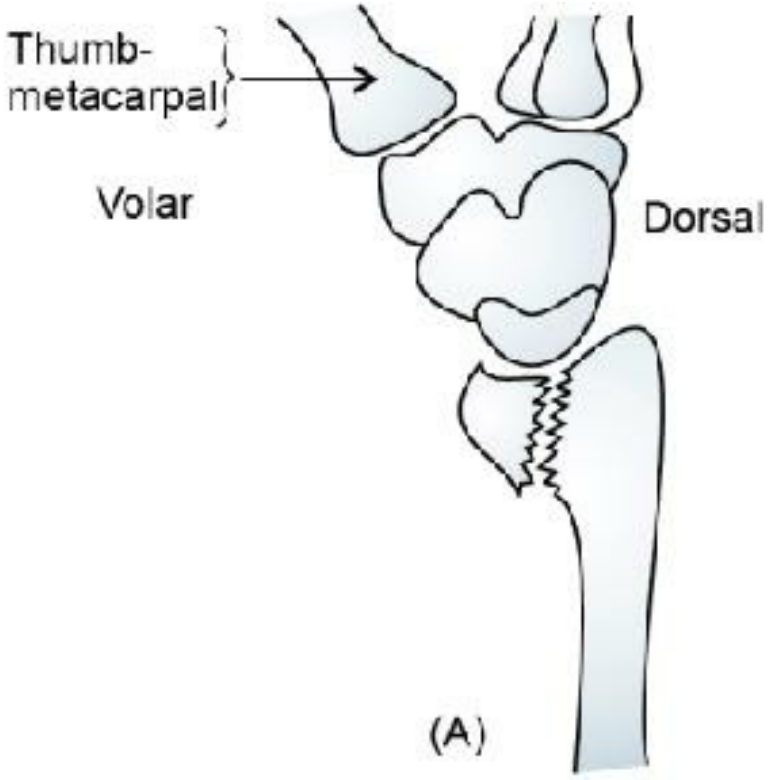

(A)

(B)

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FIG. 9-9 Volar Barton's fracture: **(A)** there is a fracture of the volar cortex of the radius. The dorsal cortex is intact. **(B)** As seen on a radiograph.

Treatment

1. Closed manipulation is done under anaesthesia, followed by an above-elbow plaster cast for 4–6 weeks.

2. Open reduction and internal fixation (Fig. 9-10) is indicated if closed reduction fails or if the reduction is lost in plaster as it is prone to redisplacement.

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FIG. 9-10 Volar Barton's fracture treated by internal fixation.

Physiotherapeutic management

Physiotherapy for the Smith's and the Barton's fractures on the whole follows the same pattern as described for the Colles' fracture.

Fracture of the distal radius: Current status

The pattern of fractures of the lower end of radius (also called distal

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radius) has changed considerably over the years from a relatively simple Colles' fracture to a much complex, often comminuted fracture. The fractures seen these days are high energy injuries which occur as a result of motorcycle accidents and sports injuries. The newer classification of the fractures of distal radius broadly divides them into the following three basic types:

1. Extra-articular fractures

2. Partially articular fractures

3. Combined extra- and intra-articular fractures.

Treatment

The following treatment modalities are used:

- Plaster of Paris (POP) cast
- Percutaneous pin fixation (Fig. 9-11)
- A combination of pin fixation and POP cast (Fig. 9-12)
- External fixator: The external fixators are of two types – bridging and nonbridging (Figs 9-13 and 9-14).
- **Bridging external fixator**: It is the commonly employed method. In this method, the proximal pins of the fixator are put into the radius, proximal to the fracture, while the distal pins are fixed in the second metacarpal bone. The fixator thus spans across the fracture site.
- **Nonbridging external fixator**: In this method, the placement of the proximal pins is the same but the distal pins are passed into the distal fragment, thus sparing the wrist joint.

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■ Internal fixation with special plates (see Fig. 9-4)

FIG. 9-11 Percutaneous pin fixation.

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FIG. 9-12 Pre- and postoperative X-rays of fracture of distal radius treated by **(A)** pin and plaster and **(B)** K-wires – a cost-effective and easy option.

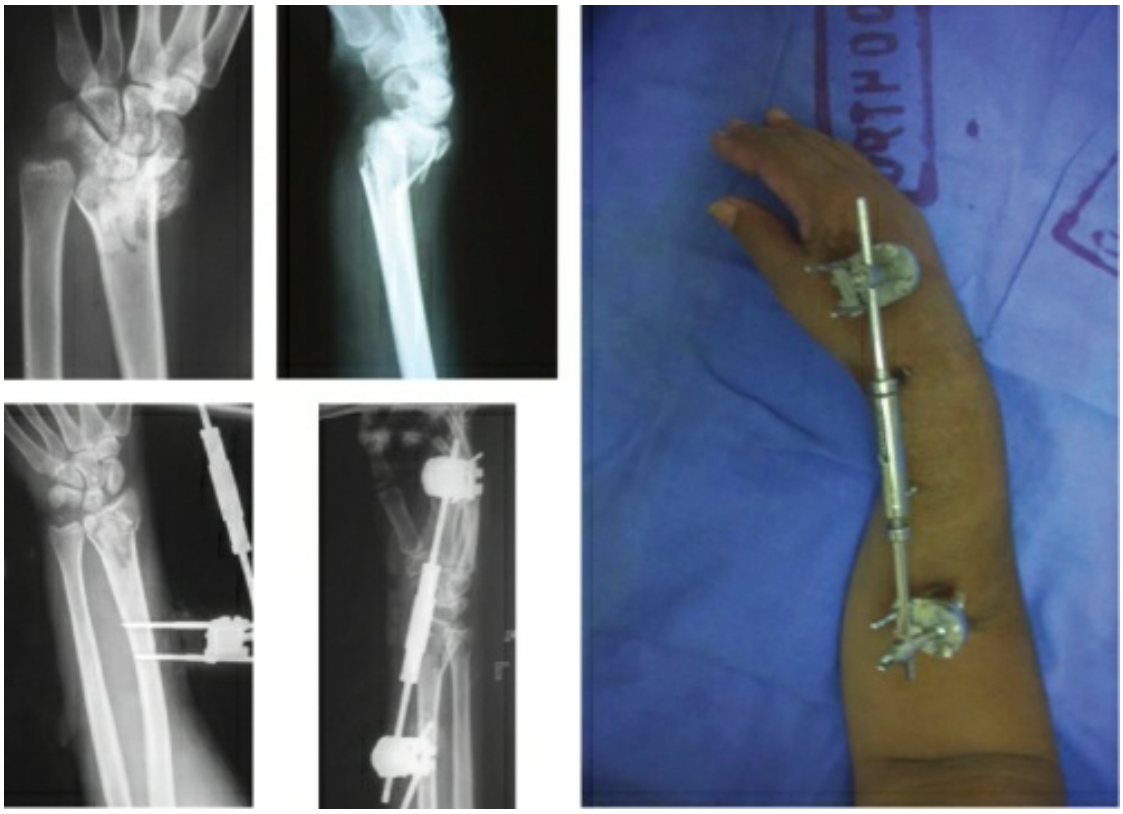

FIG. 9-13 Bridging external fixator in the treatment of fracture of the distal radius.

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FIG. 9-14 Fracture of the distal radius treated by nonbridging external fixator. Note that the distal pins are in the distal fragment keeping the wrist joint free.

Fracture of the scaphoid

Fracture of the scaphoid is the commonest amongst all the carpal bones. It is seen in adults following a fall on the outstretched hand. The bone may be fractured at any of the three anatomical sites (Fig. 9-15A) – the distal pole (the tubercle), the middle (the waist) or the proximal pole. Fracture through the waist is the commonest of the three. Union is generally not a problem in fractures of the distal pole. However, the blood supply to the proximal fragment may be cut off in fractures of the waist and the proximal pole as the vessels run in the bone from the distal to the proximal end. Nonunion of the fracture and avascular necrosis of the proximal fragment, therefore, may result in fractures through the waist or proximal pole of the scaphoid.

FIG. 9-15 Fracture of scaphoid. **(A)** Common sites of fracture. T, tubercle;

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W, waist; PP, proximal pole; VF, vascular foramina. **(B)** Immobilization by a scaphoid POP cast gripping the first metacarpal and the proximal segment of thumb. **(C)** Fracture of the scaphoid as seen on radiograph. **(D)** Fracture united after internal fixation by a screw.

Treatment

1. *POP Cast*: Undisplaced or minimally displaced fractures are treated by POP scaphoid cast. A scaphoid plaster cast is applied with the wrist in slight dorsiflexion and radial deviation. The thumb is held away from the palm in 'glass holding' position. The thumb is incorporated in plaster up to the base of the nail while the finger knuckles are kept free (Fig. 9-15B).

In fractures of the distal pole, the plaster is maintained for a period of 3 weeks whereas for fractures of the waist and proximal pole, the limb is immobilized for a period of 8–12 weeks.

2. *Internal fixation:*

(a) Minimally invasive surgery: Minimally displaced or undisplaced fracture of the scaphoid through its waist or proximal pole can be fixed internally with a cannulated screw percutaneously by a minimally invasive surgical technique.

(b) Open reduction and internal fixation: Displaced fractures of the middle third or proximal pole of scaphoid need open reduction and internal fixation using Kirschner (K-) wires or cannulated screws (Fig. 9-15D).

Complications

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1. *Nonunion*: In fractures of the scaphoid, the incidence of nonunion is rather high. It is treated using ORIF by a K-wire or a screw and bone grafting.

2. *Avascular necrosis*: In fractures of the waist and proximal pole of the scaphoid, the blood supply to the proximal fragment may be cut off resulting in avascular necrosis of the proximal fragment. In such a case, excision of the proximal fragment and radial styloid gives good results. The wrist is immobilized for a week after surgery.

3. *Osteoarthritis of the wrist*: Osteoarthritis of the wrist may develop in later years following avascular necrosis and/or nonunion of the fracture scaphoid (Fig. 9-16).

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FIG. 9-16 Osteoarthritis of the wrist.

One of the following surgical procedures may be done to relieve pain:

1. *Excision* of the proximal fragment and radial styloid.

2. *Wrist arthrodesis*: The limb is immobilized in a below-elbow plaster cast for 3 months with the wrist in slight dorsiflexion and the knuckles free.

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Physiotherapeutic management

During the initial period of immobilization, vigorous movements of the shoulder, elbow, forearm, metacarpophalangeal and interphalangeal joints should be encouraged and checked.

Resistive movements to the fingers and elbow are necessary to augment the circulation at the fracture site.

After removal of the plaster: Fractures of the distal pole of the scaphoid are easy to treat and do not need specific physiotherapy as the period of immobilization is only 3 weeks.

Fractures at the waist and proximal pole require longer immobilization. These fractures are difficult to unite in spite of the longer period of immobilization, due to jeopardy in the blood supply.

Heavy resistive exercises to the free joints are, therefore, especially important in these fractures.

Immediately after removal of the cast, reduction of pain assumes priority and modalities like ultrasound, TENS and hot pack may be employed.

Active mobilization of the thumb should be started immediately. Power grasp should be avoided as it may put extra stress and increase pain.

Relaxed passive mobilization is initiated and resistance is to be added as early as permissible since stiffness may set in due to the long period of immobilization.

Protective splint to immobilize the thumb may be necessary if the wrist remains weak (Basley, 1981). Within 1–5 weeks following removal of the cast, full and strong movements should return to the wrist (Taleisnic, 1982).

Carefully controlled physiotherapy may succeed in achieving good and strong hand function. In that case, surgical intervention may not be necessary even in the presence of nonunion, avascular necrosis or osteoarthritis of the wrist.

Noninvasive pulse electromagnetic field (PEMF) can be used effectively to deal with nonunion or delayed union. It modifies cell behaviour by inducing weak electrical currents. It vascularises and calcifies the fibrocartilage which is replaced with bone. It has been

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found to be highly successful in 84% cases of nonunion (Bassett et al., 1982).

When excision of the proximal fragment and radial styloid is performed, acceptable functional results can be achieved with routine physiotherapy in 6 weeks.

In the event of wrist arthrodesis, besides other physiotherapeutic procedures, special attention is necessary to re-educate and guide the patient about the use of hand with ankylosed wrist joint. ADL training assumes an important role in the management.

Injuries of the lunate

Fracture of the lunate is often missed on radiographs, if not looked for carefully.

The lunate may be fractured through its body, following a fall on the extended hand. Occasionally, there may be dislocation of the lunate from its bed resulting in a rather complicated injury (Fig. 9-17). Dislocation of the lunate is caused by forceful hyperextension of the lunate.

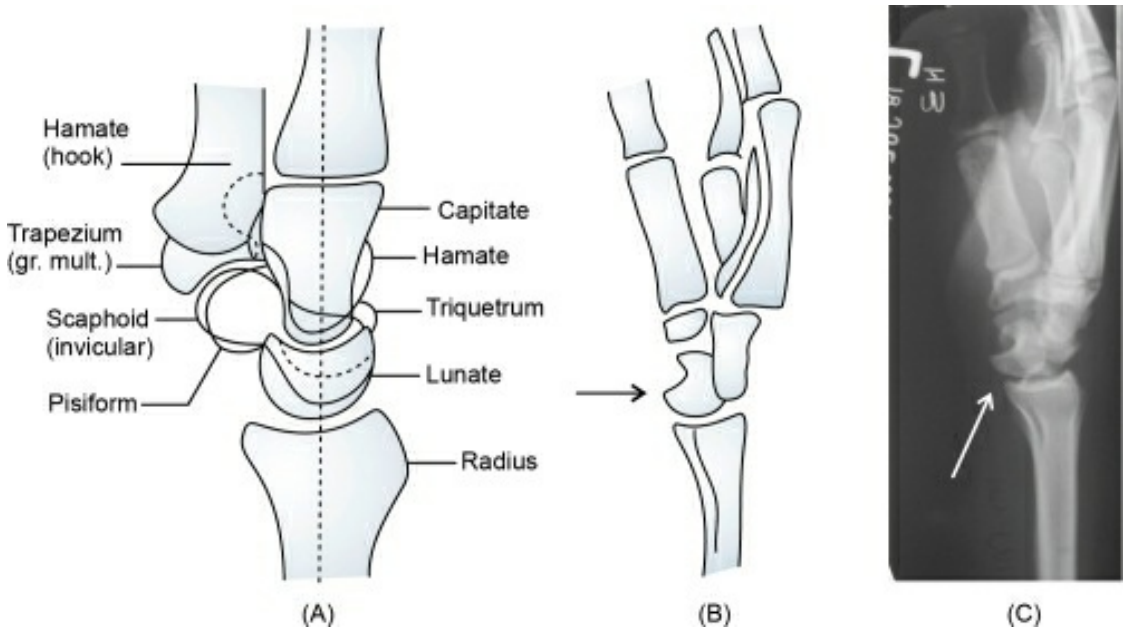

FIG. 9-17 Dislocation of lunate. **(A)** Diagrammatic representation of the

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normal disposition of the carpal bones as seen on a lateral view. **(B)** Line diagram showing dislocation of lunate (arrow). **(C)** As seen on radiograph.

Treatment

Conservative treatment

The fracture of lunate is treated by immobilization in a below-elbow plaster cast for about 3 weeks.

Dislocation of lunate needs reduction under anaesthesia, followed by immobilization in a below-elbow plaster cast for about 3–4 weeks.

Surgical treatment

Late cases may require open reduction of the lunate bone. However, fusion (arthrodesis) of the wrist is indicated in cases having severe osteoarthritis and instability of the wrist.

Complications

Avascular necrosis of the lunate (Kienbock disease): Blood supply to the lunate may occasionally be cut off following an injury (fracture or dislocation) resulting in Kienbock disease which is characterized by sclerosis and collapse of the lunate (Fig. 9-18).

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FIG. 9-18 Kienbock disease: Avascular necrosis of the lunate.

The patient complains of pain in wrist and instability with weakness of grip strength. Osteoarthritis of wrist may set in after a few years.

Physiotherapeutic management

1. **In conservatively managed patients:**

During immobilization (3–4 weeks): The period of immobilization is longer. Therefore, all the precautions should be taken to maintain the strength and regain full ROM of the uninvolved joints of the fractured limb.

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Special efforts to guide positioning of the limb and supervised vigorous and slow stretched finger movements should be carried out as often as possible.

Strong repetitive isometrics to both the flexor as well extensor groups under immobilization at the wrist should be taught and checked.

Paraesthesia in the distribution of median nerve due to compression or injury to the median nerve may be encountered occasionally and should be checked repeatedly.

Mobilization (after 4 weeks): As there is every possibility of articular and ligamentous damage, there is significant limitation and pain at the wrist joint. Reduction of pain and relaxation of the stiff wrist joint needs early attention. Modalities like partial weight bearing (PWB) and hot pack (HP) may be used before initiating mobilization.

Mobilization following relaxation should be started in the gravity eliminated position as described for the Colles' fracture.

Progressive resistive exercises should be started using low weight dumbbells.

The patient's forearm is placed on a table in a position of supination or pronation with the wrist and hand hanging over the table. He holds a dumbbell in his hand while the physiotherapist stabilizes the forearm just proximal to the wrist joint. The weight of the dumbbell and the force of

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gravity will offer stretch to the wrist joint to improve mobility, whereas active movement with the dumbbell against gravity will provide strengthening.

Hand functional activities emphasizing wrist extension movements play an important role along with strong gripping finger actions.

Generally acceptable results can be achieved within 8 weeks. However, return to heavy labour may take 6 months or even longer (Green, 1982).

2. **In surgically managed patients:**

The line of treatment remains the same as described previously, only deep heating modality like ultrasound or friction massage for the surgical scar may be necessary to control pain and adhesions. The PEMF can be used to a great advantage.

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CHAPTER
10

Injuries of the hand

OUTLINE

- Fracture of metacarpals (closed injuries)
- Bennett's fracture dislocation
- Fracture of the phalanges
- Mallet finger

Fracture of metacarpals (closed injuries)

Fractures of the metacarpals are caused by direct injuries to the hand or due to the fall of a heavy object on the hand. A fracture in the metacarpal can occur through its neck, shaft or base (Fig. 10-1). Fractures of multiple metacarpals and open fractures (due to machine injuries) are common (Fig. 10-2). Fractures of the neck usually occur in the 5th metacarpal. Fracture through the shaft occurs in any metacarpal and can be transverse or oblique, whereas fractures at the base commonly involve the first metacarpal or thumb.

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FIG. 10-1 Sites of fracture in the metacarpal: through neck, shaft and base.

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FIG. 10-2 Open fractures of the metacarpals.

Treatment

Conservative treatment is the treatment of choice for undisplaced or minimally displaced fractures. A below-elbow plaster of Paris (POP) slab is given for 3 weeks after which the hand is mobilized. Fracture through the neck of the metacarpal with volar angulation (Fig. 10-3) needs reduction and immobilization in flexion.

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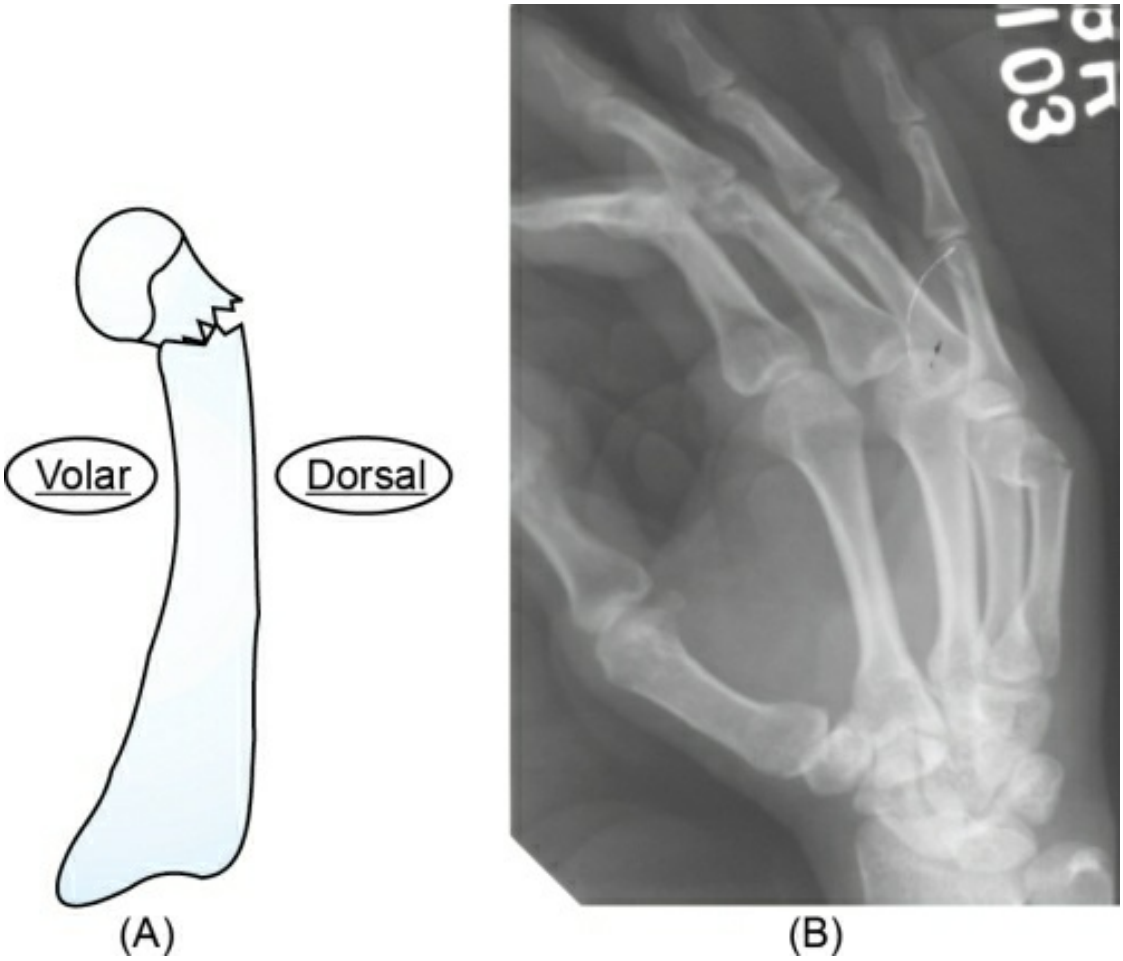

FIG. 10-3 **(A)** Fracture through the neck of the metacarpal is usually angulated. **(B)** Fracture of the neck of the 5th metacarpal seen on radiograph.

Displaced fractures are treated by internal fixation using Kirschner wires or occasionally by plating (Fig. 10-4 A and B). Postoperatively a below-elbow POP slab is maintained for about 10 days before mobilization is begun. Comminuted or open fractures can also be treated by external fixator (Fig. 10-5). Oblique fractures of the shaft of the metacarpal are unstable injuries and cause overriding of the bone leading to shortening of the metacarpal. Shortening, in turn, will cause change in the level of the knuckles resulting in limitation of flexion at the metacarpophalangeal (MP) joint. The patient will not be able to make a full fist. These fractures, therefore, can be treated by transfixing the other metacarpals by K-wire, maintaining the length of the metacarpal (Fig. 10-6).

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(A)

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(B)

FIG. 10-4 Fracture of the shaft of the 5th metacarpal. **(A)** Preoperative and **(B)** postoperative radiographs of the fracture treated by plating.

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(A)

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(B)

FIG. 10-5 **(A)** Fracture of the 5th metacarpal treated by external fixator and **(B)** clinical photograph of the same patient.

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FIG. 10-6 **(A)** Displaced fracture of the 4th metacarpal. **(B)** Treated by transfixation with the other metacarpals by K-wire.

Physiotherapeutic management

The basic objective is to provide functional painless ROM of the fingers.

During immobilization (2–3 weeks)

1. It is important to control oedema of the hand to prevent extensor tendon adhesions and future deformity. Compression dressing, elevation, pulsed galvanic stimulation, massage (milking massage), electrical

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stimulation on a sensory excitation level and nylon and string wrapping are some of the effective measures.

2. Check the position of the fractured finger frequently for any rotational or angulation deformity, especially in cases of 4th or 5th metacarpal fractures. Protective splint is applied to avoid retraction of the collateral ligaments, which may cause extension contracture.

3. Circulation is to be augmented by vigorous active movements of the adjacent free joints.

4. Relaxed passive movement should be initiated in small range in the proper groove of movements, with the line of pull perpendicular to the joint surface. Intrinsic contracture is to be prevented by early maximum passive flexion of PIP and DIP joints while maintaining the MCP joints in neutral.

5. TENS, phonophoresis, ultrasound or diapulse can be used to reduce pain.

Mobilization (3 weeks onwards): This is an important phase of initiating tendon glide. Active mobilization to glide the tendons of flexor digitorum sublimis and profundus, extensor digitorum communis, extensor indicis propreus and extensor digiti quintii are carried out meticulously:

1. Properly executed active movements are important to prevent adhesions between bone and tendon (osteotenodesis), between tendon and tendon (tenodesis) or tendon and skin (dermotenodesis). Active movements improve circulation, decrease residual oedema and also

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exert compression at the fracture site, thereby prompting early healing. To achieve full range of tendon glide as well as selective tendon gliding, exercises should be performed in the following three different fists (Webbe, 1987):

(a) *Claw fist:* Flexion of the PIP and DIP joints maintaining MCP in neutral extension. This exercise produces maximum gliding of FDP tendons. The palmar aspect of the finger and the tips should contact the palm. It should be held in this position as much as possible to facilitate maximum gliding and further ROM.

(b) *Sublimis fist:* In this fist, the MCP and the PIP joints are flexed and the DIP joints are maintained in extension (maximum gliding occurs at FDS and FDP tendons – Fig. 10-7).

(c) *Full fist:* Simultaneous full flexion of the MCP, DIP and PIP joints.

Correct stabilization and assisted guidance are necessary to achieve effective gliding.

2. Passive ROM exercises done to maximize the range of motion can also improve the active range of motion as well as the healing of the articular cartilage.

3. *Splint*: The initial static splint should have 50–70 degrees of flexion at the MCP joint with full extension at the IP joints. At this stage, this should be changed to a dynamic splint with a low load sustained stretching device.

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4. Resistive exercises are important as they provide strength to the hand function. Resistive movements in a small range can be started by 4 weeks. They are delayed only in fractures treated by percutaneous pinning or in avulsion and spiral fractures.

The graduated compressive forces due to these exercises lead to early fracture healing and correct scar remodelling.

5. Proper measures to maximize ideal collagen synthesis during the period of scar remodelling need to be observed to avoid adhesions and deformities.

6. Functional activities may be included at the earliest but without subjecting the fracture site to strenuous activities.

The hand should regain full functional status by 8–12 weeks.

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FIG. 10-7 Simultaneous flexion of the MCP, PIP and DIP joints.

Bennett's fracture dislocation

It is an intra-articular fracture of the base of the first metacarpal or thumb (Fig. 10-8A).

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(A)

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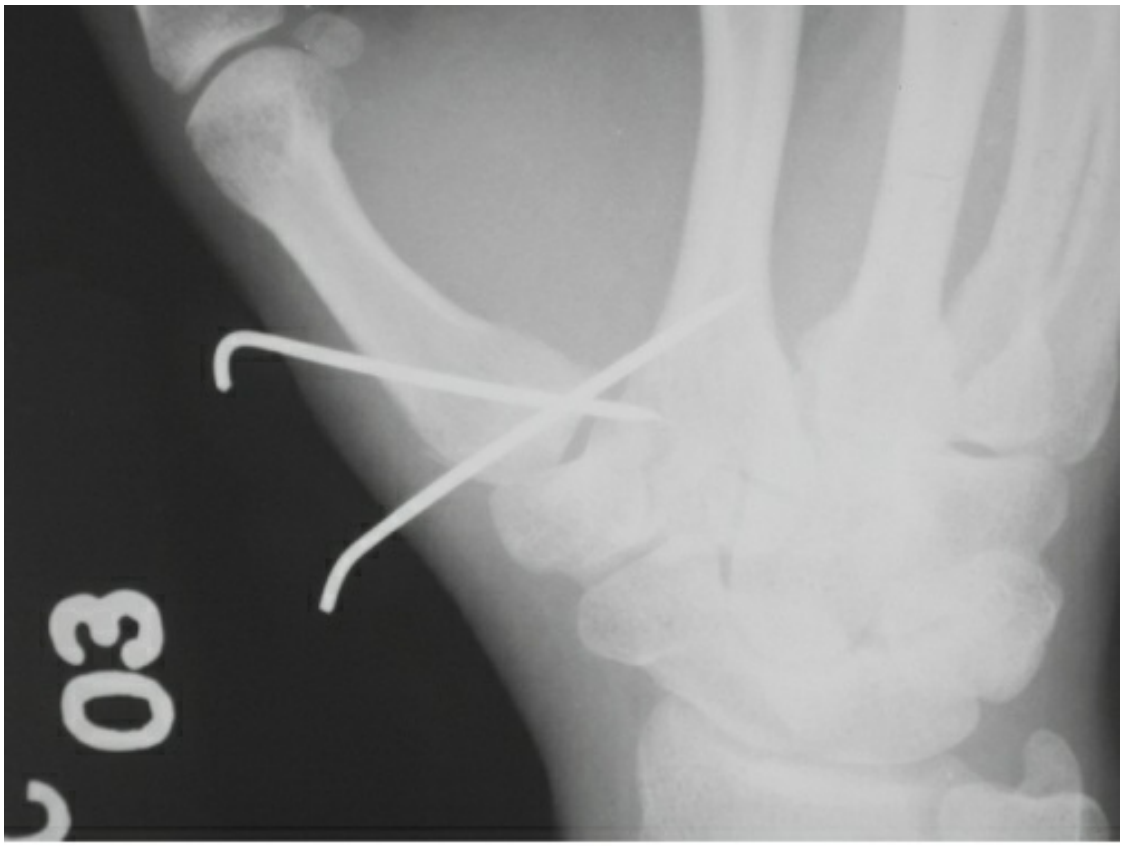

(B)

FIG. 10-8 Bennett's fracture dislocation. **(A)** Fracture with dislocation at the base of the thumb. **(B)** Internal fixation by K-wires.

Treatment

It is an unstable fracture and often needs internal fixation by a Kirschner wire or a screw (Fig. 10-8B). The period of postoperative immobilization is 3 weeks.

Physiotherapeutic management

During immobilization: Measures are taken to reduce pain and inflammation. Healing may be augmented by the use of diapulse.

Mobilization: Intensive therapeutic procedures are initiated to improve ROM, strength and endurance of the muscles of thumb. Dynamic flexion splint and scar remodelling to be emphasized to the extensor

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pollicis longus tendon.

Gradually progressive therapy should be given so that the thumb regains normal function by 10–12 weeks.

Complications

1. *Malunion:* Malunion of a metacarpal fracture may result in angulation or rotational deformity, which may need correction by osteotomy (Fig. 10-9).

2. *Stiffness of the hand:* Prolonged immobilization or inadequate physiotherapy may cause stiffness of the hand. However, it can be prevented by controlling oedema and swelling, minimum splintage and early mobilization.

3. *Osteoarthritis of the first carpometacarpal joint:* It occurs in Bennett's fracture dislocation where joint incongruity persists.

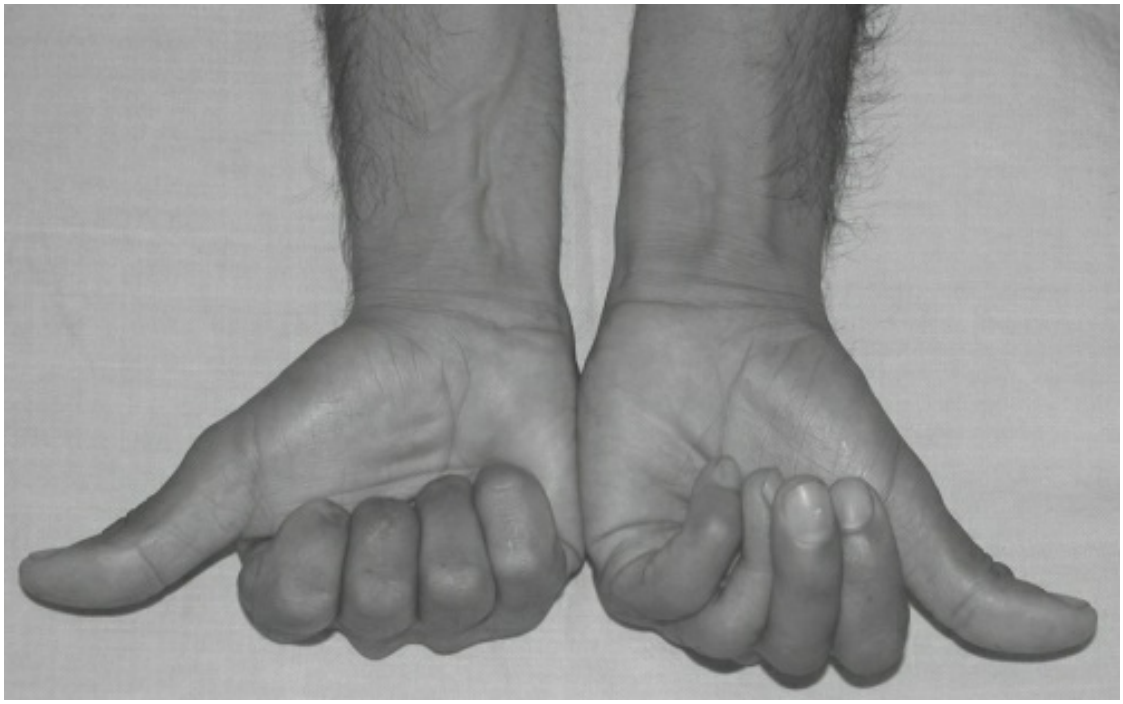

FIG. 10-9 Malalignment of the finger due to a malunited phalangeal

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fracture in the ring finger of the patient's left hand. The right hand is shown for comparison.

Fracture of the phalanges

Phalanges are fractured due to direct trauma or a twisting force. Distal phalanges get comminuted fractures due to crushing injuries. Direct injury to the phalanx results in a transverse or oblique fracture, whereas a twisting injury causes a spiral fracture (Fig. 10-10).

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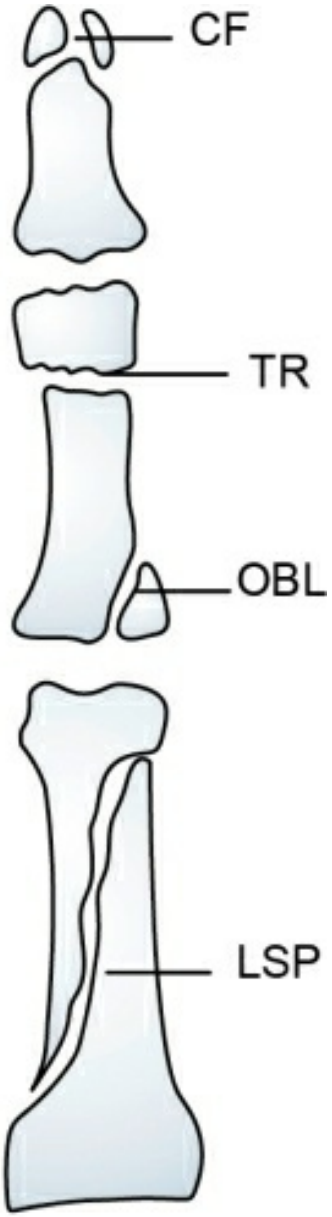

FIG. 10-10 Sites and types of fracture in the phalanx. Common types: LSP, long spiral; OBL, Oblique; TR, transverse fracture of shaft; CF, comminuted fracture of the distal phalanx.

Treatment

Proximal and middle phalangeal fractures are usually treated by closed manipulation and splintage in a 'ball bandage' or by splinting the injured finger to the adjacent intact finger (Fig. 10-11A) (called *buddy splint*) for a period of 3 weeks. Grossly displaced fractures may

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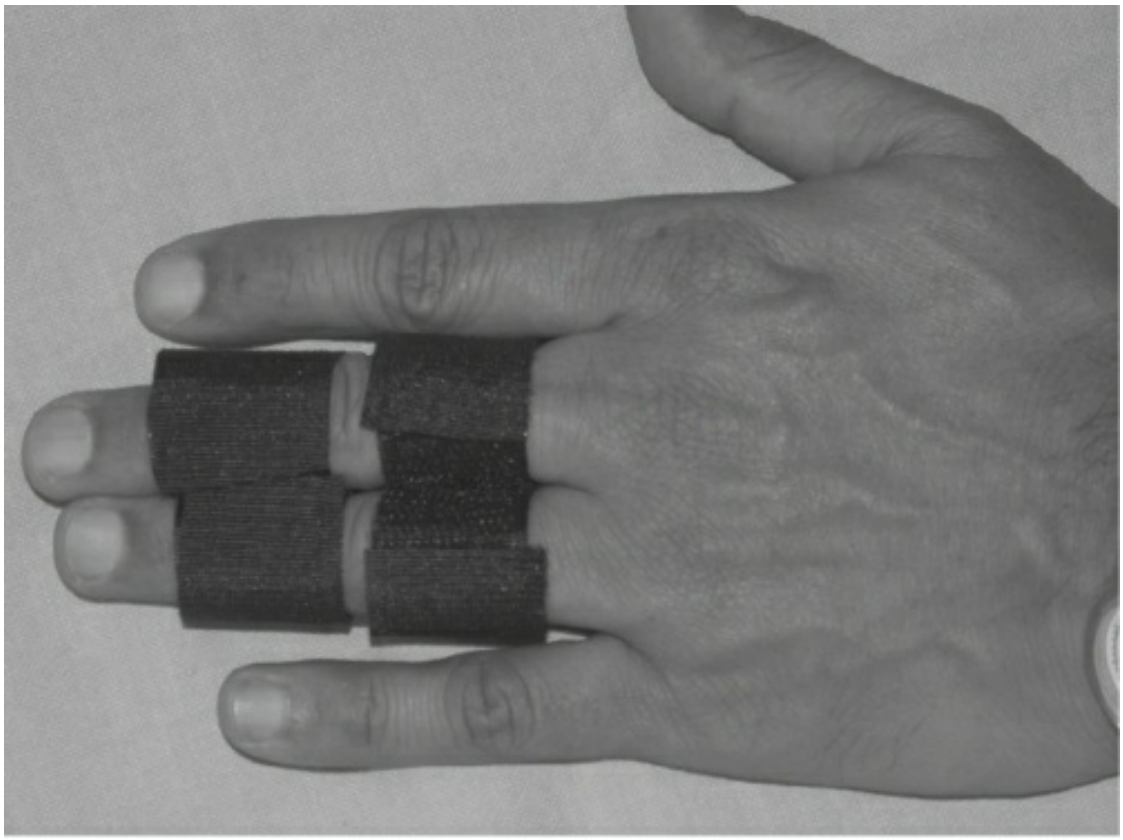
need internal fixation by a Kirschner wire or mini screws (Fig. 10-11B).



(A)

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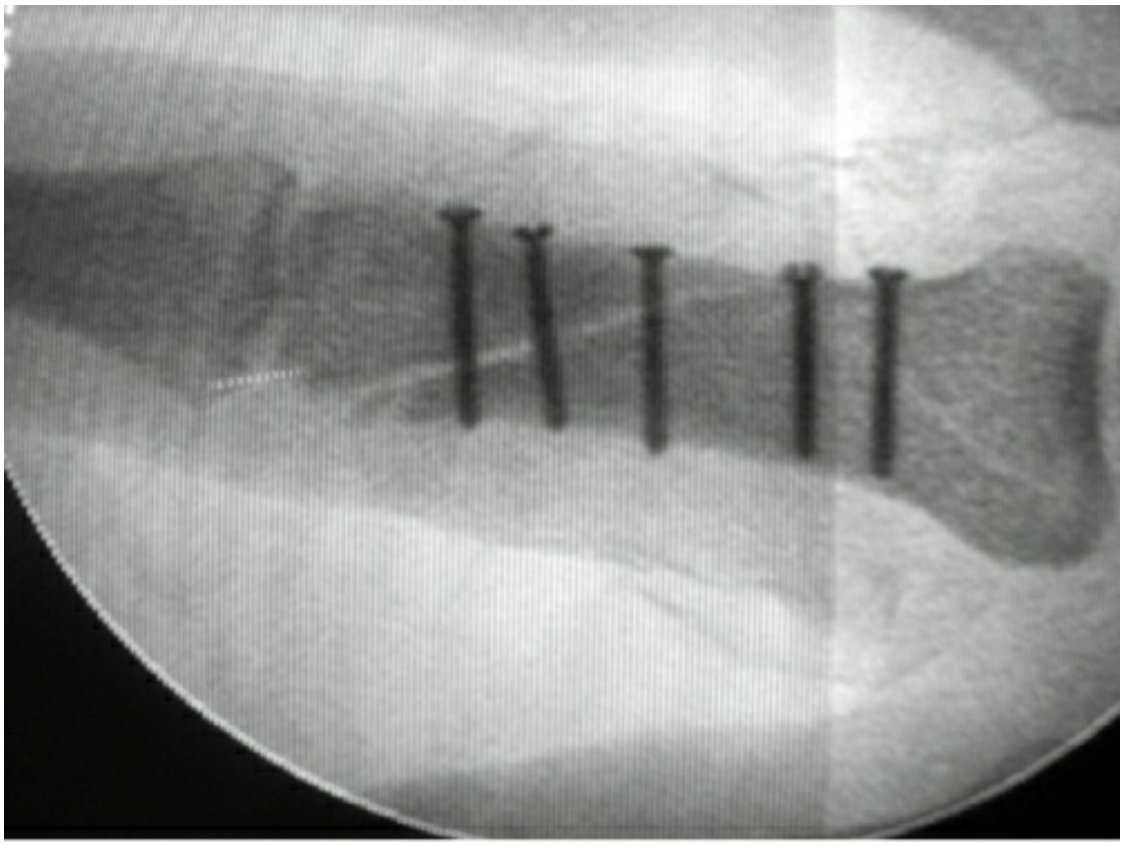

(B)

FIG. 10-11 **(A)** Immobilization by buddy splint. **(B)** A spiral fracture of phalanx fixed by multiple screws.

Fractures of the distal phalanx do not need any splinting. They are generally treated as soft tissue injuries.

Physiotherapeutic management

Fracture of the proximal phalanx: Proximal phalanx is very important for various functions due to their anatomical positioning.

Fracture healing with angular or rotational deformity results in stiffness of the MCP and PIP joints and adherence of the flexor and extensor tendons thereby causing functional inadequacy of the hand.

During immobilization: Routine measures are taken to control oedema, inflammation and pain. Improved circulation by vigorous movements and resistive exercises of the joints in the exact groove to the free fingers are important.

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Mobilization: When the fracture is stable, mobilization should be made vigorous by gentle relaxed passive movements in the maximum arc. Well-supported active exercises can be given. Static or dynamic splint to prevent or to minimize deformity as well as to aid scar modulation is necessary.

Continuous and repeated active movements play an important role in facilitating tendon glide and strength.

The exercise programme should be made progressive and functional.

Good hand function should be regained by 3 months.

Fracture of the middle phalanx: The basic objective of physiotherapy is to regain full active ROM of the joints proximal and distal to the fractured middle phalanx.

During immobilization: All the routine measures to control inflammation, pain and swelling are taken.

Irrespective of the method of immobilization, early measures to initiate mobilization are extremely important (5–15 days).

Individual joint ROM exercises, passive as well as active, are given by stabilizing the phalanx just proximal to the joint being exercised. This helps to obtain effective tendon glide by avoiding tendon adherence to the callus.

Mobilization: After 2 weeks, active flexion–extension exercises are started for the immobilized PIP joint. Care must be taken to avoid the terminal range of extension with the use of a dorsal block splint (Fig. 10-12). Extension is limited to 30 degrees and 15 degrees during the first and second weeks, respectively.

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(A)

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(B)

FIG. 10-12 Fracture of the middle phalanx. Dorsal block splint to limit extension up to 30 degrees during the first week, 15 degrees during the second week, and finally allowing full extension by the third week.

After 4 weeks, extension can be initiated at the PIP joint and a dynamic extension splint is given to further the extension (Belsole, 1980).

Therapy progresses on the same lines to attain full function. However, it may need 6 months to get full active extension at the PIP joint.

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Mallet finger

The tendon of the extensor digitorum communis sometimes gets avulsed from its insertion to the base of the distal phalanx (Fig. 10-13A). The tendon may be avulsed along with a small piece of bone from the distal phalanx (Fig. 10-13B and C). Sudden forced flexion of the distal phalanx is the usual mode of injury.

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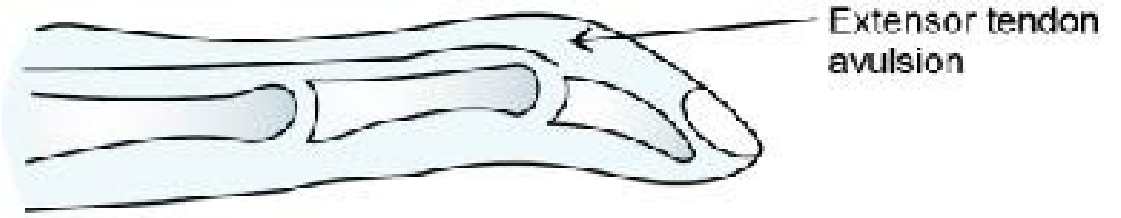

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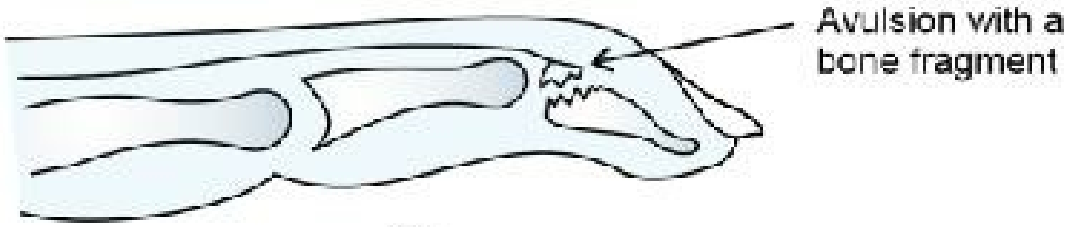

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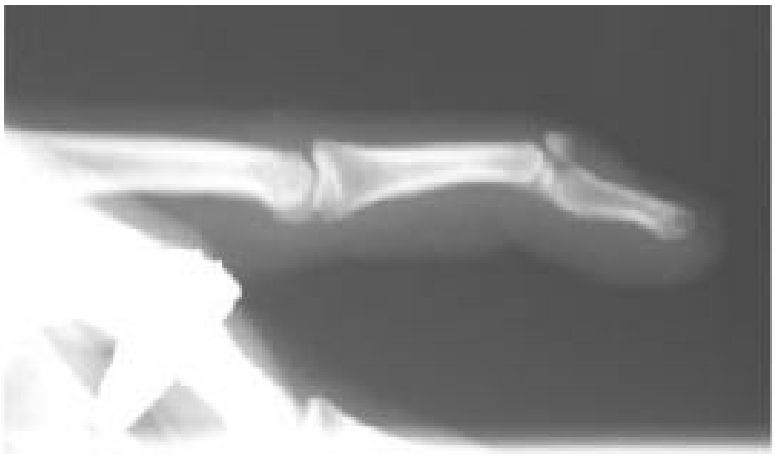

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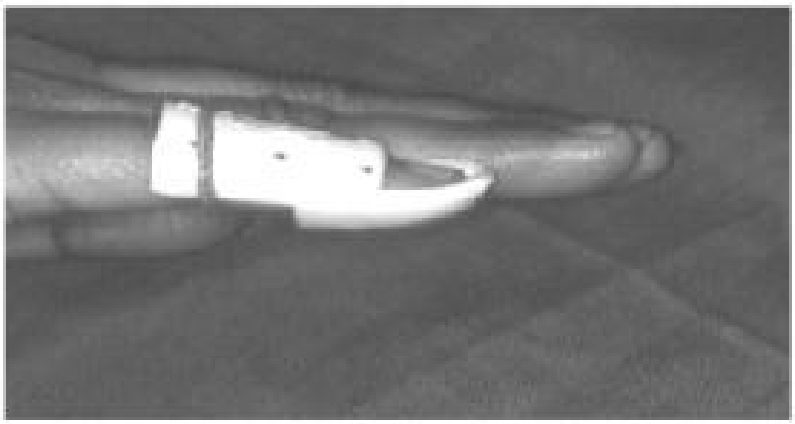

(D)

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FIG. 10-13 Mallet finger: **(A)** extensor tendon avulsion – the distal phalanx is in flexion, **(B)** tendon avulsion may occur along with a bone fragment, **(C)** radiograph showing avulsion fracture of the distal phalanx and **(D)** mallet finger splint.

The patient complains of pain and swelling of the distal phalanx of the finger and is unable to actively extend the finger at the distal IP joint. However, the finger can be fully extended passively.

Treatment

Fresh cases are treated by immobilization in a POP cast or plastic/PVC splints with the proximal interphalangeal joint in 60 degrees of flexion and the distal interphalangeal joint in hyperextension (Fig. 10-13D). The immobilization is maintained for 3–4 weeks. Extension block wiring is also a method of treating mallet finger. Two Kirschner wires are passed percutaneously and maintained for 3–4 weeks with good results (Fig. 10-14).

(A)

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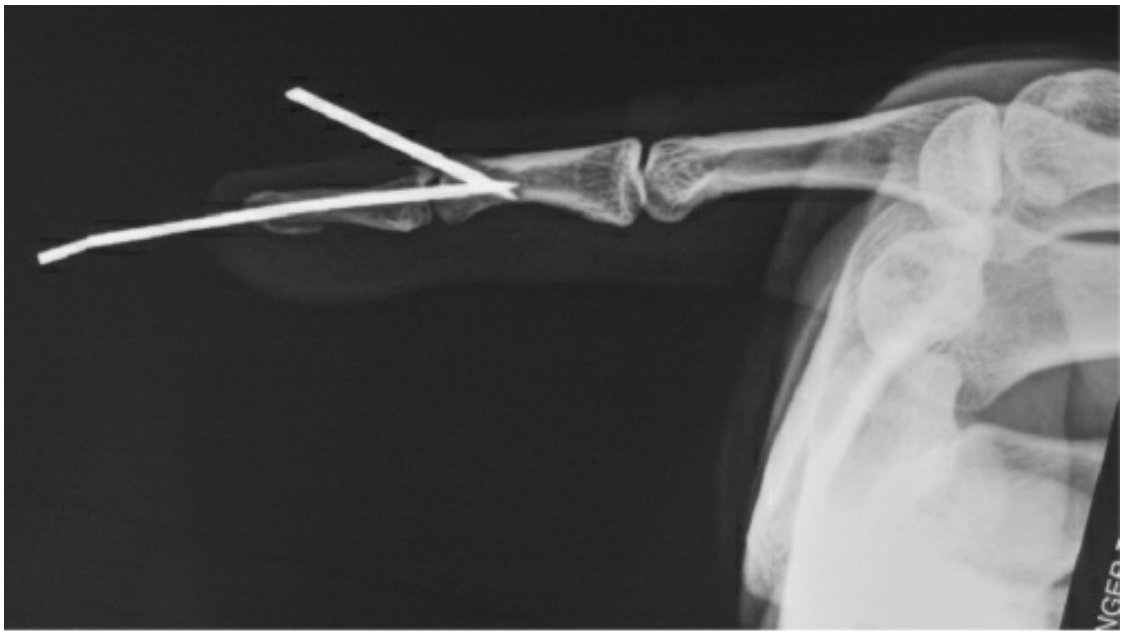

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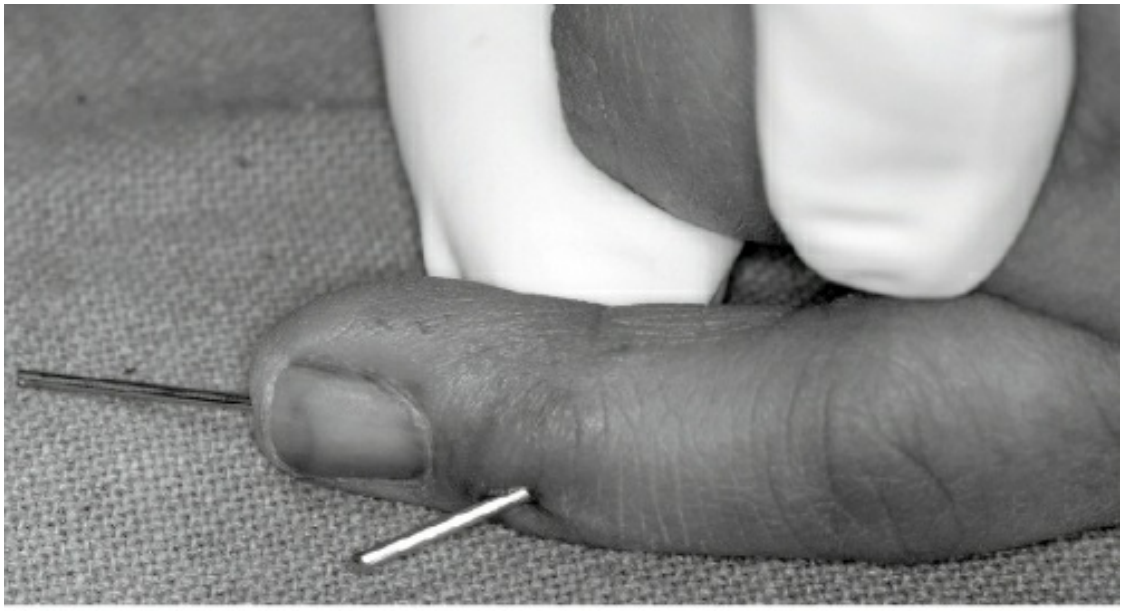

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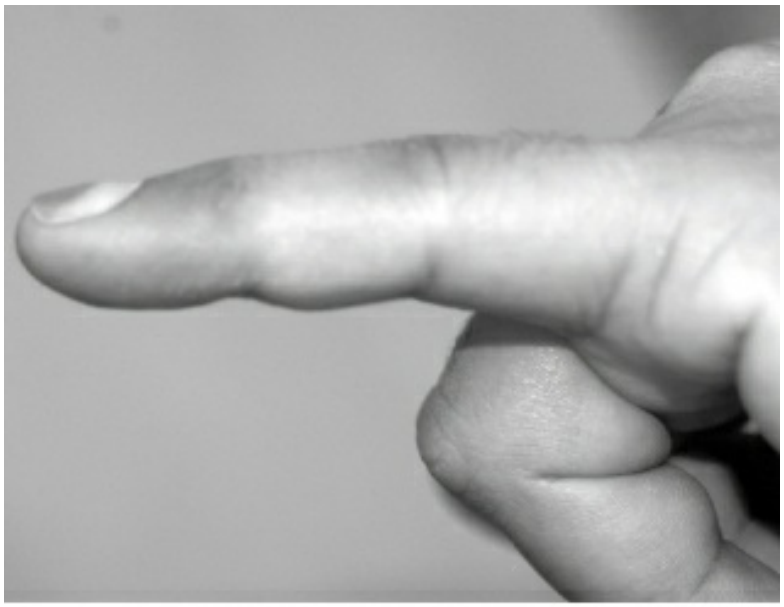

(D)

FIG. 10-14 **(A)** Mallet finger, **(B)** and **(C)** treated by percutaneous fixation with two K-wires. **(D)** End result following K-wire fixation.

The ruptured tendon is sometimes repaired by surgery. The avulsed bony fragment is fixed to its parent bone by a Kirschner wire. Postoperatively the finger is immobilized in a cast or splint for 3–4 weeks. Late cases are treated by open reduction and repair of the tendon or the avulsed fragment. Rarely, when the pain and deformity persist, arthrodesis of the distal IP joint in 15 degrees of flexion is performed. The postoperative immobilization after arthrodesis is generally prolonged for a period of 8–10 weeks.

Physiotherapeutic management

The basic aims of physiotherapy:

1. To regain voluntary extension at the distal IP joint

2. Full ROM and strength at the distal IP joint

Cases treated by immobilization/surgical repair

During immobilization: The patient is encouraged to use hand with a

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splint or POP cast.

Vigorous early movements are begun to all the fingers and MP and PIP joints of the index finger with the splint protecting the DIP joints. Measures are also taken to control inflammation, oedema and pain.

Mobilization

1. Paraffin wax bath is extremely useful to improve ROM of the distal IP joint and to facilitate stretching of the injured or repaired tendon.

2. Encourage maximum active movements to the DIP joint with emphasis on flexion. Special attention may be necessary for exercising the extensor digitorum communis.

Extensor lag due to extensor tendon attenuation may be present.

3. Strengthening and re-education of the extensor digitorum communis is achieved by synchronizing voluntary exercise efforts with electrical stimulation.

Exercises of the lumbrical are also important.

Splint is continued till voluntary full extension at the distal IP joint is regained.

Active use of hand with splint and light hand activities without splint are encouraged. Use of splint is gradually weaned off as the voluntary extension returns.

Full function should return by 3–4 weeks following mobilization.

Long period of immobilization results in pain and stiffness of the PIP joint. Therefore, several sessions of mobilization in a day are extremely important.

Guidance in the functional use of the hand initially with immobilization and later following mobilization is important.

Caution

The patient needs to be warned against performing forced flexion

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movements like tight grasp and lifting weights to avoid recurrence.

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CHAPTER
11

Injuries of the spine

OUTLINE

- Injuries of the vertebral spine
- Injuries of the cervical spine
- Injuries of the lower cervical spine
- Fracture of the lower cervical spine
- Injuries of the thoracolumbar spine
- Fractures at the thoracic spine
- Thoracolumbar spine injuries
- Lumbar spine injuries

Injuries of the spine are serious injuries since they may be associated with injury to the spinal cord resulting in paralysis which may be irreversible. Injuries are common in the most mobile segments of the spine, i.e., lower cervical and thoracolumbar spine.

Spinal cord injuries need extensive acute care to avoid seriously disabling consequences.

Injuries of the vertebral spine

Brief Functional Anatomy: Vertebral spine, the backbone of all the physical activities of our daily life, is composed of 33 vertebrae, forming four compact units.

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- Cervical unit of 7 vertebrae
- Dorsal or thoracic unit of 12 vertebrae
- Lumbar unit of 5 vertebrae, and
- Sacrococcygeal unit of 9 fused vertebrae

The units are specially designed to perform the following three functions:

1. *Free mobility* to the neck by the cervical unit, and free mobility of the trunk by the thoracolumbar unit

2. *Stability* (static as well as dynamic) to the body's movement by the thoracic and sacrococcygeal unit

3. *Protection* to the soft vital organs by the thoracic unit and to the spinal cord by the vertebral chain formed by the cervical, dorsal as well as lumbar units

Incidence

Vertebral injuries account for 5–6% of all trauma cases. The common sites of injury being the cervical spine followed by the thoracolumbar spine.

Causes of spinal injury

Spinal injury is caused by direct or indirect trauma like fall of a heavy object or a fall from height, road traffic accident (RTA), diving into shallow water, or a direct injury by bullet or *lathi*.

Clinical features: Signs and symptoms

- Unconsciousness, spinal shock
- Cardiorespiratory insufficiency or failure

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- Deficiencies in the neuronal system with impaired or loss of motor power (e.g., quadriplegia or quadriparesis following injuries of the cervical spine and paraplegia or paraparesis following injuries to the cervical and thoracolumbar injuries)

- Sensory impairment with altered reflexes

- Impaired bladder and bowel functions

Planning the treatment programme

The treatment programme is planned on the basis of the mechanism of injury and the status of the stability of the injured spine.

Direct injury – bullet or a *lathi* blow – directly over the spine can smash any part of the spine. A *lathi* blow generally causes fracture of the spinous or transverse processes.

Status of stability of the injured spine

The characteristics of stable and unstable injuries are listed in Table 11-1.

Table 11-1
Characteristics of Stable and Unstable Injuries

Stable Injury	Unstable Injury
Intact intervertebral linkage and anatomical alignment	Disturbed intervertebral linkage and anatomical alignment
Intact posterior longitudinal ligament	Break in the continuity of the posterior longitudinal ligament
Injury in only one direction e.g., true flexion or extension	History of rotational element in the mode of injury
Regaining full consciousness and alertness and usually without neurological defects	Usually associated with unconsciousness, cardiorespiratory episode or appearance of flaccid paralysis of the limbs

Denis determined the stability on the basis of the involved vertical columns. The vertebral body is divided into two vertical columns, whereas post elements of the vertebra constitute the third column. The injury is labelled as stable when only the anterior column is involved, whereas it is labelled unstable when two or all the three columns are involved (Fig. 11-1).

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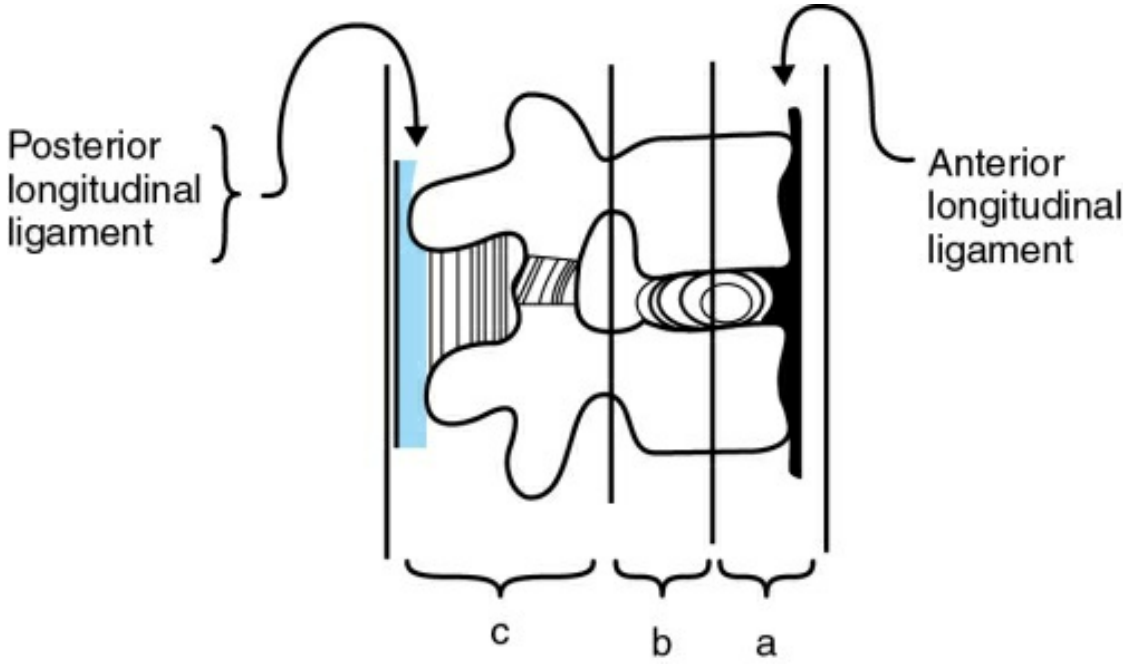

FIG. 11-1 Denis's three-column concept: (a) anterior column, (b) middle column, and (c) posterior column.

Examination

- Quick survey of all the vital signs and possible associated injuries to the head and viscera is done.
- Critical examination of the neuromusculoskeletal parameters including bulbocavernosus reflex is conducted.
- Spinal examination is done with extra care to avoid further damage to the injured spine.
- Strictly avoid jerky movements to the spine during resuscitation, turning, examination, etc.
- Assess overall functional status (abilities as well as inabilities)
- Assess renal function with urine output and the overall bladder and bowel control.

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Investigations

Radiographic investigation provides important information about the site and type of lesion.

Digital AP and lateral radiographic views in general

- Oblique view of the suspected rotational injury
- Open mouth view of upper cervical lesions, suspected at C1, C2 level
- **CT scan:** To identify spinal canal compromise
- **MRI scan:** Provides precise information about bony integrity, status of spinal cord, IV discs, neural structures including nerve roots and musculotendinous complexes

General plan of treatment of spinal injuries

Treatment of stable injuries without displacement or paralysis is done by a conservative approach

- Bed rest
- Immobilization in a four-poster cervical collar, extended plaster jacket (Minerva jacket), Minerva jacket brace or hollow cast
- Reduction of the unstable fractures or fracture dislocation by heavy skeletal traction up to 9 kg; then a light skeletal traction is maintained for 3–6 weeks followed by a four-poster collar for another 3–4 months

Surgical treatment

Surgery by the following is indicated in uneducable or highly unstable injuries:

- Anterior decompression with removal of the vertebral body and the

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IV disc followed by stabilization with bone graft and spinal instrumentation

- Posterior decompression by removal of lamina and the spinous process followed by stabilization with bone grafting and spinal instrumentation

The technique of bone grafting and spinal instrumentation markedly reduces the period of recumbency along with providing stability of the injured spine.

Injuries of the cervical spine

Fractures of the cervical vertebrae often result in paralysis (quadriplegia) and could even be fatal.

Common injuries at the upper cervical spine include the following:

1. Fracture of the atlas (Jefferson's fracture)

2. Atlantoaxial subluxation

3. Hangman's fracture

4. Fracture of the odontoid process

Injuries to the upper cervical spine

Injuries to the upper cervical spine especially at C1–C2 with occiput and the base of the skull are devastating due to respiratory failure; the patient invariably succumbs to it. Even if the patient survives, he may develop crippling quadriplegia.

The common sites of injury are C1–C2 and at C5–C6 levels. Nearly 40–60% of the patients have associated spinal cord injury and the residual neurological defects.

1. **Fracture of the atlas (Jefferson's fracture):** A common injury is vertical compression injury due to the axial force through the skull,

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breaking either one or both the arches of the atlas (Fig. 11-2). It is a stable injury sparing the spinal cord.

Treatment:

Immobilization is performed with a moulded high cervical collar, four poster cervical collar, Minerva POP jacket or Minerva jacket brace for 3 months.

2. **Atlantoaxial subluxation:** It is caused by injury to the atlas and the transverse ligaments or following neck or throat infection. It may be associated with fracture of the odontoid process mostly at its base as a result of forward displacement due to jerky flexion injury. The displacement will be backwards in extension injury.

The spinal cord however is usually spared.

Treatment:

- Undisplaced fracture is treated by a high four-poster collar for 3 months.
- Displaced fracture is treated by skull traction for 4 weeks, followed by a Minerva jacket or a hollow cast cervical brace.

Persistent instability is treated by atlantoaxial fusion.

3. **Hangman's fracture:** Injury usually involves axis at the neural arch along with traumatic spondylolisthesis of C2.

Treatment:

It is treated by skull traction followed by a four-poster

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cervical collar.

4. **Fracture of the odontoid process:** Many a times this fracture is missed on a routine X-ray. It is better seen in an AP view taken with the patient's mouth kept open during the investigation. However, this fracture is suspected when the patient complains of severe pain and tenderness at the base of the skull. Luckily, most of the time, the spinal cord is spared. The fracture at the odontoid may occur either at the tip (oblique) or at the junction of the odontoid process and the body of the vertebra (transverse) or through the upper portion of the vertebral body.

Treatment:

Skull traction followed by halocervical orthosis or cast (see Fig. 11-12).

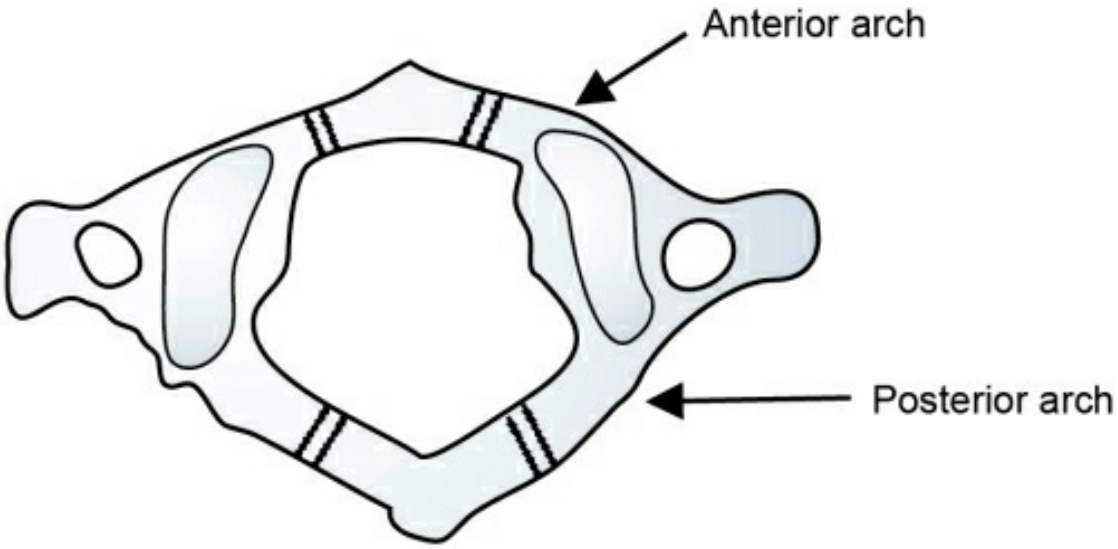

FIG. 11-2 Possible common sites of fracture in the atlas (C1) vertebra.

Physiotherapeutic management

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Objectives

The objectives in the treatment of injuries of the cervical spine are as follows:

1. To restore the normal or at least functional ROM of all the basic four movements of the neck (Table 11-2).

2. To restore adequate muscular strength and endurance to make the patient functionally independent in the use of the neck.

Table 11-2
Normal and Functional ROM at the Cervical Spine

Movement	Normal ROM	Functional ROM
Flexion	0–65º	0–40º
Extension	0–65º	0–30º
Lateral flexion (either side)	0–45º	0–20º
Rotation (either side)	0–75º	0–45º

Expected problems

The complications include the following:

- Irreversible paralysis (motor as well as sensory)
- Bladder and bowel incontinence
- Severe psychological trauma with loss of interest in life in severely disabled
- Life dependency and strenuous efforts to perform activities of daily living (ADLs) in patients who suffer from spinal cord lesions

If the injuries to the upper cervical spine are undisplaced or stable without causing damage to the spinal cord, the physiotherapeutic management may be uncomplicated.

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Jefferson's fracture or fracture of the first vertebra or atlas

The fracture is immobilized in a moulded high cervical collar, a four-poster cervical collar or a Minerva jacket brace for 8–12 weeks.

During immobilization:

- Check the immobilization for a close fit ensuring that it checks the close skin edges of a brace for discomfort or excessive pressure.
- Strictly instruct the patient not to put any uncalled-for efforts to move neck in collar, and teach and guide moving the whole body rather than follow the natural instinct to move the neck.
- Provide guidance to carry out activities of daily routine with a brace.
- Demonstrate and guide the patient to work up light isometrics in a pain-free range by pressing against the immobilization.

During mobilization:

- Begin with a gentle soothing massage before initiation of mobilization.
- In the supine position, with neck and head resting on a soft pillow, initiate relaxed rhythmic small-range free active rotation.
- Initiate gradual flexion and extension with the patient sitting in an arm chair with the back totally supported.

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- Guide the patient on performing strong isometrics against self-resistance using palms as a resistive force.
- As the ROM of all the four basic cervical spine movements improve, guide the patient on self-stretch-hold modes to gain further ROM.
- Encourage the patient to carry out all the ADLs.
- Increase the vigorosity of exercises to reach the preinjury level by self-efforts.
- By 16 weeks, the preinjury freedom of ROM and adequate strength should be restored.

Physiotherapy for the other three stable upper cervical spine injuries (atlantoaxial subluxation, Hangman's fracture and fracture of the odontoid process) follows the same pattern.

Guidance to continue for further improvement and also to prevent recurrence is a must.

Precaution

To prevent discomfort during night, guidance may be given in ergonomics of the cervical spine. In addition to this, the use of a soft conventional collar may also be advised.

Injuries of the lower cervical spine

Lower cervical spine injuries commonly involve the C5–C6 vertebrae. These injuries can cause severe damage to the spinal cord resulting in quadriplegia.

The lower cervical vertebra has a cylindrical body; the posterior neural arch is made up of a pair of pedicles, a pair of lateral masses, a pair of laminae and bifid spinous processes. The lateral processes have a deep bony canal for the passage of spinal nerves and the vertebral

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artery through the foramina transversarium.

The types of injuries depend on the mechanism of the injury:

- Flexion injury causes wedge compression fracture.
- Flexion–rotation injury will cause subluxation or dislocation.
- Hyperextension injury will cause rupture of the anterior longitudinal ligament with wide anterior opening of the bodies.
- Vertical compression injury will result in a burst fracture of the body of vertebra, fragments of which may impinge upon the spinal cord.

Treatment

1. Treatment of the stable injuries
2. Treatment of the unstable injuries
3. Management of paralysis (quadriplegia)

The treatment is discussed in subsequent sections.

Physiotherapeutic management

During immobilization:

- Conduct detailed objective clinical examination.
- Strong isometrics are given to the muscles of the neck within the limits of pain.
- Provide full-ROM resistive movements to all the joints of the nonimmobilized sections of the body, along with chest physiotherapy during decumbency.
- Guide all the functional activities as early as possible, avoiding

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excessive stress over the injured section of the spine.

During mobilization:

Begin well-supported relaxed active free exercises to ensure early mobilization in a graded manner, gradually working towards full ROM.

Patients treated with surgery need to be taught and guided on the techniques to perform functional tasks by compensatory mechanisms using dorsolumbar spine and the joints of the lower limbs.

Aetiology

1. Fall from a height

2. RTAs

3. Diving injuries

Injuries to the cervical spine are caused by the following forces, either singly or in combination:

1. Flexion

2. Extension

3. Rotation

4. Vertical compression

1. **Flexion injuries:** Most flexion injuries (about 75%) occur in the lower cervical spine. There may be a wedge compression fracture of the vertebral body (Fig. 11-3A and B). Subluxation or dislocation may occur due to disruption of the posterior ligaments (Fig. 11-3C), the severity of injury depending upon the extent of ligament disruption.

Involuntary forced flexion may result in avulsion fracture of the spinous process of C6, C7 or Tl vertebra (Fig. 11-3B),

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called *clay-shoveler's fracture*.

A flexion *tear drop fracture* indicates complete disruption of the posterior ligaments and a large triangular fragment of bone avulsed from the anterior aspect of the vertebral body.

Complete disruption of the posterior ligament complex can also cause bilateral facet dislocation, with anterior displacement of the vertebra.

2. **Extension injuries:** Hyperextension and distraction cause rupture of the anterior longitudinal ligament (Fig. 11-4A) with posterior dislocation of the vertebra. The dislocation often gets reduced during transportation and handling of the patient; therefore a radiograph taken later in the casualty department may not show any bony injury, although the patient has quadriplegia. This injury, therefore, becomes evident on forced extension radiographs of the cervical spine.

Extension *teardrop fracture* results from a hyperextension injury. In this fracture, a large triangular fragment of the anterior superior or inferior corner of the vertebral body gets avulsed along with the anterior longitudinal ligament.

Fracture of the atlas, axis and odontoid process (Fig. 11-4B) may also occur.

3. **Flexion with rotation:** Excessive flexion force with rotary displacement causes unilateral facet dislocation, with mild displacement of the vertebral body. Severe injury may cause dislocation of the C5 vertebra with injury to the spinal cord (Fig. 11-5).

4. **Hyperextension with rotation:** Hyperextension with rotation causes fracture of the lateral masses of the vertebra, which are called

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pillars. This fracture also includes a portion of the articular facet joint.

5. **Vertical compression:** Vertical blow on the head as in a diving accident can cause burst fracture of the vertebral body (Fig. 11-6).

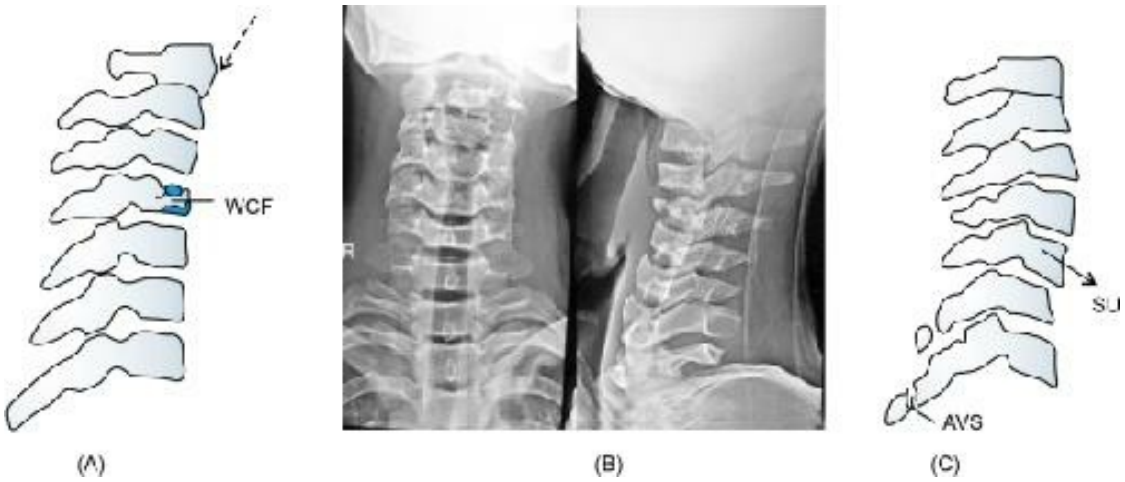

FIG. 11-3 Flexion injuries of the cervical spine. **(A)** Wedge compression fracture (WCF). **(B)** Wedge compression fracture of C5 vertebra, as seen on an X-ray. **(C)** Subluxation of the cervical spine at C5–C6 level (SU): avulsion fracture of the spinous process (AVS).

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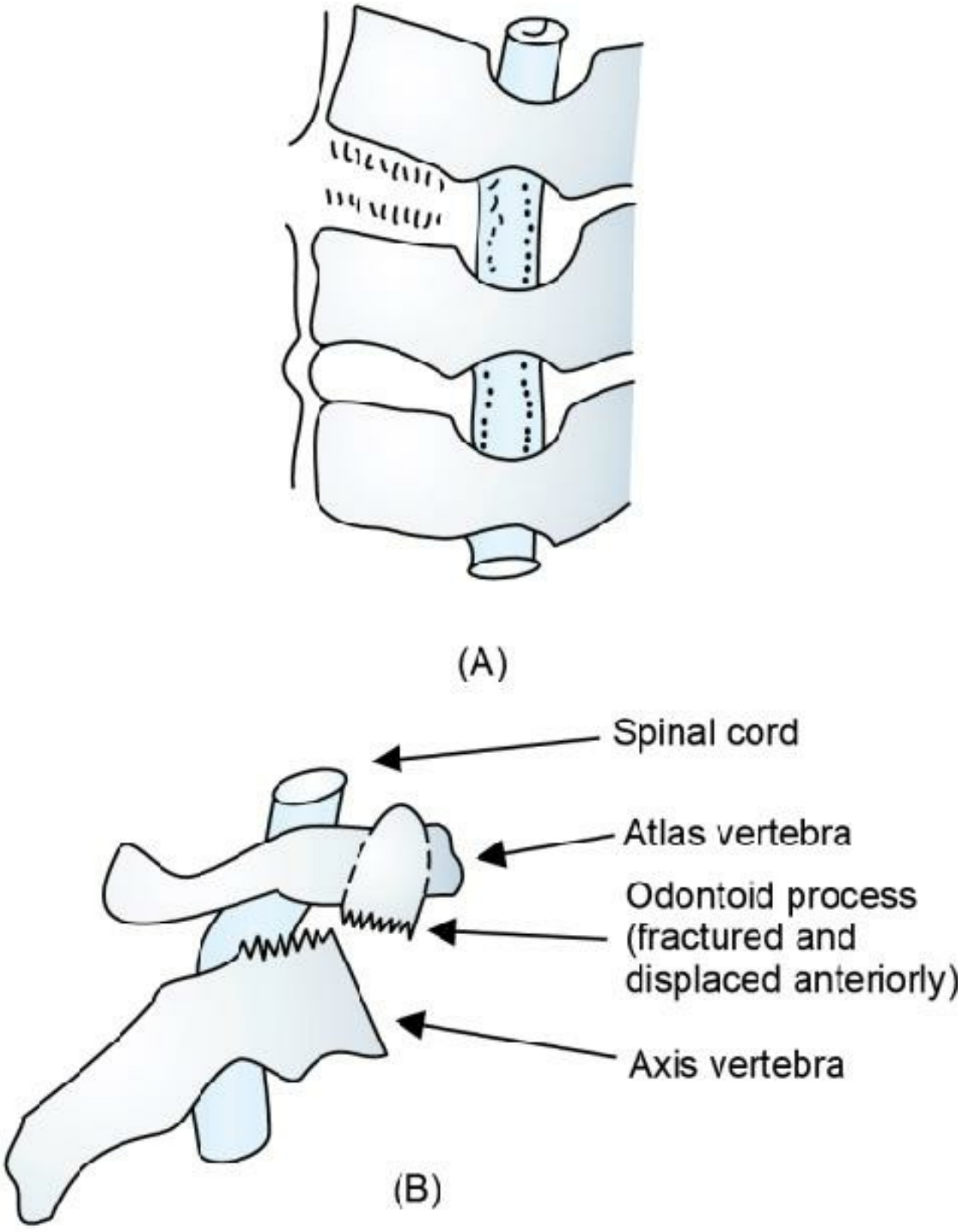

FIG. 11-4 Extension injuries of the cervical spine. **(A)** Rupture of the anterior longitudinal ligament. **(B)** Fracture of the odontoid process with posterior dislocation of the vertebra.

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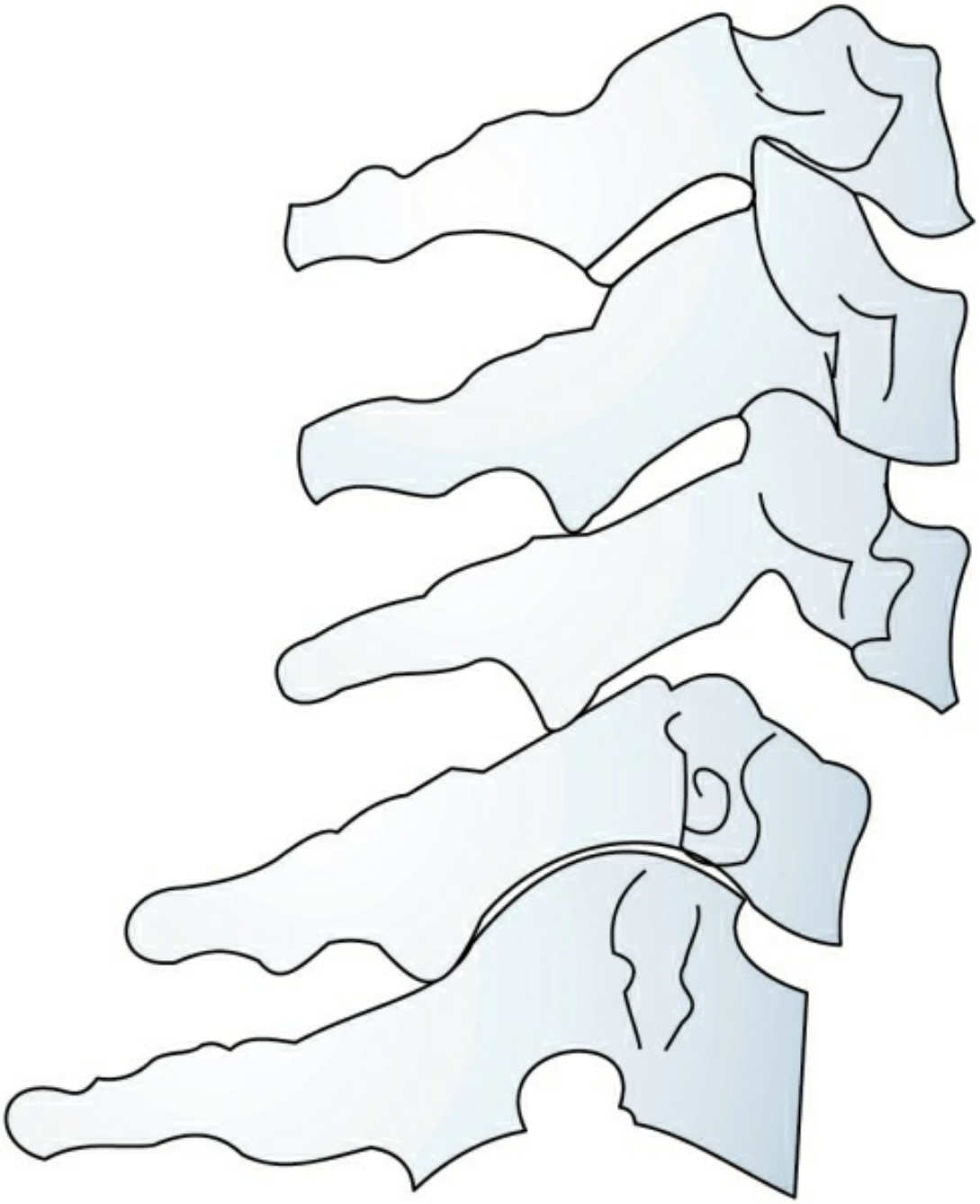

FIG. 11-5 Flexion with rotation injury. Marked dislocation of the C5 vertebra over the C6 vertebra is likely to cause injury to the spinal cord.

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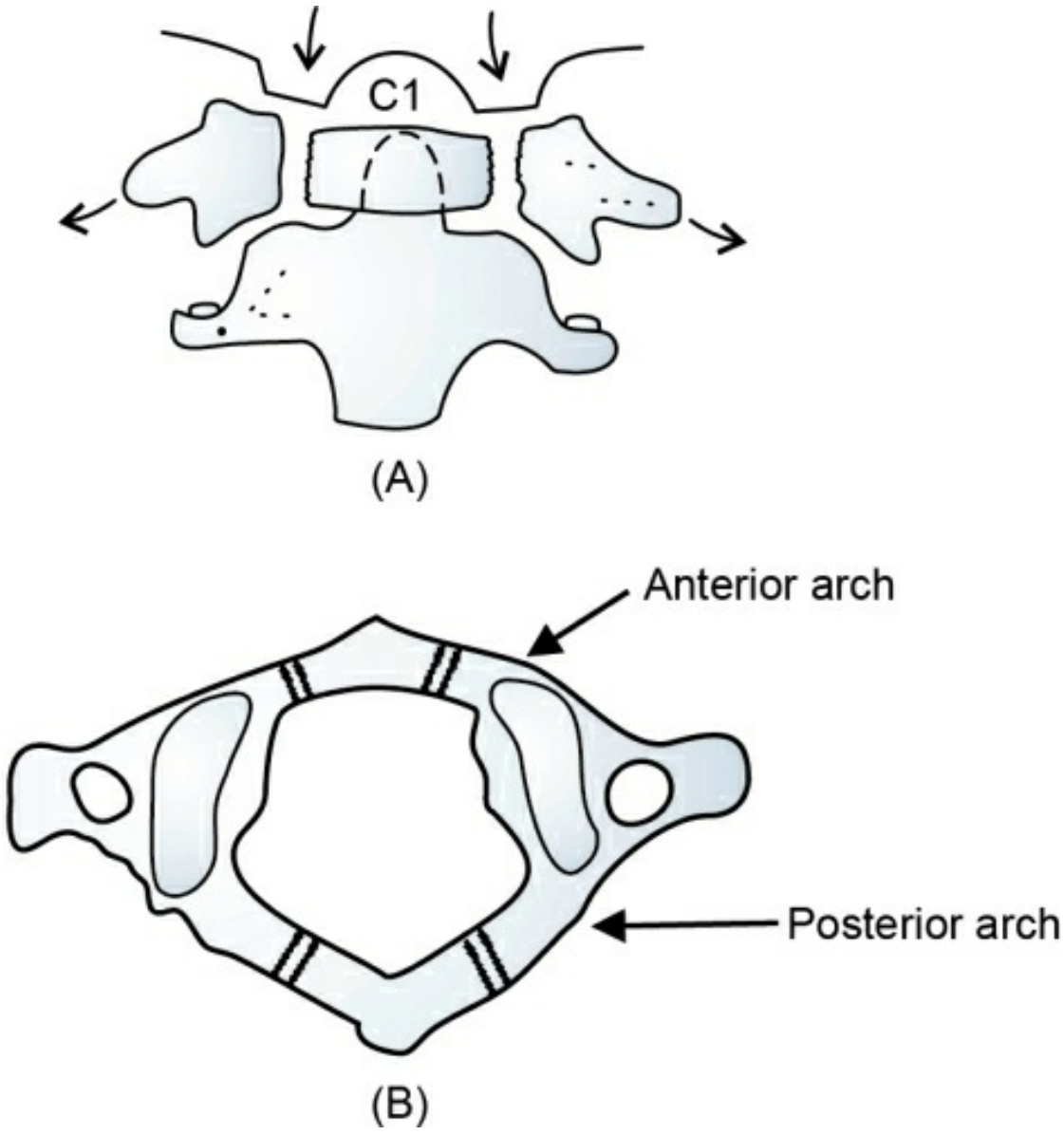

FIG. 11-6 **(A)** Burst fracture of the atlas by vertical compression. **(B)** Possible common sites of fracture in the atlas (C1) vertebra.

Fracture of the lower cervical spine

Burst fracture of the cervical vertebrae, commonly affected level is C5-C6, may cause quadiplegia, can result from vertical compression force. Displacement of the fractured fragments can cause compression of the spinal cord leading to significant neurological deficit (Fig. 11-7).

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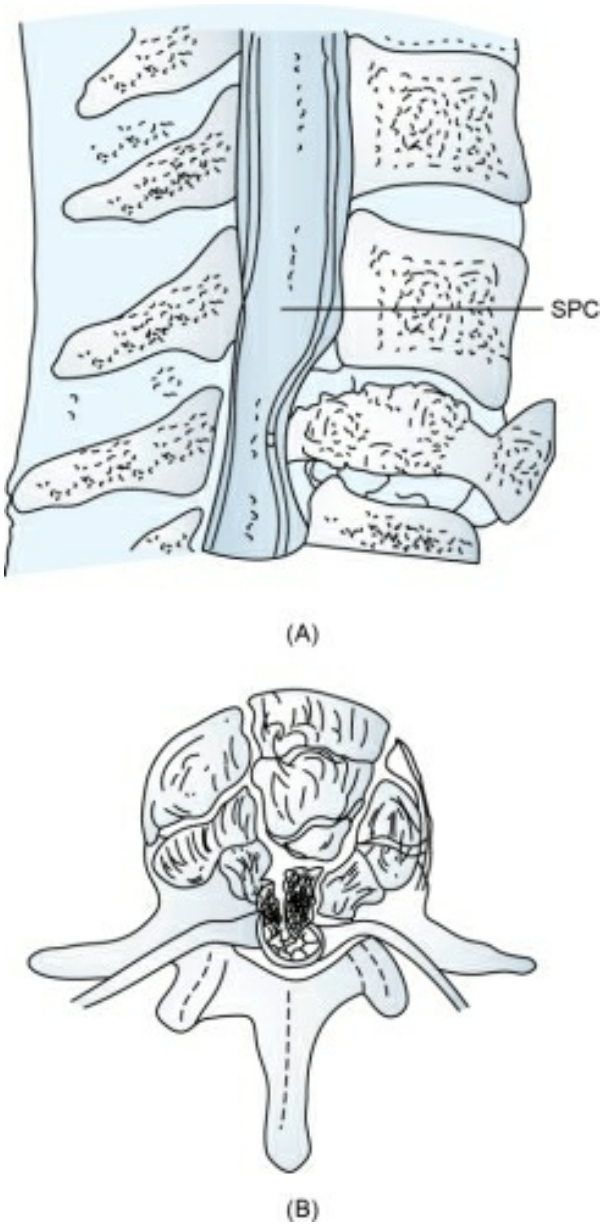

FIG. 11-7 **(A)** Burst fracture due to vertical compression with crushing of the entire vertebral body with its posterior projection causing pressure on the spinal cord (SPC). **(B)** Burst fracture impinging the spinal cord.

Mechanism of injury and common sites

1. Flexion injury – fall from height on the heels or the buttocks (C5–C7; L1>L2>D12) (Fig. 11-8A)

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2. Flexion-rotational injury – heavy blow over one shoulder causing sudden flexion and rotation to the opposite side. (CL1, D12; C5–C7) (Fig. 11-8B)

3. Flexion-distraction injury – violent jerky flexion of upper trunk over the seat belt on sudden stoppage of a car (dorsal spine) (Fig. 11-8C)

4. Extension or hyperextension injury – forehead striking against the windscreen and violently forcing neck into hyperextension or in rear-end automobile collisions (whiplash injury) (C5–C6; lumbar spine) (Fig. 11-8D)

5. Vertical compression injury – fall from height with head erect, or a heavy object striking the head from above (C5–C6) (Fig. 11-8E)

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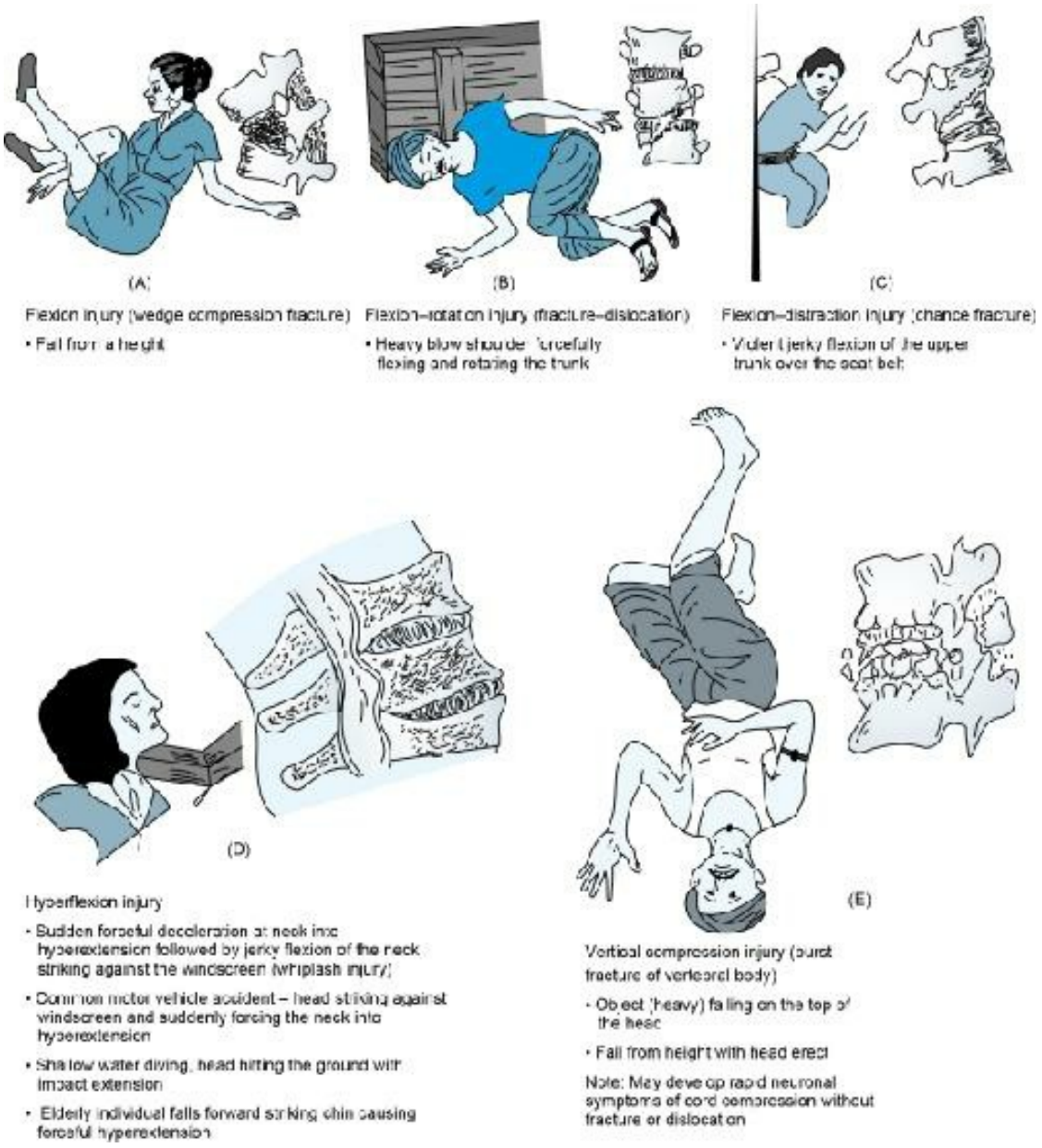

FIG. 11-8 Mechanism and types of spinal injuries: **(A)** flexion injury; **(B)** flexion–rotation injury; **(C)** flexion–distraction injury; **(D)** hyperflexion injury; **(E)** vertical compression injury.

Investigations

The following investigations may help in the diagnosis of the body injury as well as in the evaluation of injury to the spinal cord:

1. Radiographs

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2. CT scan

3. MRI scan

Treatment

The treatment of cervical spine injuries can be broadly divided into the following categories:

1. Treatment of stable skeletal injuries

2. Treatment of unstable skeletal injuries

3. Management of paralysis (quadriplegia)

1. **Treatment of stable injuries:** Stable injuries of the cervical spine, without displacements and paralysis, are treated by immobilization of the cervical spine by a four-poster cervical collar (Fig. 11-9), a POP Minerva jacket (Fig. 11-10A), a Minerva jacket brace (Fig. 11-10B) or by halo casts (Fig. 11-10C). The immobilization is maintained for a period of 6–8 weeks.

2. **Treatment of unstable injuries:** Unstable fractures or fracture dislocations of the cervical spine are reduced and immobilized by skeletal traction. The reduction is achieved by heavy skeletal traction given up to 20 pounds (9 kg) through Crutchfield tongs (Fig. 11-11) applied into the skull.

The reduction is confirmed by portable radiographs taken in bed with the traction on. After the reduction is achieved, a light skeletal traction is maintained for a period of 6–8 weeks, after which the neck is supported in a four-poster collar for another 3–4 months. The paralysis may also improve after reduction of the fracture/dislocation.

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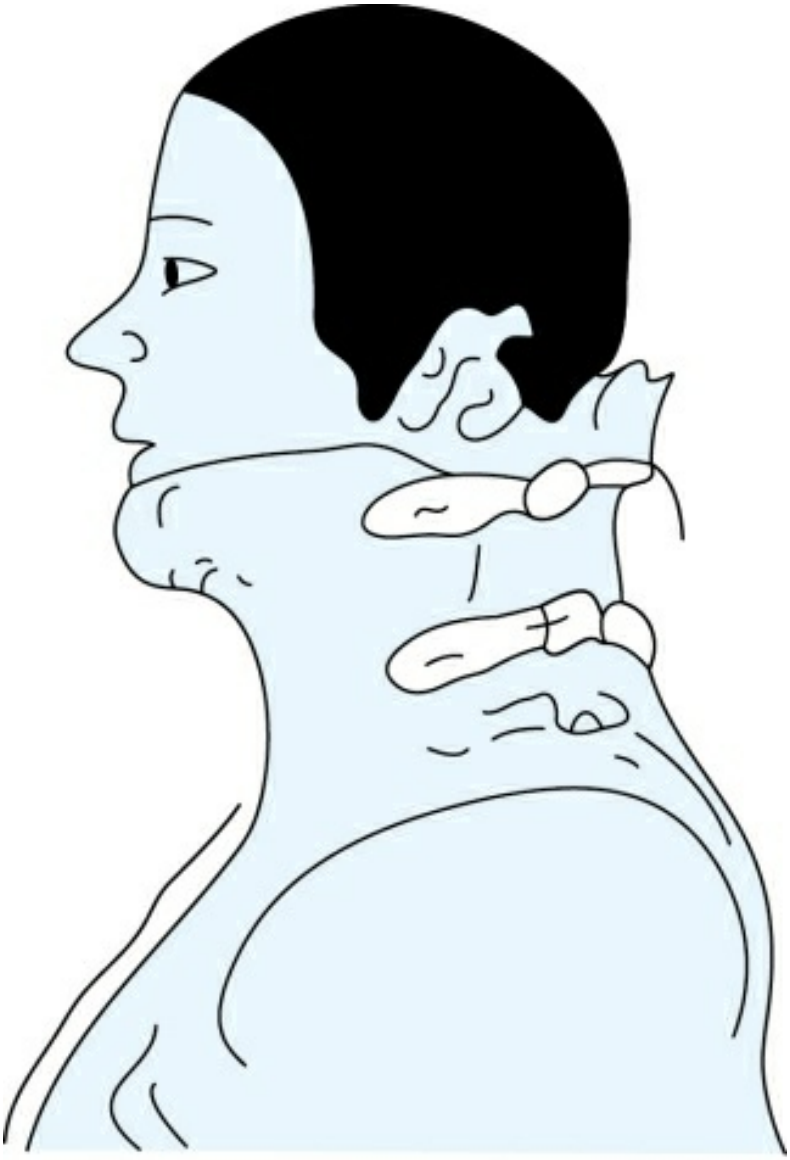

(A)

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(B)

FIG. 11-9 Stable injuries: **(A and B)** four-poster collar.

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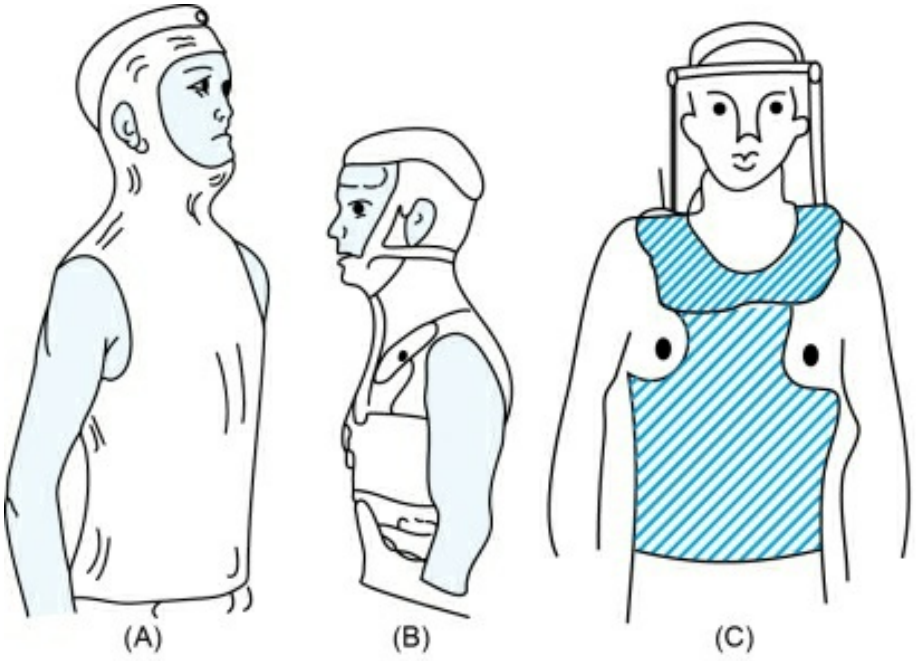

FIG. 11-10 Stable fracture of the cervical spine – methods of immobilization. **(A)** POP Minerva jacket. **(B)** Minerva jacket brace. **(C)** Halo cast

FIG. 11-11 Crutchfield skull traction.

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Operative treatment

In selected cases the dislocation is reduced by surgical operation and stabilized by spinal instrumentation (Fig. 11-12). The spine is also fused either posteriorly or anteriorly (Fig. 11-13). The neck is supported in a collar for a period of 3 months. However, spinal stabilization reduces the period of recumbency and thereby the subsequent complications of the latter.

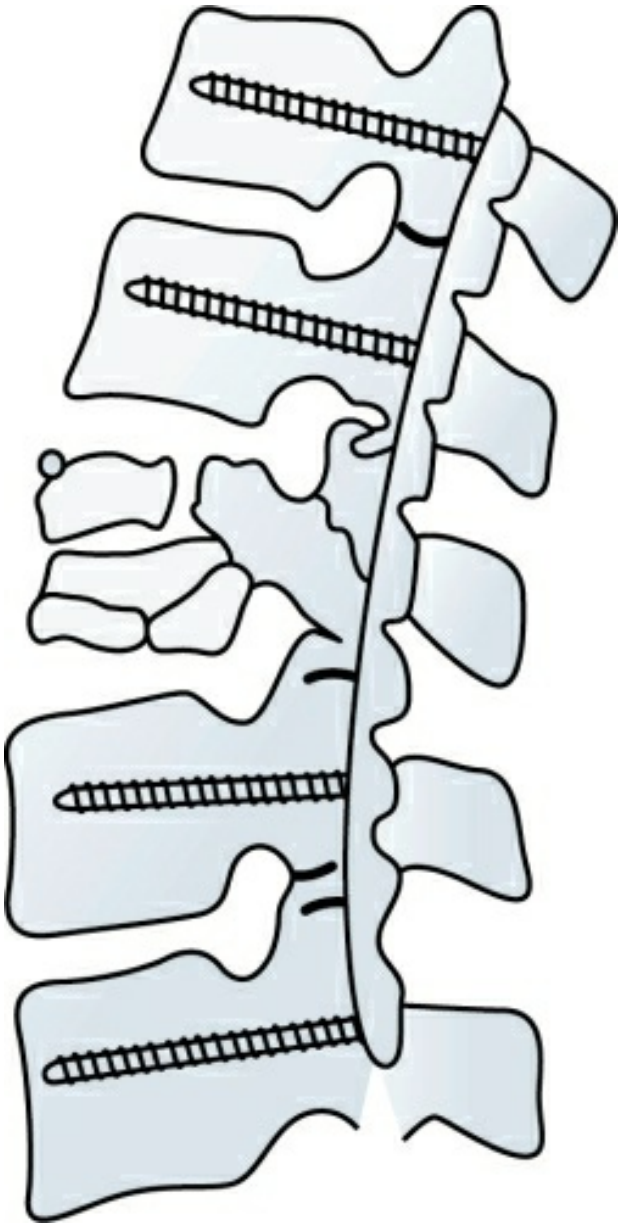

FIG. 11-12 Spinal instrumentation with plate and screws.

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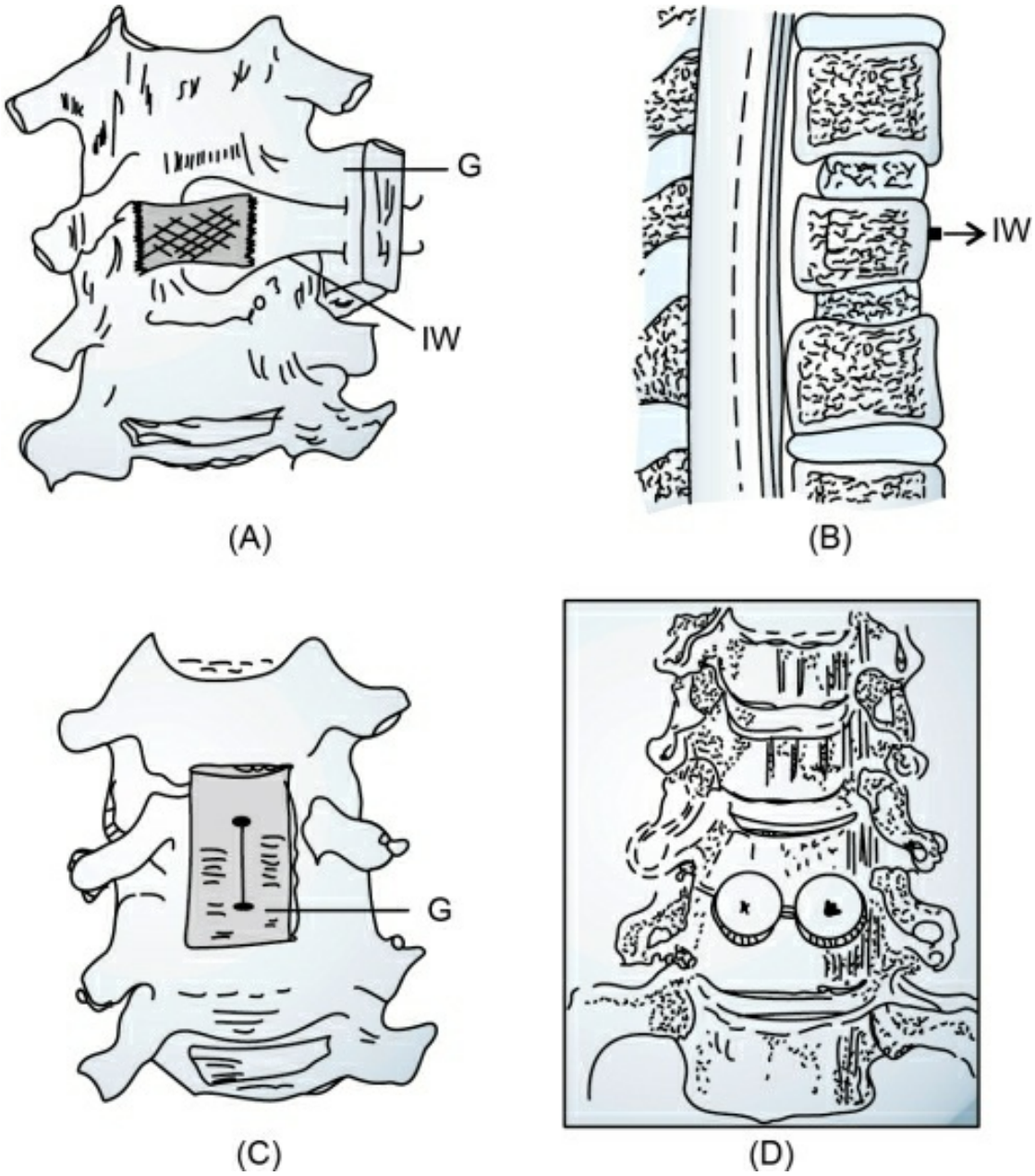

FIG. 11-13 Spinal fusion single interbody block fusion. **(A and B)** Widening of the spinal defect and graft (G) secured with isthmus wire (IW). **(C)** Graft in place. **(D)** Double-dowel interbody block fusion.

Physiotherapeutic management

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1. **Treatment of stable uncomplicated injuries:** The role of physiotherapy in these types of injuries is limited only to continuing general exercises or strengthening of the weak muscles. Ergonomic advice to manage activities without putting strain on the cervical region during immobilization is important. Graduated neck movements, in smaller range, can be started as soon as the immobilization is discontinued. Full recovery occurs within 3–4 weeks.

2. **Treatment of unstable injuries:** As soon as the reduction of the fracture and/or dislocation is stabilized and light skeletal traction is applied, a thorough physical examination is conducted. The level of the lesion and the extent of cord damage are identified (Table 11-3) and, accordingly, therapeutic programme is planned and instituted (Table 11-4). In patients without severe neuromuscular defects, vigorous bedside physiotherapy is given during immobilization. As soon as traction is discontinued and a four-poster collar is given, graduated mobilization in the form of turning, sitting, standing and ambulation is begun. Patients with paralysis need extensive physiotherapy.

3. **Management of patients with paralysis (quadriplegia):** To provide maximum functional independence to the patient with various degrees of paralysis is a challenging proposition. It requires untiring efforts both from the physiotherapist and the patient. The achievement depends mainly upon the site and nature of the lesion, the degree of residual neuromusculoskeletal deficiencies and application of the correct methods of physiotherapy.

Table 11-3

Relationship between the Spinal Segment and the Cord Segment at Different Levels

Spinal Segment	Cord Segment
Cervical vertebrae	Add 1 to the vertebral level
Upper dorsal vertebrae	Add 2 to the vertebral level
Lower dorsal	Add 3 to the vertebral

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vertebrae	level
At D10 vertebra	All dorsal segments over
At D12 vertebra	All lumbar segments over
At L1 vertebra	All sacral segments over
Below L1 vertebra	Cauda equina

Note: Due to the disproportionate growth of the vertebral column and the spinal cord, the spinal cord segment corresponding to the given vertebra is always above the level of that particular vertebra. The spinal cord ends at the lower border of the first lumbar vertebra (L1). Beyond this, up to S2 there is only a dural sac containing a bunch of nerve roots – the cauda equina.

Table 11-4

General Guide to the Mechanism of Injury, Common Sites of Injury, Column Involvement and the Stability of the Spine

Mechanism of Injury	Type of Injury	Common Site	Column Involvement	Stability
Flexion injury • Fall on buttocks • Heavy object falling on the flexed spine (see Fig. 11-1A)	Compression fracture	• C5–C7 • L1>L2>D12	Only anterior column failure	Stable
Flexion–rotation injury • Fall on one side • Blow on the side (see Fig. 11-1B)	Fracture dislocation	• C5–C7 • L1>D12	All the three columns	Unstable
Flexion–distraction injury • Car seat belt injury or hypertension injury (see Fig. 11-1C)	Chance fracture	Dorsal spine	Middle and posterior columns	May be unstable
Extension injury • Whiplash injury • Shallow water diving (see Fig. 11-1D)	Burst fracture	• C5–C6 • Lumbar spine	Only anterior column	Stable
Vertical compression injury • Fall from the top with head erect • Heavy object falling on top of the head (see Fig. 11-1E)	Burst fracture	• C5–C6		May be unstable
Direct injury, e.g., bullet injury • Uncontrolled muscle contraction	Fractures of the • Spinous process • Transverse process	Any region	Anterior and middle column	Variable
			Any/all column's failure	Variable

Note: Guidelines to assist in the whole process of physical rehabilitation are presented in, tables 11-3 to 11-6 and 11-8 to 11-12.

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Table 11-5

Major Segmental Innervation of the Muscles of the Upper Limb

C2	C3	C4	C5	C6	C7	C8	T1
Sternomastoid							
		Trapezius					
		Levator scapulae					
		Diaphragm	Deltoid Rhomboids Teres minor Supraspinatus Infraspinatus				
			Biceps, brachialis				
				Brachioradialis, supinator, subscapularis, teres major, coracobrachialis			
				Serratus anterior, latissimus dorsi, extensor carpi radialis longus			
				Pectoralis major			
					Pronator teresPectoralis minor Extensor-digitorum Flexor carpi radialis		
					Triceps, extensor carpi radialis brevis, palmaris longus		
						Flexor carpi ulnaris, extensor carpi ulnaris, flexor digitorum superficialis and profundus, extensor indicis, abductor pollicis longus and brevis, opponens pollicis, flexor pollicis longus, extensor pollicis longus brevis	
						Adductor pollicis	
							Flexor pollicis brevis, abductor digiti minimi, opponens digiti minimi, lumbricals

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							interossei

Table 11-6

Major Segmental Innervation of the Muscles of the Lower Limb

L1	L2	L3	L4	L5	S1	S2	S3
Psoas minor							
	Psoas major Iliacus						
	Sartorius						
	Hip adductors						
		Quadriceps					
			Obturator externus				
			Tensor fascia lata Tibialis posterior				
			Tibialis anterior, extensor hallucis longus, extensor digitorum longus, peroneus tertius, popliteus				
				Gluteus medius Gluteus minimus			
				Quadratus femoris, semitendinosus, semimembranosus, biceps femoris, peronei			
					Obturator internus Gastrocnemius		
					Gluteus maximus		
						Flexor hallucis longus Flexor digitorum longus Soleus	
						Interossei	
							Abductor hallucis, adductor hallucis, lumbricals, abductor digiti minimi

Table 11-8

Guide to Functional Control of the Joints in Relation to the Segmental Levels

Upper Extremity	
Joint	**Segmental Level**

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	C5	*C6*	*C7*	*C8*	*T1*
Shoulder, Elbow	Poor	Fair	Normal		
Wrist		Poor	Fair	Normal	
Hand			Poor	Fair	Normal
Lower Extremity					
Joint	**Segmental Level**				
	L2	*L3*	*L4*	*L5*	*S1*
Hip	Poor	Fair	Fair	Normal	
Knee		Poor	Fair	Normal	
Ankle			Fair	Fair	Normal
Foot			Poor	Fair	Normal

Table 11-9

Expected Self-Care Independence in Relation to the Segmental Level of Involvement and the Areas of Therapeutic Emphasis

Segmental Level	Areas of Therapeutic Emphasis	Expected Self-Care	Self-Care Independence Aids	Transfers
C4	Strengthening upper trapezius, sternomastoid, platysma; use of special respiratory equipment; using vasomotor control by using neck, shoulders and visuospatial feedback to learn balance and equilibrium; tilt-table standing wheelchair training	Typing with special typewriter, turn pages, use of telephone, painting Power wheel chair, controlled by chin or breath controlled 'puff suck' tubes in the mouth	Mouth stick, dental bite, robotic arms, other electronic aids	Total dependenc
C5	Strengthening biceps, trapezius, wrist mobilization to attain flat palm and elbow locking in hyperextension. This assists body lifting in the absence of triceps. Mobilization of scapulae and shoulder girdles; Intensive mat work, turning, rolling, sitting up, self-assisted moving of paralysed limbs; assisted standing in parallel bars Trunk rotation and flexion through neck and shoulder girdle muscles	Eat, type, move papers Manage wheelchair brakes Push wheelchair on plain surfaces	Cock-up splint for wrist stabilization Slot on the palmar surface of splint to hold light gadgets like spoon.	Needs physical assistance
C6	Strengthening extensor carpi radialis to facilitate wrist extension to achieve finger grasp by tenodesis; also strengthen supination to further tighten the grip	Slow writing, eat, drink, wash, shave, brush hair Sitting from lying and reverse Dress upper	Light leather strap with slot to hold small light objects	Bed to wheelchair and back with sliding board

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		half Push wheelchair on sloped ground		
C7	Strengthening triceps, wrist flexors, extensor carpi radialis Vigorous mat work	Turn in bed Independence in dressing Effective use of hand Wheeling over uneven ground and small kerbs Pick up objects from the floor	Flexor hinge splint to facilitate pincer grip	Wheelchair to toilet, car and bath

Table 11-10

Level of Lesion and the Recovery of Function

Level of Lesion	Initial Stage	Following Rehabilitation
Above C5	Mostly fatal as all the functions are severely affected, including breathing	If survives, requires training in the use of special respiratory equipment Physical dependency for most functions Some self-propulsion in powered wheelchair may be possible manipulating with teeth Devices like environmental control units, robotic arms, other electronic aids to increase independence
C5	Loss of all functions of the limbs, thorax and trunk, sensation as well as visceral functions	Physical assistance is required in dressing, personal hygiene, transfers and writing. Independent in powered wheelchair ambulation and eating skills
C6	All functions are impaired except some muscle of the upper limbs	Majority need physical assistance for personal hygiene, dressing and transfers; independence in wheelchair ambulation, eating and slow writing is possible
C7–T1	Personal hygiene, dressing, eating, writing, transfers and ambulation impaired	Almost all achieve independence in all functions consistent with living alone; physical assistance may be needed by some
T3–T6	Personal hygiene, dressing, transfers, ambulation impaired	Independence in wheelchair ambulation, personal hygiene, dressing, and transfer are possible
T7–T12	Personal hygiene, dressing, transfers, ambulation impaired	Bladder and bowel functions recover totally Walking, only as exercise; independent in transfers, wheelchair ambulation, dressing and driving
L1–L4	Bladder, bowel and walking impaired	Bladder and bowel functions recover totally; short-distance independent walking can be regained
L5, S1, S2	Bladder, bowel and walking impaired	Bladder and bowel functions recover totally; walking with two canes or crutches, may need below-knee orthosis; prolonged standing difficult
S2, S3, S4	Only bladder and bowel functions impaired	Total recovery

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Table 11-11

Expected Status of Standing and Ambulation in Relation to the Segmental Level of Involvement

Segmental Level	Status of Standing and Ambulation
C4	Only tilt-table standing; power-driven wheelchair
C5–C6	Standing with total assistance with or without orthosis in parallel bars; wheelchair ambulation
C7–C8	Swing-to gait in parallel bars; wheelchair ambulation
T1–T5	Swing-to and four-point gaits in parallel bars; free ambulation with wheelchair Swing-to on crutches
T6–T9	Stair management on crutches with assistanceChair to crutches and back
T10–L1	All the three 'crutch gaits', managing stairs, ramps and kerbs; crutches to floor and back
Below L1	Freedom in ambulation either with two canes or crutches; prolonged standing may remain impaired

Table 11-12

Guidelines for the Expected Appliance According to the Level of Lesion

Level of the Lesion	Ambulation and the Appliance
Below T6	Wheelchair ambulation
T6–T9	Bilateral above-knee orthosis with attached spinal support
T10–T12	Bilateral AK orthosis with pelvic band
L1–L3	Bilateral AK orthosis with pelvic band; pelvic band can be discarded in due course
L4–L5	BK orthosis
Below L5	Foot drop assist

Phasewise physiotherapeutic functions

a. ***Acute phase of spinal shock (first 8–10 days)***

Immediately following an acute cervical lesion, the emphasis of physiotherapy is on the stabilization of cardiorespiratory status and prevention of early complications.

During this early phase, there is marked cardiorespiratory insufficiency and destruction of nerve cells at the actual

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level of the lesion with loss of function below the level of the lesion.

There is disruption of the reflex arc, reflexes and the reflex activity of bladder and bowel. There is loss of tone of muscles at and below the level of the lesion including the urethral mucosa, resulting in flaccid paralysis and incontinence of bladder and bowel. Deep and superficial sensations are lost. Therefore, immediate measures of resuscitation may be needed to save the patient's life. Patients with lesion at C4, those with severe chest injury, or with a history of chronic pulmonary disease usually need tracheostomy and ventilatory support.

Vital capacity (VC) needs to be monitored frequently, because VC levels below 500–600 mL require tracheostomy.

Whenever possible the use of accessory muscles of respiration like sternomastoid, trapezius and scaleni with higher segmental supply is instrumental in assisting breathing in the C4 lesion with paralysis of the diaphragm.

Patients with moderately stable cardiorespiratory status need concentrated chest physiotherapy in the form of intermittent positive pressure breathing, deep breathing techniques and assisted coughing. Prophylactic chest physiotherapy to prevent chest infection assumes priority. However, if the patient develops chest infection, postural drainage at regular intervals assumes priority over other chest procedures.

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Prevention of early complications

1. *Pulmonary embolism*: The danger of pulmonary embolism is precipitated following venous thrombosis. Therefore, regular checking for the signs of thrombosis like leg swelling with erythema or a low-grade fever is necessary.

2. *Renal complications:* It is a well-documented fact that renal complications account for the majority of deaths following spinal cord injury. Therefore, initially, intermittent catheterization is done three times a day as a safety measure.

3. Complication due to improper positioning in bed: Correct positioning of the patient in bed during this critical phase is of vital importance for the following reasons:

(a) *Prevention of pressure sores*: Susceptible pressure points like sacrum, trochanters, ischial tuberosities, fibulae, malleoli, posterior aspect of heels, fifth metatarsals, occiput and elbows need adequate protection against pressure. The deficient vasomotor control results in ischaemia over these bony prominences. Keeping skin over these parts clean and dry, and regular changing of the patient's position in bed without disturbing the alignment of the shoulders and neck is necessary in these patients (Fig. 11-14).

(b) *Prevention of deformity*: Malpositioning of the limbs invariably results in tightness of the soft tissue which

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results in contractures and later on organize into deformity (e.g., equinus deformity due to the neglect of positioning of the ankle and foot). Thus, these susceptible sites should be taken care of by proper positioning, supports and gentle full-ROM exercises along with frequent checks.

(c) *Maintenance of correct alignment of fracture*: Proper positioning of the neck in relation to the body is important to maintain the correct alignment of the fracture. Therefore, this also needs regular checks.

(d) *Prevention of heterotrophic ossifications*: Excessive stretching of some of the susceptible joints or the spastic muscles (e.g., at hip, knee, elbow and medial aspect of femur) may result in ectopic ossification (Fig. 11-15), a complication which further complicates rehabilitation. Overstretching of the joints in the terminal range should be strictly avoided.

(e) *Prevention of oedema*: The loss of vasomotor control and muscle tone results in stasis and the hands and feet are prone to develop gravitational oedema. Therefore, proper positioning of the limbs with elevation and other physiotherapeutic measures are necessary to reduce oedema to the maximum. Persistence of oedema may lead to trophic changes, hand stiffness, or even Sudeck's osteodystrophy. While maintaining correct positioning of the body, maintenance of paralysed hand in good functional position is important. This is achieved by using a short cock-up splint, palmar roll and bandage. The wrist is maintained in 45° of extension, the

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metacarpophalangeal (MCP) joints in 90° of flexion, IP joints in 30° of flexion and thumb in opposition. Keeping MCP joints in full flexion puts stretch on the collateral ligaments preventing the swelling (Cheshire and Rowe, 1970–71). However, regular sessions of relaxed full-range passive movements by removing bandage and splint are necessary to avoid tightness.

(f) *Autonomic dysreflexia*: It occurs as a result of *malfunctioning* of the body's normal regulatory mechanisms for blood pressure and temperature in the lesions above T10 level. It is a serious complication which could be life-threatening if not detected and controlled at the initial stage. The signs and symptoms of autonomic dysreflexia are as follows: irregularity in the level of blood pressure which may shoot up suddenly, variation in the skin temperature and colour, excessive sweating above the level of lesion, severe headache and feeling of congestion. Factors like bladder distension, urinary complications, stool impaction and pressure sores may produce irritation or discomfort to the body below the level of injury. Autonomic dysreflexia is more commonly seen in patients with lesions above T5 level, but it can be avoided with early detection and proper measures.

When any of the for-mentioned symptoms is noticed, it is necessary to check for the distension of bladder, bowel obstruction due to accumulation of stools, skin irritation or lesion due to tight clothing, appliance or aids, etc.

Adopting sitting or semireclining posture and adequate measures to control the respective causative factors is

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useful to control autonomic dysreflexia (Ozer et al., 1987).

(g) *Chronic pain:* Receiving and processing of the sensory information from the periphery continues below the level of the lesion. However, it is blocked at that level and cannot be transmitted to the higher centres, resulting in the loss of normal smooth interplay and appropriate action. This malfunctioning of both the reflex centres results in an overexcited response to the stimuli entering the spinal cord. The stimuli are perceived either as inappropriate sensations of pain without any tissue damage or as uncontrolled muscle contractions like spasticity.

The pain could be mechanical (sharp, localized and aggravated by movements), inflammatory (not localized to the site of injury), due to contracture, arthritis, or inflammation of the joints and tendons, or as a phantom sensation of tingling, burning or dull ache in the back, legs or feet.

The treatment depends upon the clinical evaluation. Combination of treatment like appropriate choice of physiotherapeutic modality, exercises, medication and psychotherapy are effective. Transcutaneous electrical nerve stimulation (TENS), however, is the treatment of choice.

(h) *Prevention of osteoporosis*: Immobilization and prolonged bed rest are associated with atrophy of the musculoskeletal system which alters the mineral

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mechanism of bone formation resulting in osteoporosis. Osteoporotic bone becomes susceptible to spontaneous fracture even with sudden stretching of the joints. Frequent turning in bed during early stage, passive movements to the paralysed limb, resisted movements to the paretic limbs and early weight bearing like tilt-table standing can prevent osteoporosis.

(i) *Early identification of paralytic ileus*: The presence of abdominal distension with breathing difficulty and nausea is the sign of paralytic ileus. This interferes with respiration and needs immediate medical attention.

b. ***Weaning phase of the spinal shock***

1. A thorough evaluation of the residual neuromusculoskeletal deficiencies

2. Planning and efficiently conducting the therapeutic programme on an individual basis

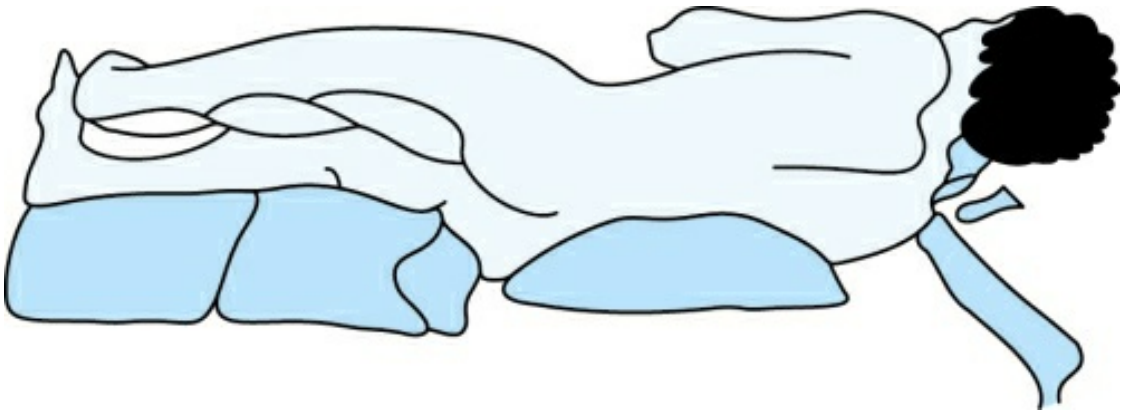

FIG. 11-14 Positioning of the patient in bed to prevent pressure sores (side lying).

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FIG. 11-15 Radiograph of the hip joint showing ectopic bone formation connecting the ilium bone with the trochanteric region.

When the symptoms of the acute spinal shock recede, the cells of the isolated cord recover function. Spasticity sets in with the return of reflexes. However, when there is longitudinal vascular damage to the cord, or when the cord is injured in longitudinal as well as transverse planes, flaccidity may persist. In incomplete and bilaterally asymmetrical lesions, there may be return of power in the muscle groups whose segmental innervation is spared.

Physical examination: As this phase is the most important phase of rehabilitation needing vigorous physiotherapy, detailed neuromusculoskeletal examination needs to be conducted. This helps to identify the site and the degree of damage to the cord and the prognosis. In fact, this forms the basis of planning the regime of physiotherapy.

Manual muscle testing of various muscle groups is critically done and analysed with reference to the segmental innervation charts (Tables 11-5, 11-6, 11-9 and 11-10). The tone of muscles is assessed through passive ROM, palpation and limb positioning. Evidence of nerve irritation is demonstrated at one level above the actual site. For example, symptoms of lesion at the C5 level will be present when actual damage occurs at the C6 level. Therefore, spasticity will be present in the deltoid, elbow flexors and forearm supinators when the actual level of the lesion is at C6. The presence of spasticity in a particular muscle group can be identified by typical spastic posture of the arm in bed. Muscle length and joints are carefully examined for the functional requirement of the individual joints as well as the whole limb. Sensory status is examined in detail for pain, touch, position sense and superficial and deep reflexes.

Guidance to formulate the individualized management programme is provided by a series of the following tables only after critical evaluation (Table 11-7).

Table 11-7

Guidance to Identify the Involved Nerve Root by the Respective Decrease in the Sensory Motor Response

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Involved Nerve Root	Decrease in the Sensorium or Sensory Response	Decrease in the Motor Response
C2	Over the back of scalp	
C3	Over the anterior aspect of neck	In C2–C4 nerve root injuries, survival of a patient itself is rare
C4	Over the lateral aspect of neck and inferiorly over the clavicle down to the ribs	
C5	Over the lateral part of deltoid muscle	Voluntary activity of the deltoid and biceps
C6	Over the radial aspect of forearm, thumb, index and middle finger	Extensor carpi radialis longus (ECRL) and brevis (ECRB)
C7	Over the ulnar border of ring and little finger	Triceps, finger extensors, pronator teres and flexor carpi radialis (FCR)
C8	Over the ulnar border of forearm and hand	Flexor digitorum superficialis (FDS) and/or flexor digitorum profundus (FDP)
T1	Over the medial aspect of upper arm	
T2	Over the anterior chest wall above the nipple	Intrinsic hand function is intact

Hands and legs are examined for oedema. Lack of muscle tone and vasomotor-control deficiency greatly enhances oedema. Persistence of oedema converts collagen deposits into fibrous tissue, resulting in fibrous contractures. The findings of all these tests are correlated with the relative spinal segmental innervation to confirm the lesion.

After extensive evaluation of patient's ability and the inability records, the prognosis of recovery should be considered as the first priority to design correct formulation of the therapeutic plan.

Therapeutic procedures

Passive movements: Relaxed slow and rhythmic passive movements aid in improving circulation, preventing deformities, reducing oedema, educating movement patterns and reducing spasticity.

Caution

Movements should be performed without eliciting muscular spasm. Overstretching of the spastic muscle group should be strictly avoided as it may result in complications like ectopic ossification, rupture of muscle fibres or even spontaneous fractures.

Mobility exercises: Mobility exercises provide the mobility of scapulae, elbow, wrist and fingers. Maintenance of the normal *length of the*

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muscles passing over more than one joint is of extreme importance in quadriplegics. They are needed to facilitate functional activities, and hence need special emphasis.

Active movement: Movements in the muscle groups with intact innervation should be progressed in grades from assisted active to active resistive modes to repetitive performance of guided self-resistive mode wherever possible to hypertrophy of the paretic muscle groups. Proprioceptive neuromuscular facilitation (PNF) techniques with precision are extremely useful. However, compensatory mechanisms like tenodesis and other functional controls should always be kept in mind and emphasized more than the usual muscle strengthening procedures (Table 11-8).

Vasomotor control: The blood vessels in the viscera fail to constrict on assuming vertical posture when the vasomotor control is lost. Adequate compensation can be achieved by the training of the reflex arc by breathing exercises, altering the position in bed and gradually progressing to sitting or standing on the tilt table.

Postural sensibility: Kinaesthesia below the level of lesion results in loss of perception of movements and position of the body and limbs in space. The new postural sense is developed through visual feedback. This is facilitated by long practice sessions in front of mirror. It takes a long time and needs tremendous efforts.

Control of oedema: Oedema can be controlled by elevation of the foot end of the bed, keeping the oedema to limb in further elevation, using hand splints with bandage and inflatable plastic splints. Regular relaxed passive movements or speedy isometrics, whenever possible, play an important role in the control of oedema.

Control of spasticity: Spasticity greatly obstructs smooth and coordinated movements and self-care. Therefore, it is essential to control it as soon as it sets in. This is done by proper positioning of the limb. Proper positioning in the early phase inhibits the onset of

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severe spasticity and also influences the pattern of spasticity. Reflex inhibiting postures on mat, standing with correct posture and weight distribution, relaxed controlled passive movements, PNF techniques and carefully monitored cryotherapy are useful.

Re-education of self-care: The attainment of independence in self-care is the ultimate aim of treating these patients; therefore, it needs to be initiated right from the earliest stage. The degree of functional independence *depends not only on the extent of the spinal cord lesion but also on the physical proportions,* e.g., height, weight, arm length in relation to the length of the trunk, early adequate management and motivation of the patient.

Therapeutic procedures and self-care training are planned by referring to the segmental innervation charts (Tables 11-5, 11-6, 11-9 and 11-10), expected joint control as related to the level of the lesion (Table 11-8) and the degree and distribution of spasticity as recorded in the physical examination chart. Mat activities are instrumental in initiating the training of the major self-care re-education activities like turning, rolling, sitting from lying, lying from sitting, trunk balance in sitting and balanced transfers. Training for wheelchair manoeuvres is initiated along with the mat training. The self-care training is greatly facilitated by the intelligent assistance of the surviving muscles, compensatory mechanisms, tricky movements and various simple adaptations (Table 11-9; Figs 11-16 and 11-17).

Standing and ambulation: Standing, although not practical in high cord lesions, is initiated with assistance for its following advantages:

- It prevents renal complications.
- It reduces spasticity.
- It stimulates circulation.
- It prevents osteoporosis.

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- It improves postural sensibility and vasomotor control.
- It provides tremendous psychological influence on the patient.
- Standing and ambulatory capabilities related to the various spinal lesions are elaborated in Table 11-11 and the guidelines for the expected appliances and assistive aids in Table 11-12.

Bladder and bowel management: During the acute stage of spinal shock, the paralysed bladder is unable to empty because of the suppression of the automatic cord reflex of micturition. This results in the loss of reflex detrusor contraction and the bladder gets distended. Therefore, prevention of overdistension is a must at this stage. This can be managed by intermittent urethral catheterization, indwellling catheter or indwelling suprapubic catheter. Periodic irrigation of the bladder with mild antiseptic solution is a must to prevent infection.

The behaviour of the bladder following this acute phase of shock depends upon the level and the extent of injury.

Neural control of the bladder: The reflex centre controlling the bladder is situated at S2–S3 level of the spinal cord. This, in turn, is controlled by the inhibitory influences from the cortex.

The basic principles of bladder training programme include the following:

1. Training of the bladder to hold reasonable quantity of urine before it empties

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2. Training for regulation of the interval for bladder emptying

3. Training to initiate the flow of urine

4. Training to minimize the residual urine

Automatic (reflex) bladder: When there is complete transaction of the spinal cord above T10–T11, a reflex-controlled automatic neurogenic bladder develops within 3–6 weeks following injury. This is also called *upper motor neuron bladder*. The reflex arc which extends from the bladder to the sacral cord synapses and then forms a connection with the bladder thus provides a simple reflex control to the bladder. On full distension of the bladder, the bladder wall is stretched, and sets a reflex activity which involuntarily empties the bladder. The patient has no voluntary control except the sensation of fullness in the abdomen. The intrinsic stimulus in the bladder wall or the extrinsic stimulus that provokes may lead to closure of the reflex arc due to summation of the afferent stimuli. It suddenly brings about involuntary emptying of the bladder. With training, the reflex action can be initiated on stimulation of certain 'trigger points'. This area is to be identified and tapping is done to set in the reflex for voiding. The quantity of residual urine after involuntary emptying is marginal and hence is not prone to frequent infections. The bladder reconditioning is achieved by reflex voiding of the bladder by clamping the urinary or the suprapubic catheter. The catheter or the suprapubic tube is removed when the reflex emptying of the bladder is learnt.

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Autonomous neurogenic (nonreflex) bladder: This type of bladder is also known as *lower motor neuron or atonic bladder*. This develops when the spinal cord lesion is longitudinal or on the lower motor neuron. Therefore, the bladder now totally depends for its control on the detrusor ganglia, an intrinsic plexus which is situated in the bladder musculature. This type of bladder needs training, and physiotherapy plays an important role in the training. Training of abdominals, diaphragm and pelvic floor muscle contraction and their sustenance increases the intra-abdominal pressure and facilitates bladder emptying. If this is not achieved due to involvement of the abdominals, the bladder can be emptied by teaching the patient to exert manual pressure on the lower abdomen directly over the suprapubic area.

For female patients, no satisfactory urine bags are available; therefore pads and rubber pants are the only alternatives. Training methods otherwise are the same as for males. The bladder training programmes need careful monitoring. The bladder should be emptied to the maximum; otherwise the amount of residual urine in this type of bladder is quite large (200–400 cc). It may predispose the bladder to recurrent infections.

The bladder training programme has to be associated with increased amount of fluid intake (at least 2–3 L a day), regular bladder wash, maintaining the fluid intake and urinary output chart, and closely monitoring the signs and symptoms of bladder infection.

Bowel management: The paralysis of the bowel may lead to

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discomfort due to faecal retention or uncontrolled bowel movements. In case of permanent incontinence, the patient needs to be trained in the following:

1. Attempted evacuation at regular periods (every second day)

2. Control of diet and fluid intake – to soften the faecal matter

3. Use of suppositories

4. Use of enema

5. Digital evacuation

It is important to find out the most suitable method on an individual basis and also regularize it.

Sexual functions: In male paraplegics with complete lesion, orgasm and erection are difficult; however, production of semen, which depends upon the gonadotropic hormones, is not affected. Ejaculation, which is reflex in nature, can occur; thus the power of recreation is not lost. In incomplete lesions, a great deal of variation occurs. When it returns, it does so with the reappearance of reflexes.

In females, menstruation, and even pregnancy, usually returns within 2–3 months even in complete lesions of the cord.

Proper guidance and counselling play an important role in adjusting sexual problems in these patients.

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FIG. 11-16 Guidelines for performing functional activities. **(A)** Rolling. **(B)** Sitting.

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(A1)

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(A2)

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(A3)

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(B1)

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(B2)

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FIG. 11-17 Guidelines for performing functional activities. **(A)** Transfer from wheelchair to bed. **(B)** Standing with assistance.

Injuries of the thoracolumbar spine

Fractures of the transverse processes, spinous processes and pars interarticularis

The fractures of the transverse process are seen occasionally, but those of the spinous processes are rare. Fractures of the transverse processes of the lumbar vertebrae may be associated with fractures of the spine or pelvis. Isolated injuries are usually avulsion injuries because of the pull of the powerful muscles attached to the transverse processes.

Treatment

It consists of bed rest and analgesics. In fractures of the transverse processes of the lumbar vertebrae, keeping a pillow under the knee joints in supine position may help relieve the pain. By keeping the knee joints in slight flexion, the lumbar lordosis is obliterated, thereby relaxing the paraspinal muscles.

Physiotherapeutic management

Measures to control inflammation, pain and swelling are necessary. Diapulse, TENS and ultrasound can be used as adjuncts. The patient is advised bed rest.

Early initiation of indirect isometrics through neck or legs as small-range active movements may be started, after 2 weeks.

The rest of the mobilization, strengthening and back to work programme is followed on the same lines as for the fractures of the vertebral body.

Fractures at the thoracic spine

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- Common fracture types include the following:
- Compression fractures
- Burst fractures
- Flexion–distraction fracture
- Fracture dislocation
- Subset
  - Flexion–rotation
  - Flexion–distraction
  - Shear fracture

Thoracic spine injuries

Fractures of the thoracic vertebrae are relatively less common. In the upper dorsal (thoracic) spine, the rib cage offers stability and hence, generally compression (wedge) fractures of the vertebra occur (Fig. 11-18A). However, when the injury is severe, a fracture dislocation may occur (Fig. 11-18B). The spinal canal is relatively narrow in this area and therefore the spinal cord gets invariably damaged in this type of injuries resulting in paraplegia.

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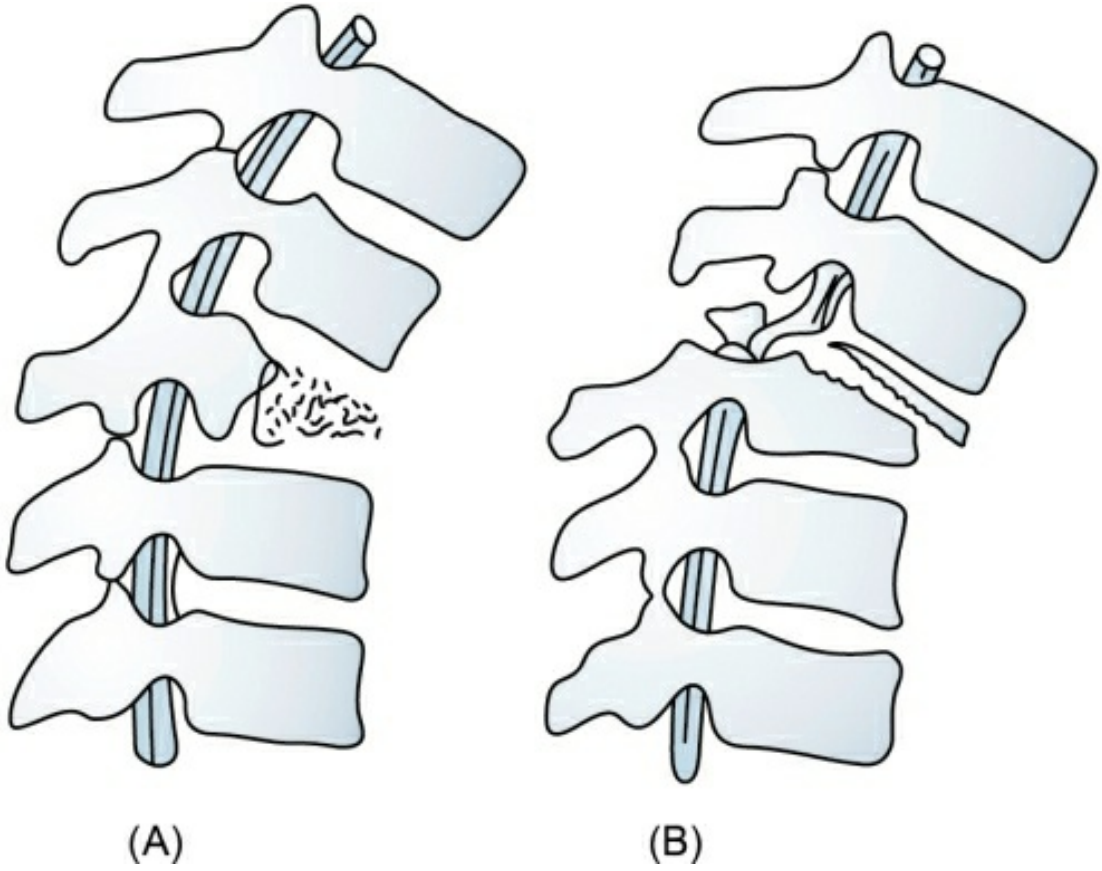

FIG. 11-18 Injuries of the thoracic and lumbar spine. **(A)** Stable to uncomplicated wedge compression fracture (intact spinal cord) due to flexion force. **(B)** Complicated or unstable fracture dislocation due to combined flexion–rotation force producing transaction of the spinal cord.

Thoracolumbar spine injuries

The thoracolumbar spine is more mobile, and therefore injuries to this region are quite common. The injuries may belong to one of the following.

McAfee classified thoracolumbar injuries into the following four varieties:

1. Wedge compression fracture

2. Burst fracture

3. Chance fracture

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4. Translational injuries

1. **Wedge compression fracture**. It is the most common type of vertebral fracture which occurs due to flexion injury. It is a stable injury since the posterior ligament complex is intact; it is also common in osteoporotic patients (Fig. 11-19).

2. **Burst fracture:** Severe compression force 'breaks' the vertebra into multiple pieces. The fragments of the body of the vertebra may get displaced into the spinal canal causing compression of the spinal cord. This can be a stable or instable injury depending upon the damage.

3. **Fracture dislocations**: This type of injury is grossly unstable and is associated with paraplegia. It is a combined flexion–compression and rotational injury (translational injury) (Fig. 11-20).

4. **Chance fracture:** It is a combination of flexion–distraction injury, e.g., sudden forward throwing of the chest and upper trunk forward against the seat belt causing grossly unstable injury on applying sudden brake while driving (Fig. 11-1C).

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FIG. 11-19 Wedge compression fracture.

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FIG. 11-20 Translational injuries.

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Lumbar spine injuries

Types of injuries to the lumber spine

Fracture patterns

- **Flexion pattern:** Compression or axial burst fracture
- **Extension pattern:** Flexion–distraction or chance fracture
- **Rotational pattern:** Fracture dislocation
- Fracture transverse process (in forceful side flexion injury)

Since the spinal cord ends below the lower border of the L1 vertebra, fractures of the vertebra below this level usually result in injury to the nerve roots with resultant incomplete paraplegia. The chances of neurological recovery are quite high in these cases.

Clinical features

- History of RTA or a fall from height
- Localized pain, tenderness, swelling or a step
- Back held rigid
- May have positive neurological signs with incomplete paraplegia (also called *paraparesis*) or complete paraplegia.
- Cauda equina lesion
- Bladder incontinence

Investigations

- Digital radiograph (especially lateral view)

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- MRI if necessary to identity the soft tissue involvement along with skeletal injuries

Treatment

It can be divided into the following:

1. Treatment of the skeletal injury

2. Treatment of the paralysed patient

Treatment of the skeletal injury

The following methods of treatment are employed depending upon the severity and the level of injury.

(a) *Bed rest*: A stable, uncomplicated fracture of vertebra is treated by simple bed rest on a hard bed for a period of 4 weeks.

(b) *Plaster jacket*: A stable fracture, without paraplegia, may also be treated by a plaster jacket for 8–12 weeks.

(c) *Brace*: A spinal brace – Jewett brace or CASH brace (cruciform anterior spinal hyperextension brace) for 8–12 weeks – may be used instead of a plaster jacket.

(d) *Postural reduction*: The patients having fracture dislocation with paraplegia are treated by rest in bed with a pillow placed under the fractured part of the spine. The patient is given a spinal brace after 4–6 weeks and mobilized.

(e) *Spinal stabilization*: A patient with fracture dislocation of spine with paraplegia is nowadays treated by spinal stabilization. The fractured segment of the spine is opened up by operation, reduced if possible, and fixed internally with a variety of internal fixation devices. Although neurological recovery is not guaranteed following this operation, particularly in cases where the cord is damaged considerably, the patient can be mobilized early, almost on the second

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or third day after operation. Early mobilization eliminates the problems of prolonged recumbency in a paraplegic patient.

Surgical treatment

Surgery is indicated in patients with

- Unstable injuries
- Deteriorating motor paralysis
- Bony fragment compressing the spinal cord or in total lesion of the spinal cord to facilitate ambulatory activities

Surgical procedures

1. Posterior decompression by laminectomy and excision of the spinous process and stabilization of the spine transpedicular screws (Fig. 11-21)
2. Anterior decompression by carpectomy and spinal stabilization by bone grafting and spinal instrumentation
3. Spinal fusion conducted with laminectomy to provide better stability to the injured spine or in old fractures with painful kyphosis

Postoperatively, the patient is nursed in bed for 3–4 weeks after which he is given a spinal brace (support) and mobilized.

Spinal fusion: Rarely, this operation is indicated in the following situations:

- Along with the operation of laminectomy: combined with laminectomy by some surgeons, with the idea of giving

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stability to the spine

- In old cases of fracture of the spine where painful kyphosis results

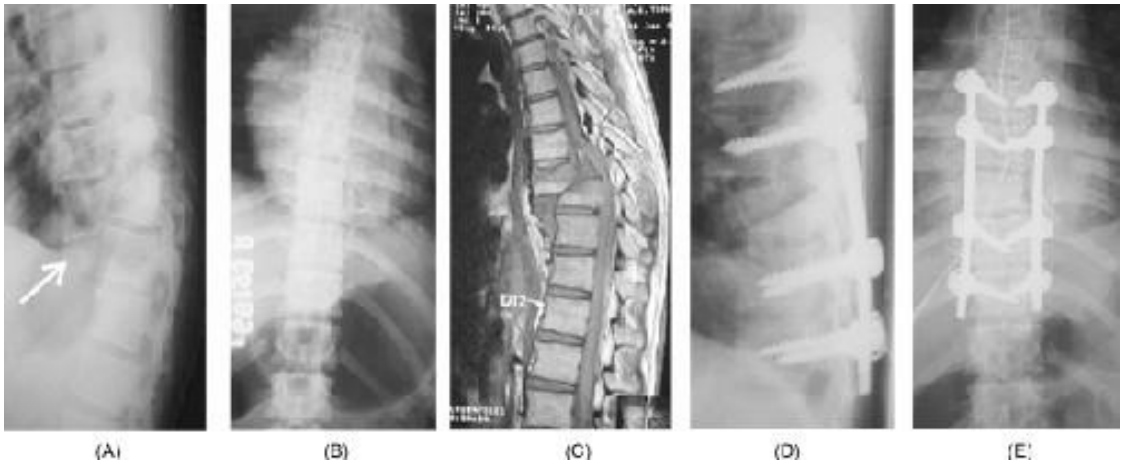

FIG. 11-21 Fracture dislocation of the dorsal spine. **(A)** Lateral view radiograph showing gross displacement (arrow) of the vertebrae. **(B)** AP view. **(C)** MRI scan of the same patient showing fracture dislocation of D8–9 vertebrae. **(D and E)** Lateral and AP views showing reduction of the fracture dislocation and fixation with pedicular screws.

Physiotherapeutic management

Cases treated by conservative approach

Objectives:

1. To restore normal or at least functional ROM at the thoracolumbar spine (Table 11-13)

2. To optimize the strength, power and endurance of the muscles of trunk and upper limbs, with special efforts to work on the functional muscles required to assist ambulation, e.g., quadratus lumborum, latissimus dorsi,

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trapezius, paraspinal muscles, biceps, triceps and wrist extensors

3. To achieve self-sufficiency in the management of the problems of bladder and bowel incontinence, and ADLs like self-dressing, maintenance and also in the correct use of devices or appliances.

4. To provide exercise to quadratus lumborum, multifidus, transverse abdominals for providing better stability to the spine

5. To increase the strength of these muscles for reducing symptoms and pain and preventing recurrence

Expected problems:

Spinal canal being relatively narrow, extensive spinal cord damage is suspected. This may result in paraplegia with its complications.

Immobilization:

1. Maintenance of the proper posture of immobilization.

2. Graduated isometric contractions are given to the spinal extensors and abdominals. If a POP jacket has been given, the isometrics can easily be performed by pressing against the plaster. If only positioning is selected as a method of immobilization, resistive flexion and extension of the neck will induce static contractions in the abdominals and spinal extensors, respectively. They are important in preventing atrophy and improving

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circulation at the site of fracture. Active exercises to the neck as well as hips are useful.

Caution

Exercises like SLR put excessive compression stress on the lumbar region and hence should be initiated late and with extreme caution.

Table 11-13

Normal ROM at the Thoracolumbar Spine

Movement	Normal ROM
Flexion	0–60º
Extension	30–40º
Lateral flexion	0–30º on either side
Rotation	0–20º on either side

3. The excursion of thorax is restricted either because of fixed lying or due to the plaster jacket. Early initiation of deep breathing is very important. Maximum expansion of the thorax and its recoiling should be encouraged either against hands or plaster. VC should be regularly monitored by spirometry.

4. Full-ROM, resisted arm and leg movements should be initiated without causing extra fatigue or pain. Slow cycling movement one leg at a time is ideal if not painful.

Patients treated by a POP jacket can be made to sit up and ambulate earlier as it is safe. However, they need training sessions of sitting, getting up, standing, balancing, weight transfers and gait training initially. They should be given functional training on the activities of daily work.

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Mobilization:

1. Mobilization should be started by training the correct method of turning in bed with the knees bent and with adequate arm support.

2. The correct method of sitting up in bed, avoiding undue strain on the fracture site, is taught, totally using both the arms.

Caution

Flexion and rotational attitudes of the spine in flexion injuries, and hyperextension in extension injuries should be strictly avoided.

3. Graded extension exercises with elbow or forearm support should be begun for patients with flexion injury and graded flexion exercises for patients with extension injuries.

4. Side flexion of the trunk should be started with the patient sitting with hands at the back of head, and the physiotherapist stabilizing the pelvis.

5. Spinal rotation should be initiated in the same position.

6. All the exercises should be made progressive in ROM, strength and endurance.

7. Progressive ergonomic training for the spinal mechanics during various daily activities is of vital importance.

8. Heavy outdoor activities, games, swimming and cycling can be progressed in stages, to regain the preinjury

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status.

Physiotherapy for patients treated by surgery

Stabilization procedures:

Spinal stabilization procedures facilitate early safe mobilization of a patient as the stability to the injured spine is ensured.

First two days: Careful monitoring to prevent the expected post-surgical complications.

Third day onwards: Gradual mobilization is begun; 'block rolling' is initiated so that the whole body is turned together as a block. This has to be observed strictly as it prevents rotational torque to the trunk.

It is progressed to supported sitting. The patient can be transferred to a tilt table for the initial period of standing. This is progressed to standing in parallel bars with adequate orthoses fabricated before surgery. This can be eventually progressed to ambulatory training in phases.

Laminectomy and spinal fusion: After surgery, besides the routine measures to prevent postsurgical complications, efforts are made to elicit voluntary contractions in the paralysed muscles. Possible muscle recovery following decompression should be monitored carefully and adequate therapy is given to strengthen these muscles.

When no muscle recovery is noticed, treatment should progress on the same lines as described for stabilization procedures. However, if the strength in the muscle groups improves, concentrated therapy is given before deciding about the orthosis.

A patient with a chronic back pain over the thoracolumbar area may report for physiotherapy. Ensure that there is no vertebral fracture, as 65% of vertebral fractures are asymptomatic and may remain so for 1.5 years following the injury.

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Identify such patients from associated symptoms like

- Reduced spinal mobility
- Impaired pulmonary function
- Osteoporosis
- Slow ambulation with gait abnormalities
- Impaired balance

Treatment of a paralysed patient (paraplegia)

Basic objective: To provide optimal physical independence within the limits of the disability.

General principles:

1. Prevention of complications

2. Maintenance of good morale

3. Maximal return of self-care and functional status, through untiring efforts

The phases of management:

- Acute phase
- Rehabilitation phase

During both the phases, the basic mode of physiotherapy, including bladder management in thoracolumbar lesions, remains the same as described for the cervical lesions. The major difference is the better self-care and functional control in the former because of the normal sensory-motor status of neck, upper extremities and upper trunk in majority of the patients. However, some areas need greater emphasis

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in the management as listed here.

1. **Prevention of deep venous thrombosis:** Legs are the common sites of deep venous thrombosis. Regular checking of the legs for swelling and erythema associated with low-grade fever is necessary. Movements of the legs should be avoided if signs and symptoms of venous thrombosis are present – to avoid serious complications of embolism.

2. **Reduction of spasticity:** The presence of severe spasticity greatly influences the achievement of ambulatory efficiency, as it needs extra attention right from the initial phase.

Proper positioning of the lower limbs is essential during the acute phase of spinal shock. Careful clinical examination is conducted to identify the pattern and the degree of spasticity and the muscle groups involved. Necessary measures like the reflex inhibiting postures, relaxed passive movements, prolonged stretching, longer periods of standing and walking and hydrotherapy or cryotherapy are taken to reduce spasticity.

3. **Prevention of ectopic ossification:** The common sites of developing this complication are the lower extremities (e.g., hip joint, medial aspect of femur and knee). Therefore, stretching around these areas should be strictly avoided. Regular checking is done to detect early signs of heterotopic ossification like spongy feeling of the joint during movements, tenderness, warmth and erythema over these sites.

4. **Prevention of tightness and contractures:** Common sites to develop tightness and contractures like hip flexion and adduction, knee flexion and ankle plantar flexion need regular monitoring. Adequate measures like proper positioning, splinting and procedures to fully stretch these soft tissues are important.

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5. **Strengthening and re-education of specific muscle groups:** Besides hypertrophy of innervated muscle groups, some muscle groups like latissimus dorsi (Fig. 11-22A and B), trapezius, abdominals play an important role in the maintenance of trunk balance. The muscle groups facilitating crutch walking and transfers like shoulder abductors, depressors, elbow and wrist extensors and finger flexors and quadratus lumborum (Fig. 11-22C) need special attention. Besides, there are activities helpful in the hypertrophy of the functional muscle groups such as:

- Wheelchair – transfers to and from bed
- Driving wheelchair with partial application of the brake
- Push-ups in the wheelchair (Fig. 11-22D)
- Use of dumbbells, weight belts will add to the confidence of a patient

6. **Standing-gait and ambulation:** Correct methods of standing from wheelchair (Fig. 11-23), standing balance, weight transfers and pelvic tilting are taught in parallel bars and in front of wall bars (Fig. 11-24).

Gait training is also initiated first in parallel bars. Basic methodology of gait training like single leg balance, moving hands first, proper placement of the feet, transferring the body weight through feet, and lifting body rather than dragging feet is emphasized. Long and repeated sessions of practice are needed to learn perfect balance, timing, rhythm and coordination of independent controlled walking.

Other ambulatory requirements like turning, side walking and back walking, climbing steps, negotiating slopes and

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ramps, getting down and up from the floor on to crutches are also practised in lesions between T6 and T10 with good abdominals (Fig. 11-24).

In general, functional walking is not expected in lesions above T6 level. Below this level, gait training and ambulation need adequate appliances and a specific pattern of gait depending upon the level of lesion (see Tables 11-11 and 11-12).

Gait patterns: The type of gait also depends on the level of lesion. During the initial phase of training, the patient is first made to walk with the simplest and the safest pattern of gait, i.e., the 'shuffle gait'. In this gait, the patient brings both the arms forward one after the other (later on crutches) and brings both the legs forward simultaneously with toe drag.

The patterns of gait for these patients:

- Swing-to gait
- Swing-through gait
- Four-point gait

Swing-to gait: This is the safest and simplest type of gait and hence is known as a universal pattern. Therefore, this gait is taught wherever there is marked instability, e.g., in patients with level above T10 lesion. Bilateral above-knee (AK) orthoses with axillary crutches are necessary. Some patients may even need spinal support during the initial stage.

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Swing-through gait: This is the fastest and most useful pattern of gait which is very much acceptable to patients. This is possible only after a long practice as it requires skilled balance to lift both the feet above the ground and carry them forward beyond the level of the crutches.

Four-point gait: This is the slowest of the three, but is more like a normal walk. This gait needs to be included as a therapeutic measure as it improves strength, balance and coordination. It also greatly helps in learning turning in confined spaces. As it needs good balance and dynamic limb control, patients with lesion lower than T12 acquire proficiency in this gait.

7. **Appliances:** The physiotherapist has to prescribe and check all the appliances needed by a patient. They need to be checked and adjusted while being used (e.g., braces in standing). The limb needs to be checked at the pressure points to the brace during its use.

The patient is also trained to put on and remove the appliances, their correct use as well as their maintenance.

While planning the therapeutic regime, it is absolutely essential to give due importance to vocational planning following rehabilitation. The physical activities expected in the postrehabilitation phase need to be incorporated in the therapeutic procedures to facilitate vocational tasks.

The goal of the physical, vocational, social and psychological independence is usually very complex. The major share of success rests with the physiotherapist because achieving social, psychological or vocational independence is impossible without physical independence.

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The untiring efforts by the patient and motivation and skill of the physiotherapist are the major requirements of rehabilitation of tetraplegic and paraplegic patients.

(A)

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(B)

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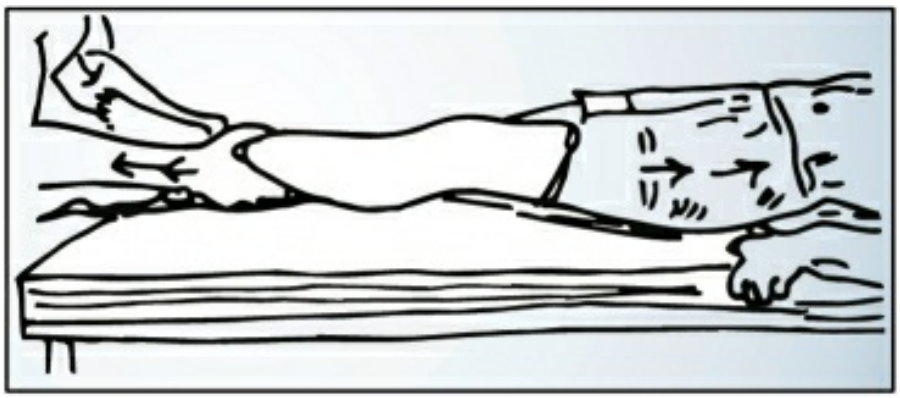

(C)

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(D)

FIG. 11-22 Strengthening exercises for functionally important muscle groups. **(A and B)** Latissimus dorsi. **(C)** Quadratus lumborum. **(D)**

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Wheelchair push-ups against body resistance.

(A)

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(B)

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(C)

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FIG. 11-23 **(A–C)** Standing from wheelchair.

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(A)

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(B)

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(C)

FIG. 11-24 **(A)** Standing balance in parallel bars. **(B)** Standing balance on crutches. **(C)** Weight transfer.

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CHAPTER
12

Injuries of the pelvis

OUTLINE

- Fractures of the pelvis
- Injuries of the coccyx
- Fracture of the ribs

Fractures of the pelvis

Fractures of the pelvis can constitute a major injury and can result from road traffic accidents. They are broadly classified into two types: due to low-impact trauma, e.g., fall on the side and heavy impact trauma – fall from height.

1. Isolated fractures of the ilium, pubic rami and sacroiliac subluxation

These are generally stable injuries since the pelvic ring is intact (Fig. 12-1).

Treatment of these injuries consists of bed rest for 2–3 weeks only.

2. Fractures of the pelvis with disruption of the pelvic ring

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These fractures occur as a result of direct trauma, e.g., in vehicular accidents or after fall of heavy objects. These are unstable injuries since the pelvic ring is disrupted and one segment of the pelvis may get displaced considerably (Fig. 12-2).

These injuries may also be associated with complications such as haemorrhage, injury to the urethra, rectum and vagina.

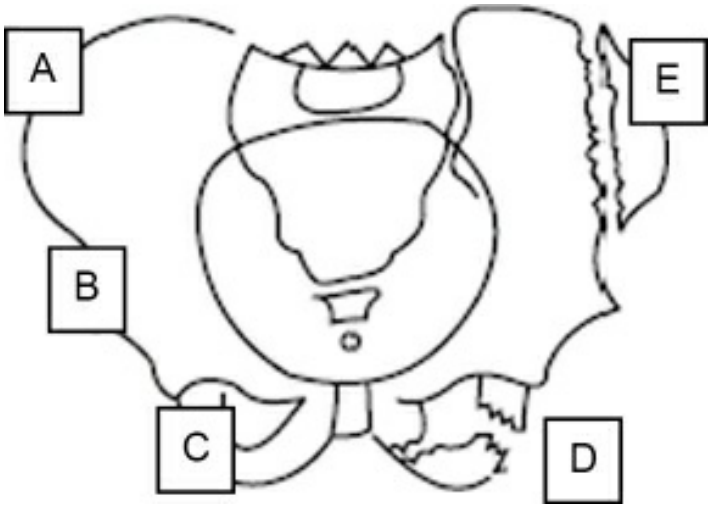

FIG. 12-1 Isolated fractures. The pelvic ring is intact. **A, B, C**: common avulsion fracture sites – **(A)** anteriosuperior iliac spine; **(B)** anteroinferior iliac spine; **(C)** ischial tuberosity; **(D)** fracture of the ischium; **(E)** fracture of the ileum.

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FIG. 12-2 Fracture pelvis: **(A)** pelvic ring broken at one level, and **(B)** ring broken at two levels.

Treatment

The treatment can be conservative or operative.

Conservative treatment

The patient is treated with heavy skeletal traction to reduce the displacements of the pelvic segments. The traction is maintained for a period of 6 weeks after which the patient is gradually mobilized.

Operative treatment

The fracture can be fixed surgically by plates and screws or by an external fixator (Fig. 12-3). The patient can be mobilized 3 weeks after surgery.

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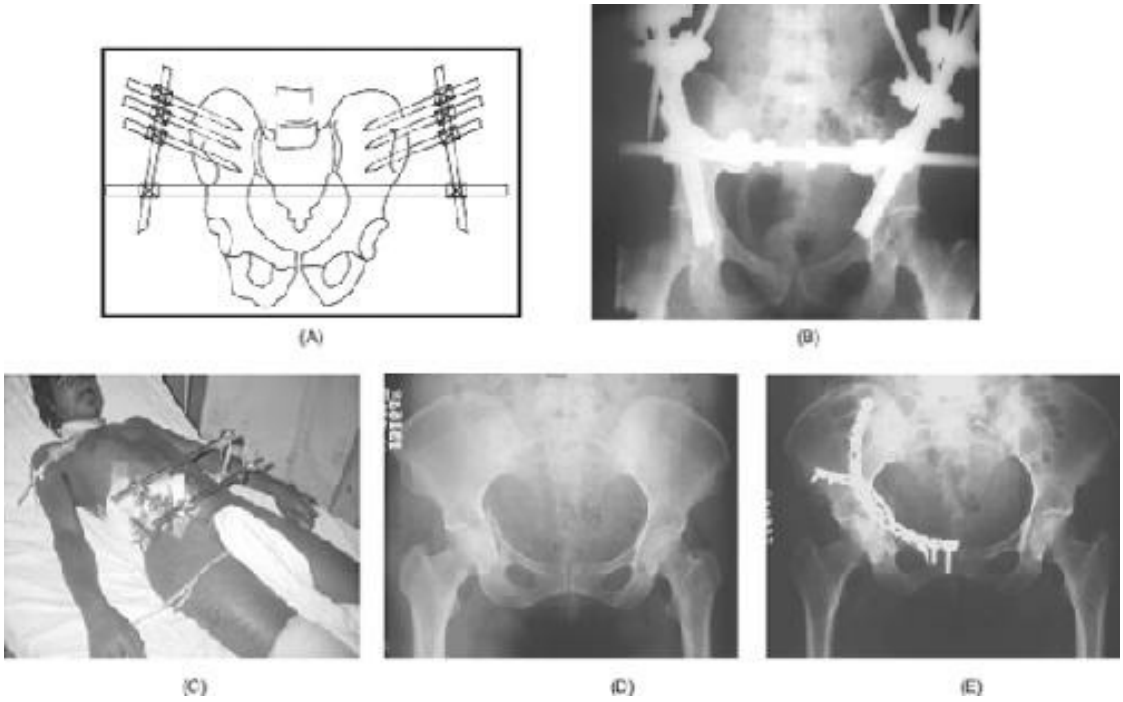

FIG. 12-3 External fixator in the treatment of fracture pelvis: **(A)** diagrammatic representation. **(B)** Radiograph showing fixator in situ. **(C)** A patient with fixator in position. **(D)** Preoperative radiograph showing displaced fracture of pelvis. **(E)** Postoperative radiograph after open reduction and internal fixation with special plates.

Surgical reconstruction for urethral injuries is taken up later when the patient is mobilized.

Physiotherapeutic management

Objectives

1. To restore a stable pelvis, with normal anatomical alignment in weight-bearing postures and also during static and dynamic activities.

2. Freedom of walking and performing ambulatory activities; and near normal gait pattern.

3. To restore normal or at least functional range of motion (ROM) of all the movements of the hip.

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4. To optimally strengthen and increase the endurance of the major muscles around the hip.

Expected problems: In severe, rotationally and vertically unstable fractures.

During the early stage after injury:

- The patient may be in hypovolaemic shock due to intrapelvic haemorrhage from the veins in the pelvic wall.
- Injury to the major vessels and nerves in the pelvic viscera.
- Complicated injuries to the viscera like intestine, bladder, urethra, rectum and vagina.
- Initial reluctance to take side turns, sit, stand and bear weight with lack of freedom of the movements and weakness of the hip joint.
- Continued uneven step gait and a limp – for a long period.

Physiotherapy management has to be planned on the basis of Tile's classification of the stability of the pelvis.

Tile's classification

Group A: Stable fractures, where the integrity of the pelvic ring is not affected.

Group B: Partially stable, where the fractures are vertically stable but rotationally unstable.

Group C: Both rotationally and vertically unstable fractures.

A. **Isolated fractures of the ilium, pubic rami and the sacroiliac**

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subluxation: These are closed, stable injuries. As such they do not need any specific physiotherapy.

- During bed rest, strong full range movements of the ankle and toes.
- Isometrics for the quadriceps, hamstrings, glutei and trunk are to be done at regular intervals.
- Active ROM exercises for ankles and toes.

After the period of immobilization,

- Instructions for gradual weight bearing and ambulation to be given.
- If pain persists, appropriate deep heating may be used.
- The patient should be back to routine activities by 3–4 weeks.

B. **Fracture of the pelvis with disruption of the pelvic ring**

Patients treated by conservative approach: These injuries are unstable injuries and need heavy skeletal traction for a period of 6 weeks. Therefore, the programme underlined for isolated fractures of ilium, pubic rami and sacroiliac subluxation has to be carried out during immobilization.

Mobilization: Initially, mobility as well as isometric strengthening exercises should be started for the lower limbs in supine position.

- Initiate and educate the patient on the techniques of self-rolling and supportive sitting on the bed.

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- Guidance may be given for sitting on the bedside with the knees hanging.

- Progress to sitting and assisted standing. Weight bearing and walking should be initiated in parallel bars on the second or third day of mobilization with guidance.

- Gait training may be necessary initially.

- Postural guidance for functional movements like sitting, getting up and turning should be given.

- Prolonged sessions of lying in prone position with isolated hip extension may be necessary in patients who have developed flexor tightness at the hip or to prevent it from occurring.

- The patient should attain full function by 8–10 weeks.

Patients treated by surgery: For fractures of the pelvis treated surgically, the period of immobilization is short (3 weeks). Therefore, there is an advantage of early mobilization. But this becomes difficult because of the patient's reluctance to do exercises, firstly, because of the operation and, secondly, because of the external fixator.

Patients should be encouraged to carry on exercises without worrying about possible harm due to the external fixator. If the physiotherapist succeeds in gaining patients' confidence in this aspect, early return of function is possible by 8–12 weeks of surgery.

Initial weight bearing and ambulation may be started on a

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walker or in parallel bars. The parallel bars need to have a mobile full view mirror to give an opportunity for self-correction to the patient. This should be progressed to independent ambulation at the earliest.

Injuries of the coccyx

A fall on the buttocks may cause fracture of the coccyx which may go unnoticed radiographically. The patient has considerable pain which may persist for months.

Treatment

The treatment consists mainly of rest, analgesics and physiotherapy.

Physiotherapeutic management

Persistence of pain for a longer period is known following injuries to the coccyx. These injuries are difficult to treat. Firstly, because of the position of the coccyx which is covered by thick fatty and muscular pads of gluteus maximus and secondly, the area is prone to postural pressure in sitting.

- Modalities like ultrasound and transcutaneous electrical nerve stimulation (TENS) may be used for relief of pain.
- Sitting on a ring cushion and occasional transfer of body weight over the alternate buttocks should be advised.
- Sitz bath and strong repeated contractions of gluteus maximus in standing, sitting, prone as well as in supine position indirectly improves circulation over the coccygeal area.
- Long sitting postures must be avoided. The pain does disappear and there is no functional handicap following this injury.
- Unremitting pain cases are treated by local hydrocortisone infiltrations.

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Fracture of the ribs

- Fractures of the rib occur rarely, mainly as a result of a direct injury.
- The common site of injury happens to be the angle of the ribs, a point of maximum convexity.

Clinical features

- Localized pain and tenderness.
- Pain during inhalation when the rib cage goes into expansion.
- Inability to lie on the side of the traumatized ribs.

Radiograph: Plain X-ray of the chest identifying the location of fractures.

Management

- Interlocking pattern of intercostal muscles provide natural immobilization beside voluntary control over the extent of inhalation.
- Pain reduction could be achieved by local ultrasound exposure or TENS.
- The point of fracture may be provided with additional support by adhesive tape or strapping.

Complications

Chest complications like haemothorax or pneumothorax may be expected in rare occasions.

Physiotherapy management

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- Deep breathing exercise with slow and deep inhalation with the patient supporting the injured area with hands.

- Speedier breathing programme may be incorporated to improve the mobility of thorax.

Home treatment with hot packs with deep breathing exercises could be very useful in reducing pain and breathing discomfort.

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CHAPTER
13

Injuries of the hip

OUTLINE

- Dislocation of the hip
- Injuries of the hip

Dislocation of the hip

Dislocation of the hip is a serious injury. The head of the femur slips out through the capsule and displaces according to the direction of the force.

Dislocation of the hip is of three types:

A. Posterior dislocation

B. Anterior dislocation

C. Central dislocation

Posterior dislocation

It is the commonest out of the three types of dislocations of the hip. It occurs when the adducted and flexed femur is pushed backwards by a violent thrust to the knee, e.g., when a passenger's knee hits against the dashboard of a car. The femoral head is pushed backwards, sometimes fracturing the posterior lip of acetabulum (Fig. 13-1).

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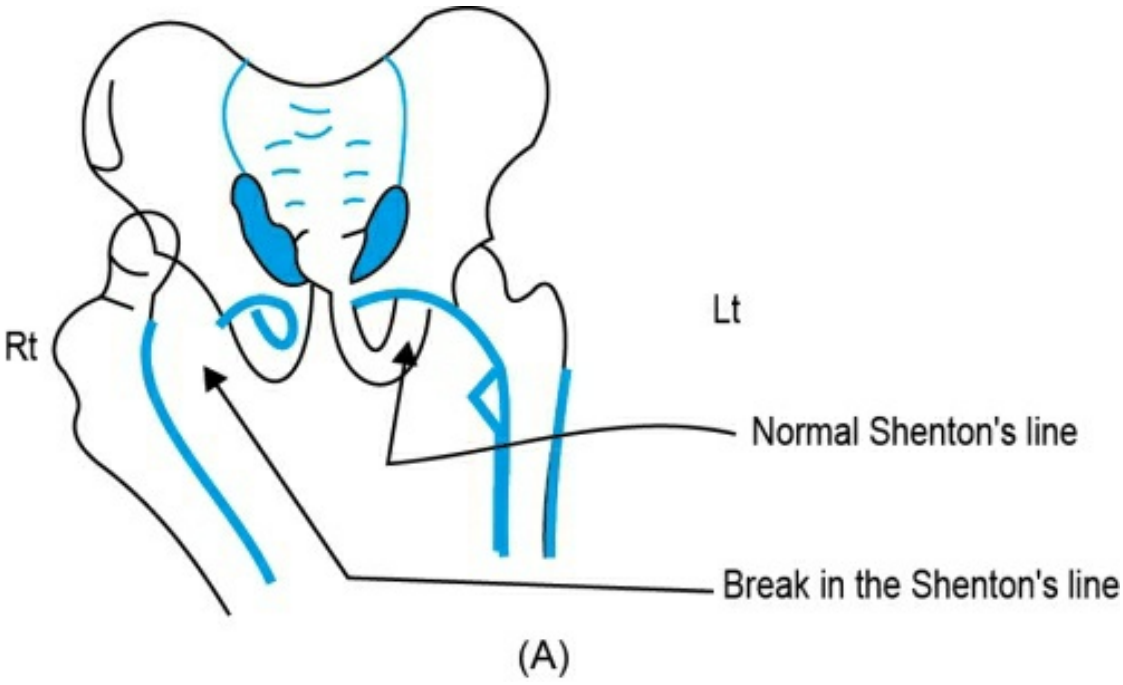

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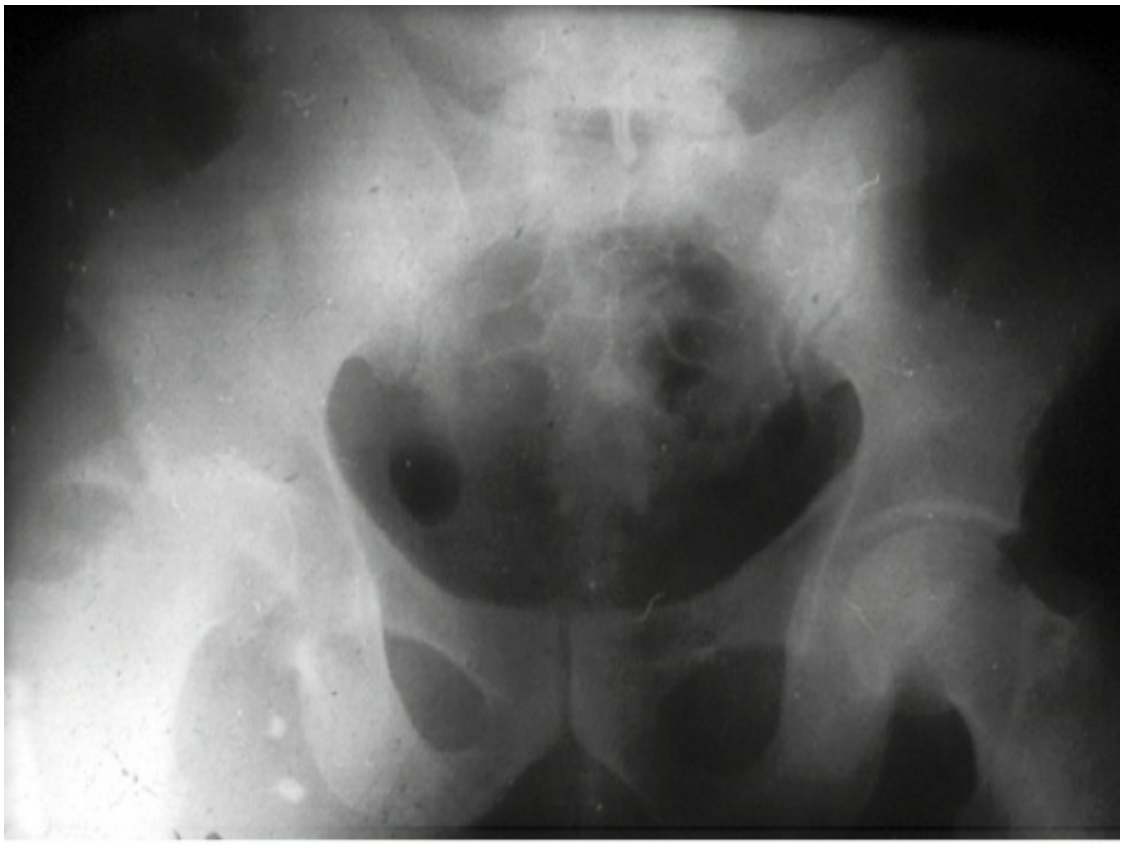

(B)

FIG. 13-1 **(A)** Posterior dislocation of the right lip of acetabulum. Note the

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break in the Shenton's line, and **(B)** radiograph showing the same.

Clinical signs

- Marked localized pain and tenderness
- The attitude of the limb is flexion, adduction and internal rotation at the hip. There is also marked shortening of the limb.
- Stiff and painful attempted movement
- Localized haematoma
- Femoral head is palpable posteriorly at the gluteal region
- Diminished or absent pulsations of the femoral artery in the inguinal region. The diminished femoral pulsations are not because of any vascular injury to the femoral artery, but due to the following reason: normally, the femoral pulsations are felt in the inguinal region against the head of the femur, which is right posterior to the femoral artery. Therefore, when the head of the femur is dislocated out the acetabulum, the femoral artery pulsations cannot be felt well.

Diagnosis: An X-ray of the pelvis with both hips will clinch the diagnosis of posterior dislocation of hip (Fig. 13-1). Occasionally, a CT scan may be required to look for any associated fracture of the acetabulum.

Treatment

The dislocation is reduced under general anaesthesia (GA) by the classical Watson–Jones axial traction technique with the limb in neutral. In fresh dislocations, closed reduction may be successful; whereas in old dislocations or in cases of associated fractures of the acetabulum, open reduction becomes necessary. A substantially large bony fragment of the acetabulum is fixed internally with the help of screws (Fig. 13-2).

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FIG. 13-2 Posterior dislocation (of Fig. 13-1B) with reduced and bony fragment of acetabulum fixed by screws.

The period of immobilization after closed or open reduction is 6–8 weeks. The limb is immobilized either in a Thomas splint with skin traction or in a plaster of Paris (POP) hip spica. Mobilization of the hip is started after 6–8 weeks.

Anterior dislocation

It is rare and occurs due to a violent abduction force, with thigh flexed. It occurs in road traffic accidents (RTAs). The dislocated head of the femur may lie on the obturator foramen (Fig. 13-3) or the symphysis pubis.

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FIG. 13-3 Anterior dislocation of hip – obturator type. Note that the head of femur is lying against the obturator foramen.

Clinical features

- Localized pain, stiffness and tenderness
- Inability to bear weight
- The limb is externally rotated with apparent lengthening

Treatment

Manipulative reduction under GA and immobilization in a hip spica or in a Thomas splint for 6–8 weeks are done. Open reduction may become necessary when the attempted reduction fails.

Central dislocation

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This type of dislocation results following a fall on the greater trochanter, or due to RTAs. The floor of the acetabulum is fractured and the head of femur is pushed into the pelvis (Fig. 13-4).

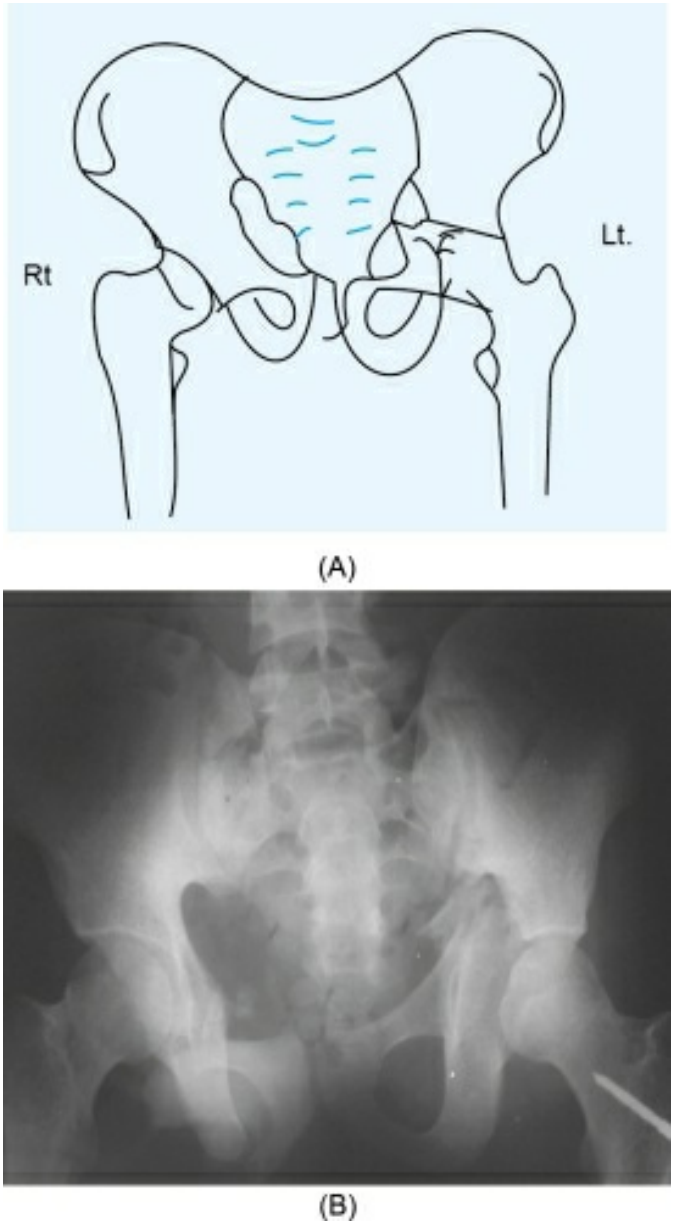

FIG. 13-4 Central fracture dislocation left hip: **(A)** diagrammatic representation, **(B)** as seen on radiograph.

Clinical features

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- Severe localized pain and stiffness
- Hip abduction and rotation is markedly restricted with severe pain on attempted movement of the hip joint.
- Bony mass is palpable in per rectal examination.
- The limb remains in neutral rotation and short.

Treatment

The dislocation is reduced by traction with pelvic compression (Fig. 13-5A) or heavy skeletal traction in two directions, longitudinally along the line of the leg and laterally through the greater trochanter (Fig. 13-5B). After reduction, the traction is maintained for 6–8 weeks. The hip is mobilized after 6–8 weeks. Full weight bearing, however, is started after about 3 months, after obtaining radiographic evidence of consolidation of the acetabular floor.

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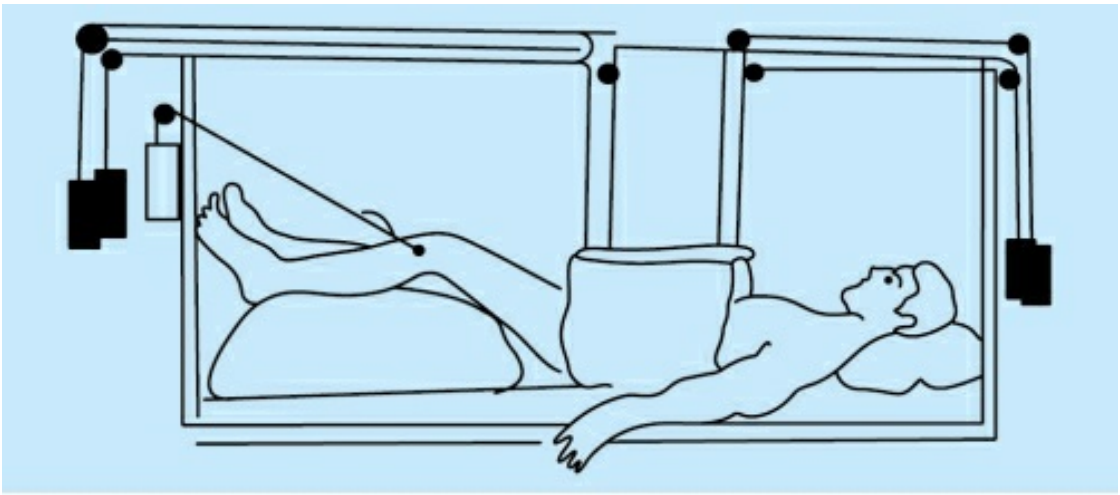

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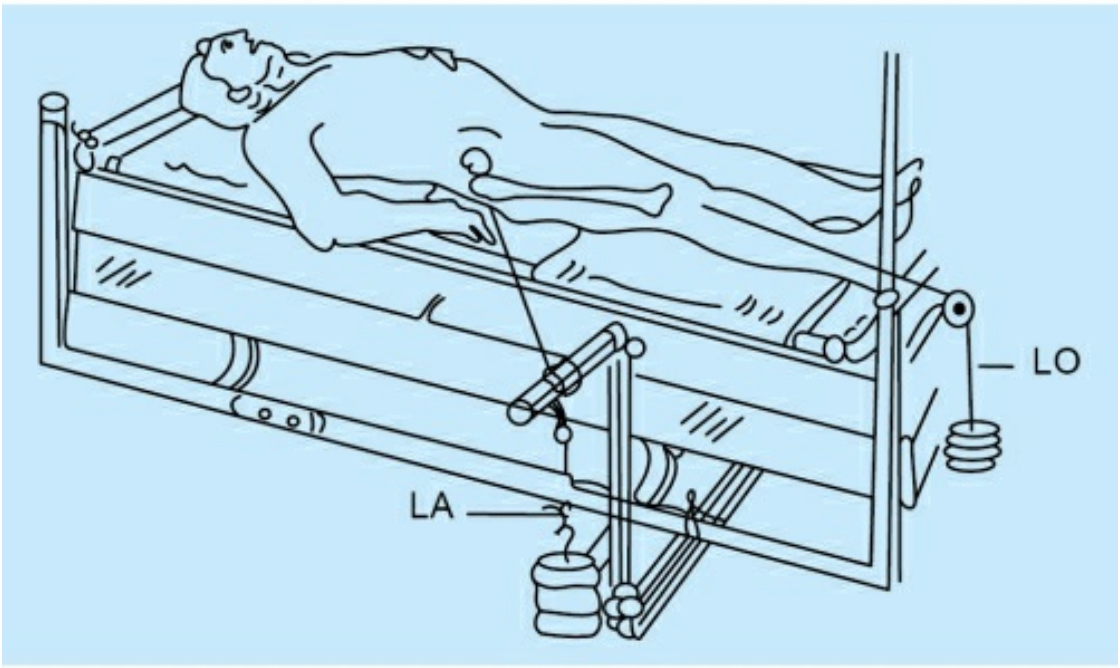

(B)

FIG. 13-5 **(A)** Traction with pelvic compression. **(B)** Two directional skeletal traction. LO, longitudinal along the line of leg; LA, lateral through the greater trochanter.

Grossly displaced fractures, these days, are also fixed internally by special plates (Fig. 13-6).

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FIG. 13-6 Hip fracture treated by internal fixation.

Physiotherapeutic management

During immobilization: It proceeds on the same lines as described for fracture of the femoral neck. In order to gain control of the hip joint, strong isometrics to the glutei, hip flexors, quadriceps and hamstrings should be ensured at the earliest.

In patients treated with skeletal traction, small range movements can be started by 3 weeks. Care should be taken while performing movements which predispose to dislocation, e.g., hip adduction and internal rotation with flexion in posterior dislocation; hip abduction and external rotation in anterior dislocation.

During mobilization: Vigorous exercises should be initiated to regain

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range of hip movements, and strength at the dislocated hip. Knee mobilization becomes necessary in patients treated with hip spica.

Assisted straight leg raise (SLR) should be initiated and emphasized to regain control of the hip joint.

Once controlled hip movements are regained, ambulation can be initiated with enough assistance by 12 weeks.

The patient should be independent in ambulation by 15–16 weeks.

Complications

1. *Associated fractures* of acetabulum, or rarely, head of the femur.

2. *Injury to the sciatic nerve:* It may occur as a result of the injury itself or following manipulative reduction.

3. *Avascular necrosis (AVN) of the head of femur*: It may eventually lead to degenerative arthritis requiring either arthrodesis or joint replacement.

4. *Unreduced dislocation:* An old dislocation cannot be reduced by closed methods or even by open reduction, at times.

5. *Osteoarthritis of hip joint*: It may eventually require total hip replacement.

6. *Ectopic ossification*: Ectopic ossification can occur around the hip joint, after posterior dislocation (see Fig. 11.15). It can give rise to pain and limitation of movements of the hip joint.

Comparative Features of Hip Joint Dislocations

Posterior Dislocation	Anterior Dislocation	Central Dislocation

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Incidence: about 70% of total dislocations	About 10–15% of total dislocations	Very rare
May be associated with a fracture of the femoral head	The femoral head may be dislocated either anteriorly or posteriorly	May be associated with a burst fracture of the floor or rim of the acetabulum
Diagnostic features: Typical flexion–adduction and internal rotation deformity, with limb shortening	**Diagnostic features:** **Position of the limb:** *Superior type:* • Flexion, abduction and external rotation Inferior type: • Extended and externally rotated	• No limb shortening • Neutral limb positioning • Positive per rectal examination
Treatment: Reduction of dislocation, commonly by Watson–Jones method	Following classic method	Skeletal traction or open reduction internal fixation (ORIF)
Complications:	**Complications:**	**Complications:**
Early: • Sciatic nerve palsy • Irreducible fracture – dislocation, sometimes due to fracture of the rim of acetabulum or femoral head • Recurrent dislocation *Late:* • Avascular necrosis of the head of femur • Myositis or ectopic ossification • Posttraumatic early osteoarthritis	*Early:* • Injury to the femoral artery, vein or nerve *Late:* • Posttraumatic early osteoarthritis. • Recurrent dislocation	*Early:* • Sciatic nerve palsy • Thrombophlebitis • Recurrent dislocations *Late:* • Posttraumatic osteoarthritis • Avascular necrosis of the femoral head • Nonunion • Myositis

The treatment needs to be started at the earliest to reduce the hazards of complications or their severity. The following measures can be taken:

1. Earliest possible reduction and stabilization of the dislocation will be effective in reducing the injury to the sciatic nerve, and incidences of neurovascular trauma.

2. Avoid recurrence by developing/strengthening the muscles around the hip.

3. Earliest initiation of repetitive strong isometrics to the gluteal muscles indirectly may help in increasing circulation to the femoral head and neck.

4. Give instructions not to resort to early passive movements, joint stretching, and massage, which may reduce the magnitude of myositis

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or osteoarthritis.

5. Early vigorous movements to the calf muscles and isometrics to the knee may contribute significantly towards the prevention of thrombophlebitis.

Lower extremity

Injuries of the hip

Avulsion injury of the lesser trochanter

Sudden powerful contraction of the iliopsoas muscle can cause avulsion of the lesser trochanter of femur. This injury occurs in sports.

Treatment

Rest in bed for 2 weeks with the hip in flexed position is all that is necessary.

Physiotherapeutic management

No specific procedure is needed. Treatment programme should proceed on the same lines as described for avulsion injuries to sartorius, rectus femoris and hamstrings.

Fracture of the neck of femur

There are two types of fractures of the neck of femur:

(a) *Intracapsular fractures*

(b) *Extracapsular fractures*: These are, in fact, trochanteric fractures and shall be discussed in subsequent pages.

Intracapsular fracture of the neck of femur

This injury commonly occurs in elderly persons, particularly women, following a trivial fall, e.g., a slip in the bathroom or a stumble over a

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carpet. The femoral neck is also a common site for a pathological fracture due to metastatic deposits.

Clinical features

- Pain, stiffness and localized tenderness
- Inability to bear body weight (except in impacted fractures)
- Active SLR is absent

Classification of the fractures of the neck of femur (fig. 13-7)

1. **Abduction/adduction type.** The *abduction type of* fracture is always impacted and hence may unite with conservative treatment. In the *adduction* or *the unimpacted variety* of fracture, the bony fragments are subjected to shearing forces causing movements at the fracture site. Since the fracture line here is more or less vertical, weight bearing will push the trochanter upwards. Therefore surgical intervention to treat this fracture is a must; otherwise nonunion may result.

2. **Anatomical classification.** In intracapsular fractures, the fracture may be close to the head of the femur, called *subcapital fracture*, or it may be somewhere in the neck away from the head called *transcervical fracture*. The fracture can be at the base of the neck of femur, when it is called *basal fracture* (Fig.13-8).

In an intracapsular fracture, the blood supply to the proximal fragment (i.e., the head of femur) may be cut off, since the blood supply to the femoral head comes mainly from the distally placed extracapsular arterial ring. Only about 10% of the head receives its blood supply from the artery of the ligamentum teres. This may result in AVN of the head of femur and may also cause nonunion of the fracture.

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3. **Garden's classification**. This is based on displacements of the head (Fig. 13-9). It is most prognostic for development of AVN of the femoral head.

Type I: Incomplete fracture, usually an impacted fracture

Type II: Complete undisplaced fracture

Type III: Partially displaced as distal fragment displaces the fragment

Type IV: Complete fracture with fully displaced fracture

4. **Pauwel's classification**. By measuring the angle formed by a fracture line with the horizontal (Pauwel's angle – Fig. 13-10).

Type I – < 30°

Type II – 30–70°

Type III – > 70°

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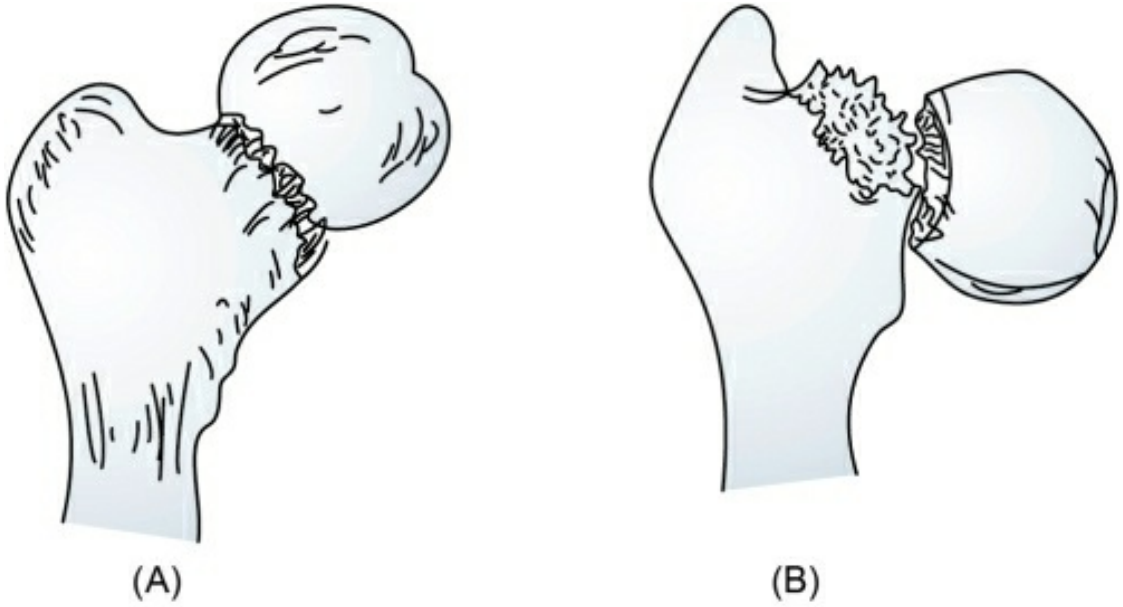

FIG. 13-7 Intracapsular fractures of the neck of femur. **(A)** Abduction or impacted fracture. **(B)** Adduction or displaced fracture.

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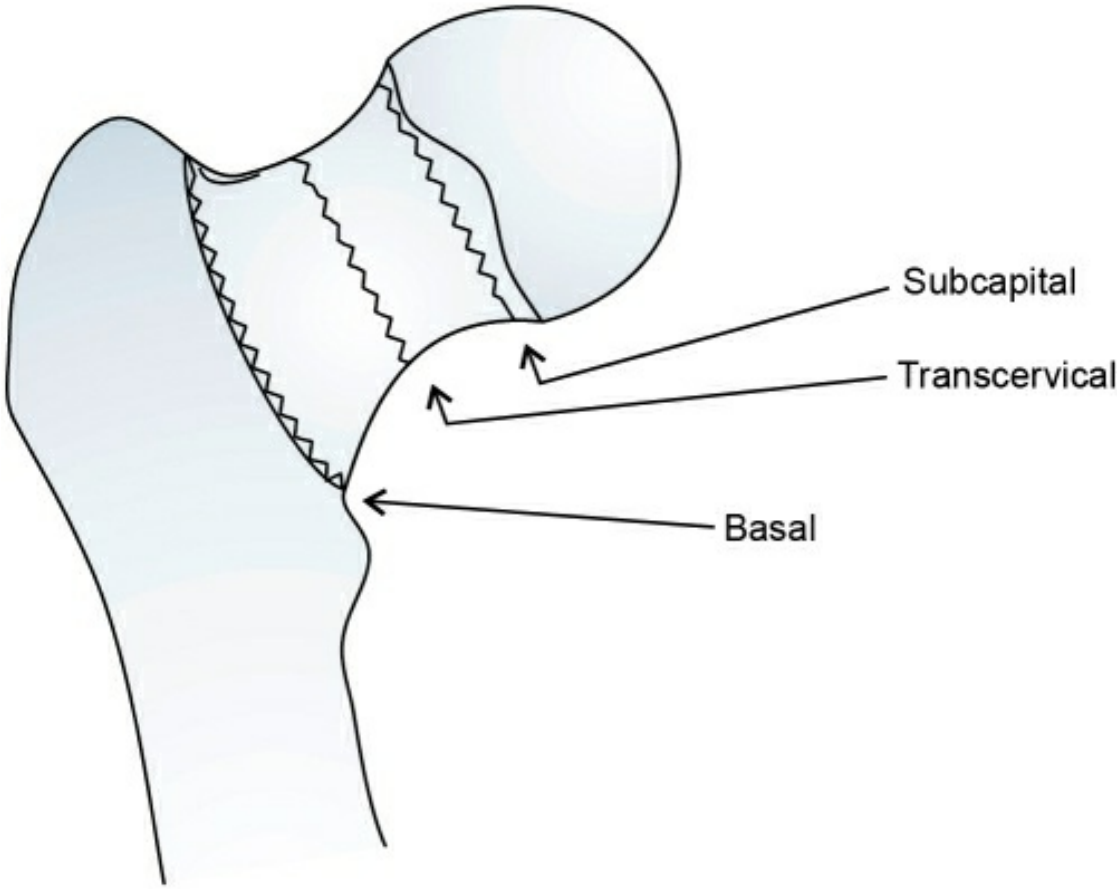

FIG. 13-8 Fracture neck of femur: anatomical classification.

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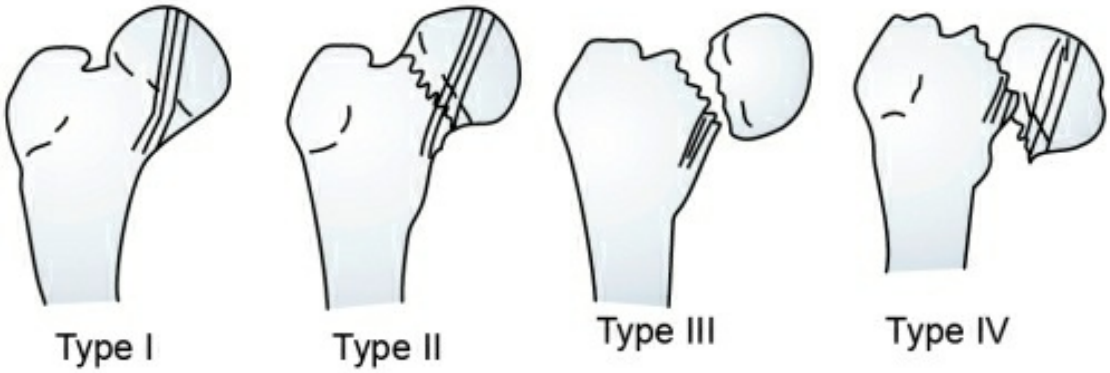
(A)



(B)

FIG. 13-9 **(A)** Radiograph showing the trabecular pattern in the neck of the femur. **(B)** Garden's classification.

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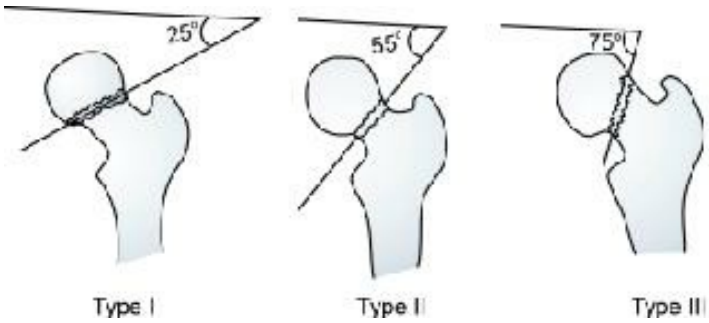

FIG. 13-10 Pauwel's classification. The fracture line is horizontal in type I; hence stability is more, the fracture line is vertical in type III.

Treatment

It can be

1. Conservative or

2. Surgical

1. ***Conservative treatment***

Conservative treatment is indicated in fractures in children and in impacted (abduction) type of fractures. The various treatment modalities can be

(a) *Skin traction*: It is given for a period of 4–6 weeks (Fig. 13-11).

(b) *POP hip spica* for 6 weeks: Hip spica is used only on children (Fig. 13-12). In elderly patients, it is contraindicated because of the various problems of prolonged recumbancy.

(c) *POP boot and bar*: It is also called a derotation bar and is given for 4–6 weeks. In elderly patients, in case of impacted fractures, a small below-knee plaster (boot) with

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a horizontal bar is applied to prevent rotation of the limb (Fig. 13-13). Although in all these modalities the immobilization is maintained for 6 weeks generally, the weight bearing is started only after the fracture is united radiographically, i.e., after about 10–12 weeks.

(d) *Painless pseudarthrosis*: Patients who are not fit for surgery or any other method of treatment mentioned earlier are mobilized as early as the pain permits. The aim here is to achieve painless pseudarthrosis.

2. ***Surgical treatment***

Various methods of internal fixation have been used. However, none of these has proved to be the best and ideal. The commonly used surgical methods are as follows:

In children: Fracture of the neck of femur is fixed internally by multiple Knowles or Moore's pins (Fig. 13-14).

In young adults: Internal fixation of the fracture is achieved by multiple cancellous screws (Fig. 13-15) or dynamic hip screws (DHS).

In elderly patients: In elderly patients, the femoral head is excised and replaced by a prosthesis (called hemireplacement arthroplasty [HRA]).

Replacement arthroplasty of the hip: In patients over 60 years of age, replacement arthroplasty of the hip joint is preferred to internal fixation mainly because of the following two reasons:

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1. Replacement arthroplasty permits early mobilization and weight bearing. The patient can be made to bear partial weight as early as 2–3 days after surgery.

2. The incidence of failure after internal fixation of this fracture is quite high even in the best of hands. AVN of the head of femur may also occur following this injury. In the event of either of the situations described here, a second operation becomes necessary while primary prosthetic replacement of the head obviates these problems.

Replacement arthroplasty is of three types:

1. *Hemireplacement arthroplasty* (Fig. 13-16): This is a commonly performed operation where the head of the femur along with the part of the neck proximal to the fracture line is removed and replaced with a metal prosthesis (e.g., Austin Moore or Thompson femoral prosthesis).

2. *Bipolar arthroplasty*: This type of HRA is performed more commonly these days. Bipolar means head within head. In this type of surgical procedure, the femoral head is replaced by a metallic prosthesis and the head of this prosthesis is covered by a metallic cup which is placed into the acetabulum without replacing the acetabulum (Fig. 13-17). The advantages of bipolar arthroplasty are as follows:

- The range of motion at the hip is better.

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- The wear and tear of acetabulum is less.
- Revision total hip replacement is easier later on.

3. *Total hip replacement arthroplasty (THR)* (Fig. 13-18): Some surgeons prefer to do a total hip replacement following a fracture of the neck of femur. In this operation, along with the replacement of the head and neck of femur, the acetabulum is also replaced by an artificial acetabular cup.

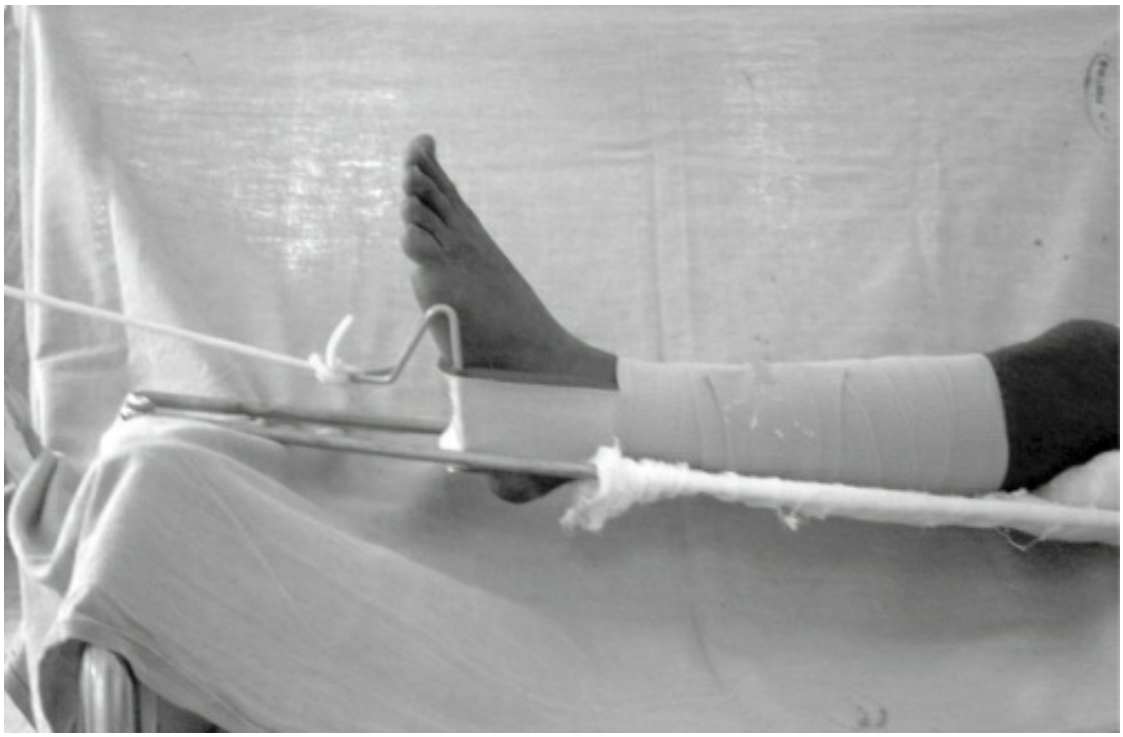

FIG. 13-11 Below-knee skin traction.

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FIG. 13-12 Plaster of Paris (POP) hip spica.

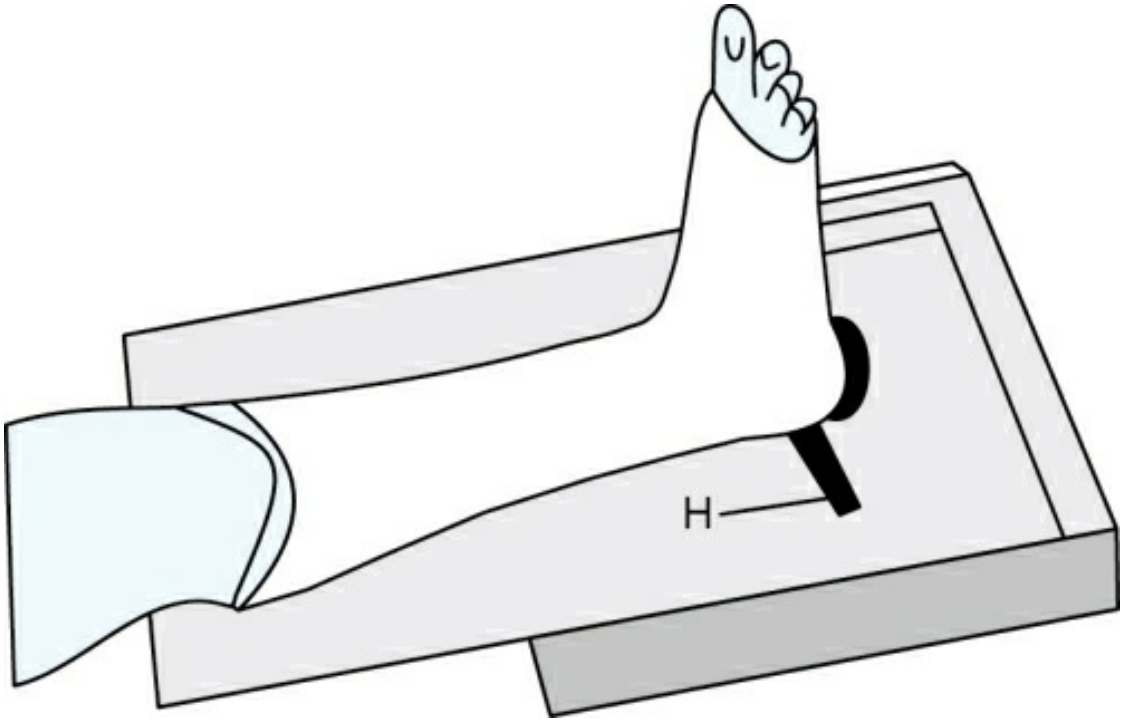

FIG. 13-13 Immobilization with below-knee plaster cast with boot and

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horizontal bar (H) or derotation bar to prevent external rotation.

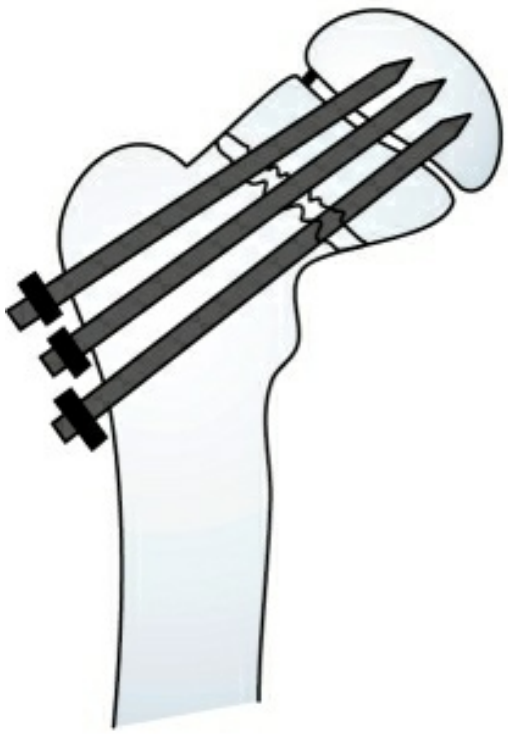

FIG. 13-14 Fracture of neck of femur in children fixed with multiple Moore's pins.

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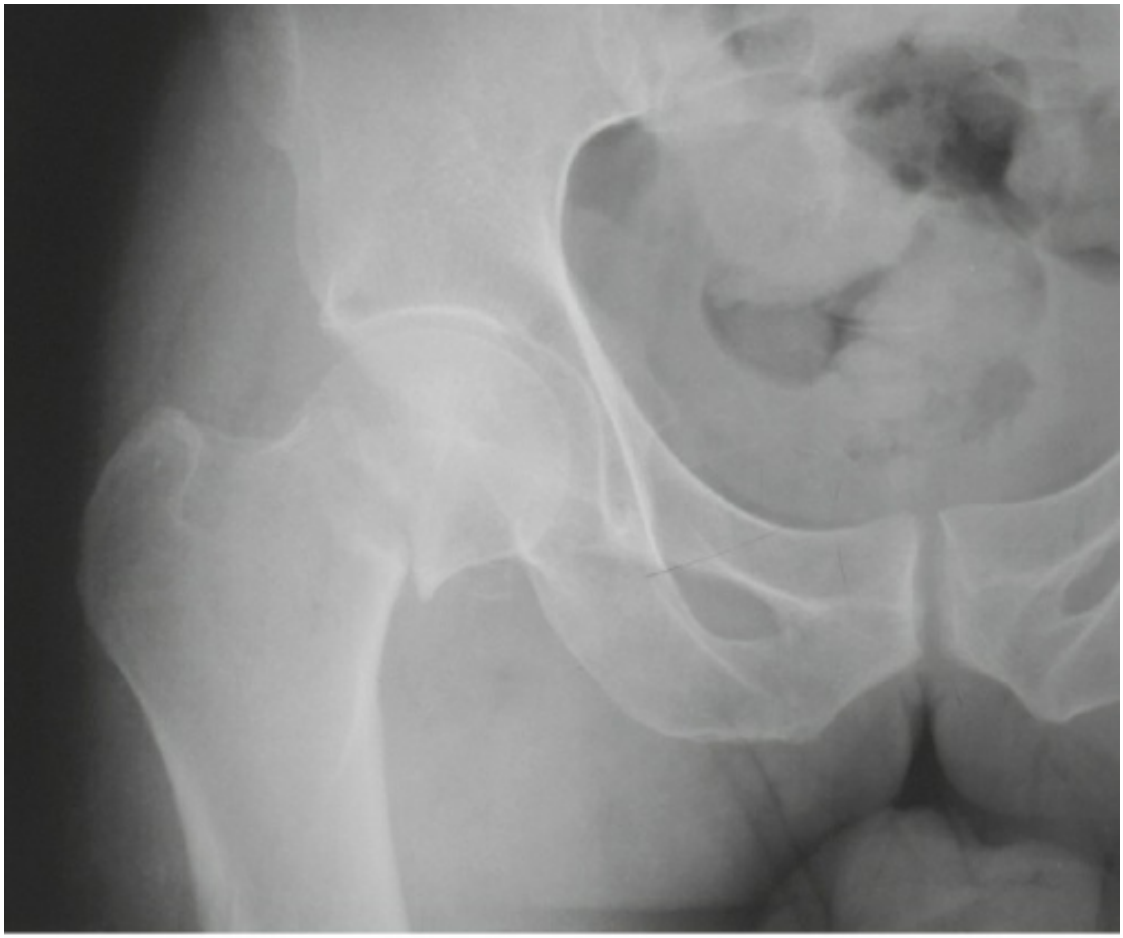

(A)

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(B)

FIG. 13-15 **(A)** Fracture of neck of femur. **(B)** Fracture of neck of femur fixed by multiple screws.

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FIG. 13-16 Fracture of neck of femur treated by Austin Moore prosthesis (hemireplacement arthroplasty).

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(A)

(B)

FIG. 13-17 **(A** and **B)** Fracture of neck of femur treated by bipolar arthroplasty.

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FIG. 13-18 Total hip joint replacement arthroplasty (THR) – both acetabulum and femoral head replaced.

Physiotherapeutic management

Conservative approach: Fracture is treated by skin traction, skeletal traction and derotational bar

Objectives

- To restore full or at least functional range of motion (ROM) to the hip joint.

Normal and Functional ROM at Hip and Knee

Movement	Normal	Functional

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	ROM	ROM
Hip joint		
Flexion Extension Abduction Adduction External rotation Internal rotation	0 → 125–130º 0 → 20º 0 → 45–50º 0 → 40–45º 0 → 45º 0 → 40–45º	0 → 90–110º 0 → 5º 0 → 20º 0 → 20º 0 → 15º 0 → 20º
Knee joint Flexion Extension	0 → 135–140º 0º	0 → 110º 0º

- To restore adequate strength, power and endurance to the muscle groups around the hip and the knee.

- To acquire self-sufficiency in performing all the ambulatory activities with ambulatory aids or suitable orthosis whenever necessary.

Expected problems

During 1st week:

1. Be alert and watchful for the symptoms and signs of thromboembolism, pulmonary embolism or hypovolaemia.

2. Strictly keep a check on the process of healing, anatomical bony alignment and the open reduction internal fixation (ORIF).

During immobilization: As the patients are generally in the age group of 60 years and above, the following measures are taken:

1. Adequate chest physiotherapy to avoid respiratory complications.

2. Repeated checks to assure correct positioning of the fractured limb; with special attention to avoid limb rotation.

3. Resistive movements to the toes and ankle joint of the fractured limb and other body joints.

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4. Strong isometrics to the quadriceps, hamstrings, hip extensors and abductors. Each static contraction should be strongly held at least for 10 s (or 30 counts), to avoid postimmobilization atrophy and weakness.

5. It is ideal to initiate early knee mobilization whenever special bed is available (slit-bed).

6. Initiate sitting on bed at the earliest opportunity; may be with backrest at the beginning.

7. Site of the skeletal traction pin should be inspected often for infection/loosening.

Mobilization: As soon as active mobilization is allowed, efforts should be concentrated to get maximum possible active ROM at the hip and knee.

Weight transfers and brief periods of full weight bearing on the affected leg alone are very important to balance the whole body weight on the affected leg during standing and walking. Guided training is needed to master it. Periods of prone lying, four-point kneeling and knee walking are extremely useful as a pre-weight bearing exercise (Fig. 13-19). This knee standing should be progressed to knee walking (Fig. 13-20). Strengthening exercises for the glutei and quadriceps should be done by progressive resistance exercise (PRE) techniques. Passive stretching ROM exercises can be progressed to get full ROM at the hip and knee joints. Supported squatting in front of wall bars and cross-leg sitting with back supported against the wall can be started with guidance and gradual progression.

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FIG. 13-19 Graduated weight bearing on the operated hip is facilitated by knee standing and knee walking with hand support.

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FIG. 13-20 Total weight bearing on the operated hip is facilitated by knee standing and knee walking without hand support.

The patient should be functionally independent by 8–12 weeks.

Patients treated with hip spica: This method is rarely adopted due to its various disadvantages. When treated by this method, strong resisted toe movements, and isometrics inside hip spica are taught and ensured. Sessions of assisted bedside standing should be initiated at the earliest.

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During mobilization, the measures and sequence of physiotherapy remains the same as described for treatment by traction and derotation bar.

Patients treated by pseudarthrosis: Patients who are not fit for plaster, traction or surgical methods of treatment are left to pseudarthrosis at the fractured hip.

Persisting annoying pain is the typical feature of these patients; therefore, the basic approach of physiotherapy is directed towards the relief of pain. Pain can be controlled by the following methods:

1. Movements started in combination with transcutaneous electric nerve stimulation (TENS).

2. The patient should be taught accurate methods of transfer and limb positioning during the activities.

3. Emphasis is laid on repeated sustained isometric contractions to strengthen the functionally important muscle groups.

4. Isotonic exercises and hasty partial weight bearing should be discouraged, as they produce movements at the fracture site leading to nonunion.

Gradual weight bearing should be started with adequate support to avoid pain.

As the degree of pain reaches an acceptable level, progressive physiotherapeutic measures should be adopted to ease ambulation.

Majority of the patients achieve functional independence. However, some may need a walker or two crutches for ambulation, because of persistent pain.

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Surgical approach

- Carefully inspect the surgical wound for early signs of wound infection.
- Check the immobilized limb for comfortable positioning.
- Guide and teach an attendant on repetitive check of positioning of the limb and how to perform assistive side turning in the bed (keeping a pillow in between the two legs to avoid or prevent pressure sores).
- No passive movements are initiated before 2 weeks of surgery.
- Educate and guide the patient, at the earliest, to perform both the modes of strong static contractions to the quadriceps to prevent disuse atrophy.
- Strong ankle and toe movements, and full ROM to the hip and knee to improve circulation to the fractured bone.
- The duration of the self-assisted, resistive isometrics to the gluteus maximus and quadriceps by simply pressing down the whole leg on the bed is easiest and self-controlled.

During week 2 and 3

By this time, the stiches are removed and the soft tissue healing has progressed adequately.

- Small range passive relaxed movements to the operated leg are begun.
- Make it self-assistive by heel drag technique providing only the required passive assistance. You may use sunmica flat board. Spread talcum powder to reduce frictional resistance (heel drag) as shown in Fig. 13-21.

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- Use of controlled, pain-free continuous passive motion (CPM) may be added.

- Whenever CPM apparatus is available, it can be used gainfully to initiate relaxed passive hip and knee flexion–extension. The patient is taught to operate it so that maximum possible work for the range of motion is facilitated.

- Progressive assisted active range of flexion can be achieved by self-assisted dragging of the heel.

- Sitting and transfer with legs hanging over the edge of the bed can be made self-assisted. The patient supports the operated leg by the normal leg.

- Assisted abduction can be initiated by sling suspension, self-assisted technology, or the patient using the sound leg as support underneath the fractured leg.

- Self-assisted SLR may be begun as early as possible, in spite of little discomfort.

- Knee swinging sitting at the edge of the bed can be made resistive either by self-resistance technique using the normal leg or by graded resisted exercises using weight belts or the DeLorme shoe.

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FIG. 13-21 Initiation of hip flexion by self-assisted “heel drag”.

During weeks 4–8

By this time, hip flexion should attain the 90º mark.

It is the appropriate time to build up and strengthen the usually painful and weak hip flexors by self-assistive hip flexion in supine position or at bedside sitting or heel drag in the supine.

Isometrics to gluteus maximus as well as medius should reach peak holds and strong muscular contractions.

After 8 weeks

Hush up exercise intensity to reach maximal muscular contractions both in strength and the ROM.

By 16–18 weeks

There will be no harm in introducing full weight-bearing activities and spot marching.

Balance and weight bearing must reach a stage of adequate stable one leg stand.

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Correction of the limp: Limp in gait should not be allowed to get organized. Repetitive sessions of self-resistance exercise, gait training with correct comfortable footwear and home practice in front of a postural mirror is ideal.

Prevent fracture susceptive tendencies like excessive tendency to bring the affected limb into adduction and internal rotation in walking. It is commonly seen in patients treated by ORIF.

The other managemental programmes should be followed on the same lines as described for the conservative treatment of these fractures. Partial weight bearing can be started after 6–8 weeks, while full weight bearing may be deferred till 12 weeks.

If there are no complications, patients of any age should be functionally independent by 3–4 months.

Hemireplacement arthroplasty (HRA): A procedure of choice if the acetabular cartilage is viable and not damaged.

Total hip replacement arthroplasty: When both femoral head as well as the acetabular cartilage are not viable or damaged.

Prevention of fractures at the pelvis and hip

- Most important contribution comes from achieving stable balance.
- Adequate warming up before undertaking any heavy activity.
- Every year, bone mineral density (BMD) along with other checks is advised.
- Nonexerting full ROM movements but not hard impact exercises when osteoporosis is confirmed.
- Correction in home hazards.
- Use cane support, in case of difficulty in walking unsupported.

Functional activity guidelines for femoral fractures

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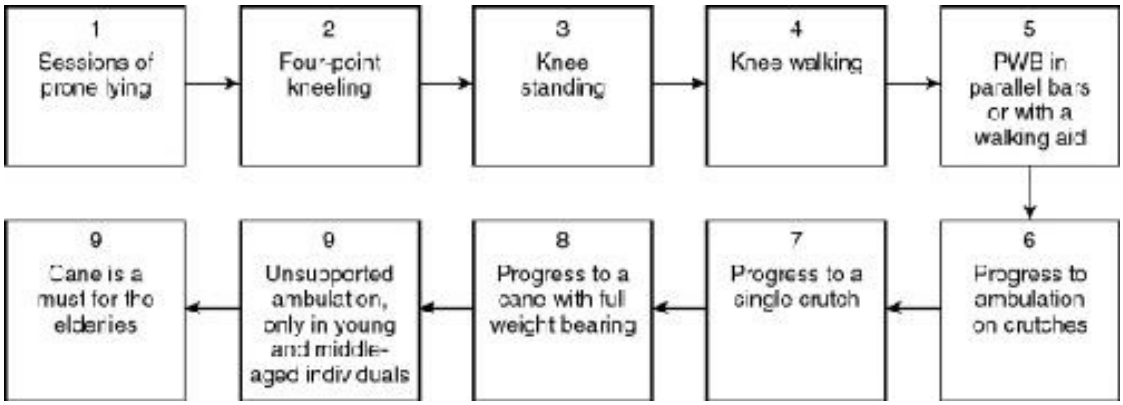
From lying in bed

- Intermittent lying on the side of the normal limb – mainly turning from the shoulder on the side of the fracture.
- Sitting up in bed from supine position, maximally using upper limbs and a normal lower limb.
- Pushing forward – same as sitting up.
- Learn walking, hopping with walker on the unaffected limb.
- Toilet activities – using walking aid or a walker, high commode seat or a chair with arm supports.
- Wearing trousers from the side of the fractured leg first while removing it is performed by the affected side first.
- Rolling body on the unaffected side before getting up from the supine.
- Maintain neutral position of the affected limb, whether non-weight bearing (NWB) or partial weight bearing (PWB). If permitted, keep hip and knee in slight flexion.

A flow chart (Flowchart 13-1) depicts the sequence of mobilisation.



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FLOWCHART 13-1 Sequence of mobilisation.

Note: Required healing time in fractures of femoral neck is 12–16 weeks.
Required period of adequate self-sufficiency is 15–30 weeks.

Caution

1. The most important aspect of this period is to regain maximum (near normal) range of hip flexion. Once the fibrous ankylosis is allowed to organize at this stage, regaining the range of flexion becomes impossible at a later stage.

2. All the measures to avoid fixed flexion or abduction deformity at the hip should be strictly observed.

3. If the patient starts complaining of excruciating pain and tenderness around the operated area as well as progressive limitation in the ROM at hip, complications like nonunion, loosening of the internal fixation, AVN or ectopic ossification should be suspected and reported immediately.

Management of old fractures: Procedures of open reduction

1. McMurray's osteotomy

2. Meyer's procedure

1. *McMurray's intertrochanteric osteotomy*: This is done to convert the shearing stresses at the fracture site into compressive forces (Fig. 13-22).

2. *Meyer's procedure:* The muscle pedicle bone graft within the quadratus femoris is applied on the posterior aspect over the fracture site supplementing the fracture by multiple screws (Fig. 13-23).

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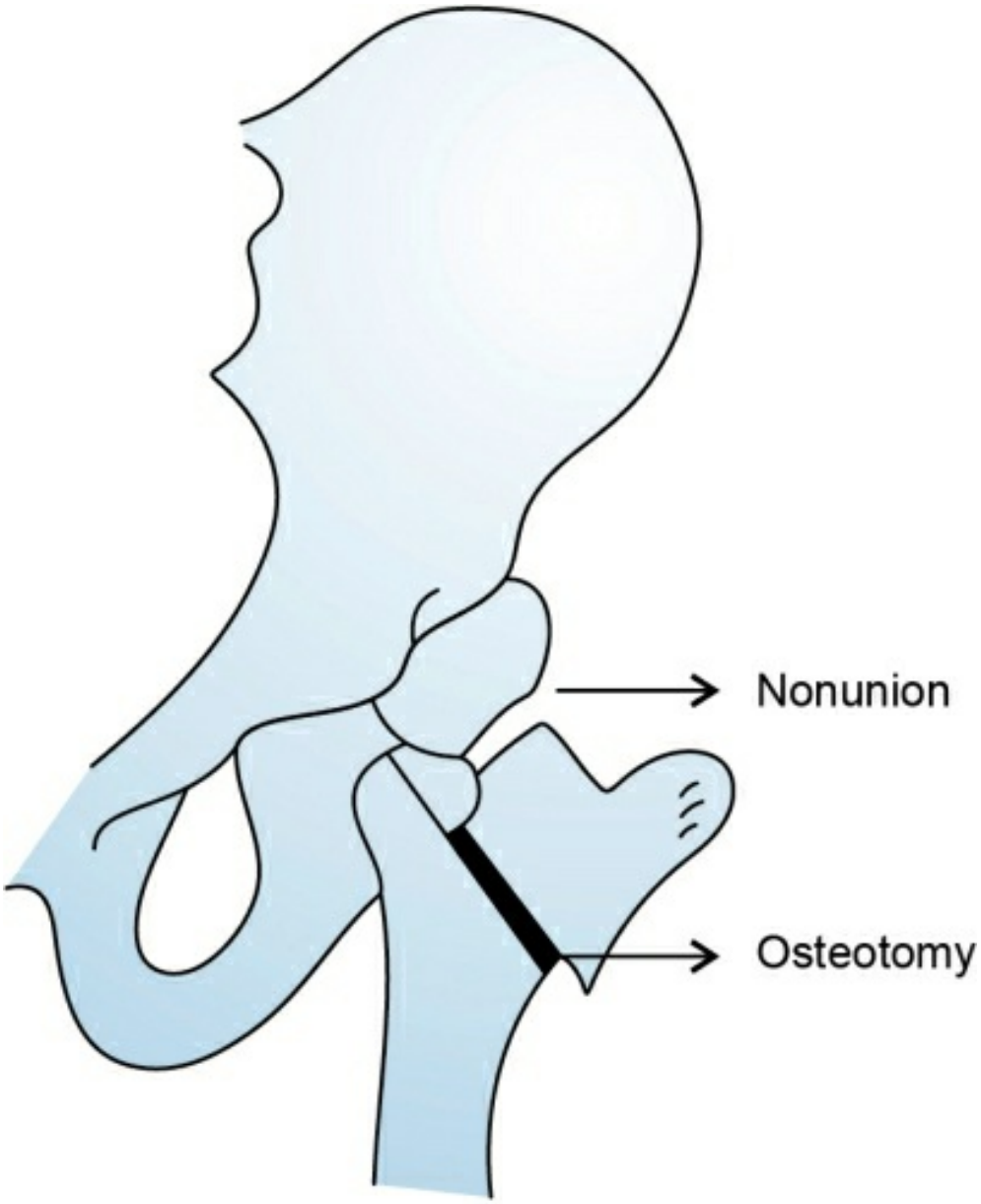

FIG. 13-22 McMurray's osteotomy. Osteotomy done below the greater trochanter; the distal fragment is displaced medially; the transmission of body weight occurs from the head of femur to the distal fragment directly, bypassing the fracture.

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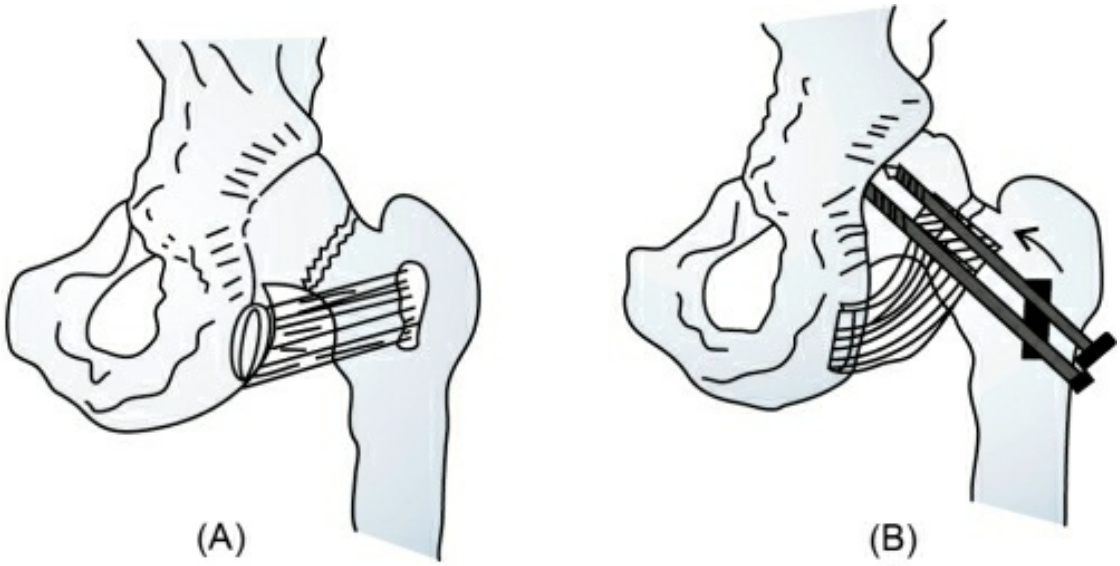

FIG. 13-23 Meyer's procedure: **(A)** Posterior aspect–position of quadratus femoris muscles, and **(B)** fracture fixed with compression screws. Quadratus femoris harvested along with a block of bone from its insertion and rotated to the fracture side.

Complications

- Nonunion: When there is no radiographic evidence of bone union by 6–12 weeks with the presence of telescoping, positive Trendelenburg's sign and diminished pain, treatment of choice is either Pauwel's osteotomy or else by hemireplacement or THR.
- AVN: Late on radiography (6 months to 2 years), shows collapse of the head of femur; it is also treated by osteotomy or replacement arthroplasty.
- Osteoarthritis – Radiographic evidence appears lately (few years).
- Stiffness, pain on weight bearing and marked limp.

Treatment

- McMurray's osteotomy in young patients

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■ Total hip replacement in older patients

Physiotherapeutic management

1. *After McMurray's osteotomy* (during immobilization, first 6–8 weeks): If the hip spica is applied, there is not much of a scope for active physiotherapy. However, the following programme should be initiated:

(a) Strong and vigorous toe movements

(b) Technique of supported rolling to the side in bed

(c) Isometrics for the hip and knee muscles

(d) Ankle, foot and knee on the normal side needs to be vigorously exercised by hanging the leg over the edge of the bed.

When the osteotomy is fixed internally with plate and screws, mobilization can be started after 3 days. The physiotherapeutic programme is followed on the same lines as detailed for the fractures of the neck of femur. The patient regains adequate functional status by 3 months if treated in a hip spica and by 6–8 weeks when treated by osteotomy with internal fixation. Occasional inexplicable weakness of the hip flexors has been noticed in patients treated by hip spica. Therefore, active assisted hip flexion needs to be initiated early.

2. *After Meyer's muscle pedicle bone grafting*: The physiotherapeutic management proceeds on the same lines as described for internal fixation of fracture of the femoral neck.

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3. *After hip replacement and arthrodesis*: The physiotherapeutic management after these procedures is discussed elsewhere.

Trochanteric fractures

A fracture in the region of the greater trochanter (up to the lesser trochanter) is called *intertrochanteric fracture* (Fig. 13-24). A fracture distal to the lesser trochanter (within 2 inches) is called *subtrochanteric fracture* of the femur. Trochanteric fracture is also called *extracapsular fracture* of neck of the femur since the fracture line is distal to the femoral attachment of the hip joint capsule.

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FIG. 13-24 Intertrochanteric fracture of femur.

Trochanteric fractures are common in elderly patients in whom the bones are osteoporotic and, therefore, trivial trauma like a stumble or a fall can cause this injury. However, this fracture is rare in young adults and results following a major trauma. The fracture may be displaced or undisplaced and may be comminuted.

Clinically the limb appears short and markedly externally rotated (much more than is seen in the fracture of neck of femur) following injury. The diagnosis is confirmed on radiography.

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Treatment

A trochanteric fracture generally unites readily as it occurs in the region of cancellous bone. The treatment, therefore, is aimed at maintaining alignment of the fracture fragments either by conservative or operative methods.

Conservative treatment

The following methods may be used:

1. Skin traction (see Fig. 13-11)

2. Skeletal traction

3. POP hip spica

4. POP derotation bar

Skin or skeletal traction (Fig. 13-25) is applied to the leg and maintained for 6–8 weeks. Active mobilization of the hip is then started. However, weight bearing should be started only after 3 months, depending upon the type of fracture and the evidence of sound radiographic union.

POP hip spica (see Fig. 13-12): This is indicated rarely, only in young adults. The plaster spica is given for 6–8 weeks.

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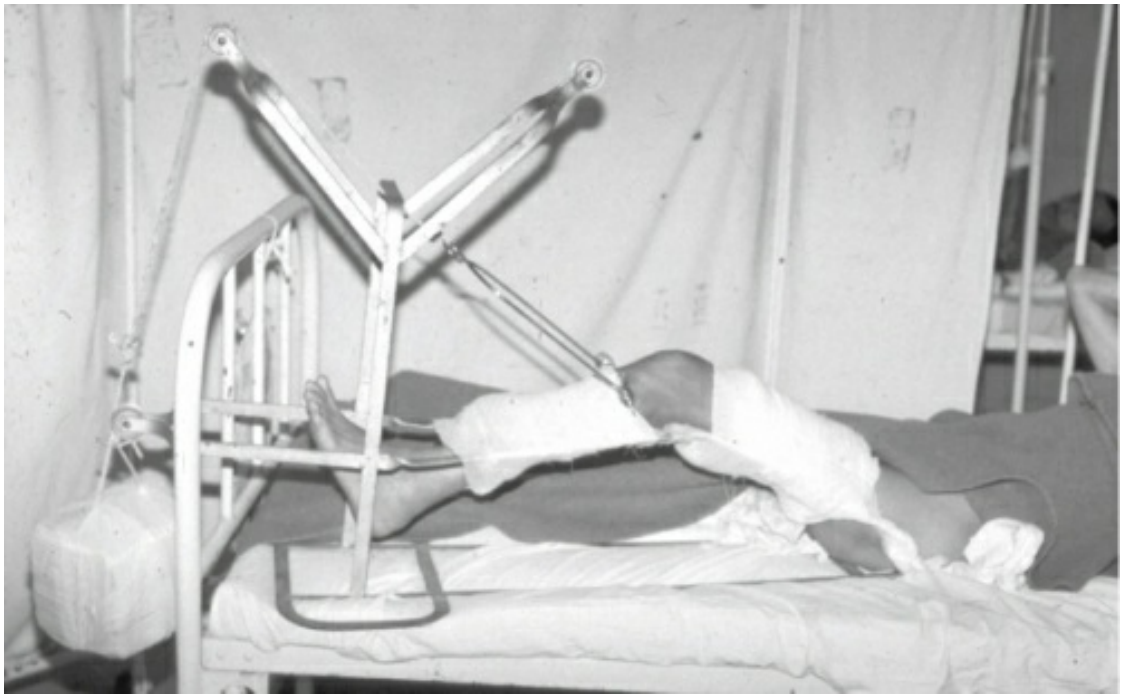

FIG. 13-25 Trochanteric fracture treated by skeletal traction on a Bohler–Braun splint.

In very elderly patients when surgery is contraindicated due to medical problems, occasionally POP boot and bar (derotation bar) is given (see Fig. 13-13). It keeps the limb in neutral rotation and thereby prevents any external rotation deformity. It, however, does not reduce the fracture accurately and, therefore, the fracture invariably malunites with shortening and coxa vara. POP boot and bar is also used in elderly patients with undisplaced trochanteric fractures.

Operative treatment

Although a trochanteric fracture can be treated by conservative methods, the operative treatment offers the advantage of accurate reduction and early mobilization, particularly in elderly patients. The operative treatment thus avoids the complications of prolonged recumbency.

The fracture is reduced by open reduction, under radiographic control, and fixed internally by DHS (Fig. 13-26) or dynamic compression screw (DCS) (Fig. 13-27) or Ender's nail (Fig. 13-28). Many other fixation devices are also available nowadays which give

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better fixation. For example, proximal femoral nail (PFN) is a better fixation device in unstable trochonteric fractures (Fig. 13-29) by the use of interlocking nail.

(A)

(B)

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FIG. 13-26 **(A** and **B)** Pre- and postoperative radiographs of a case of trochanteric fracture treated by dynamic hip screw fixation.

Screw fixation.

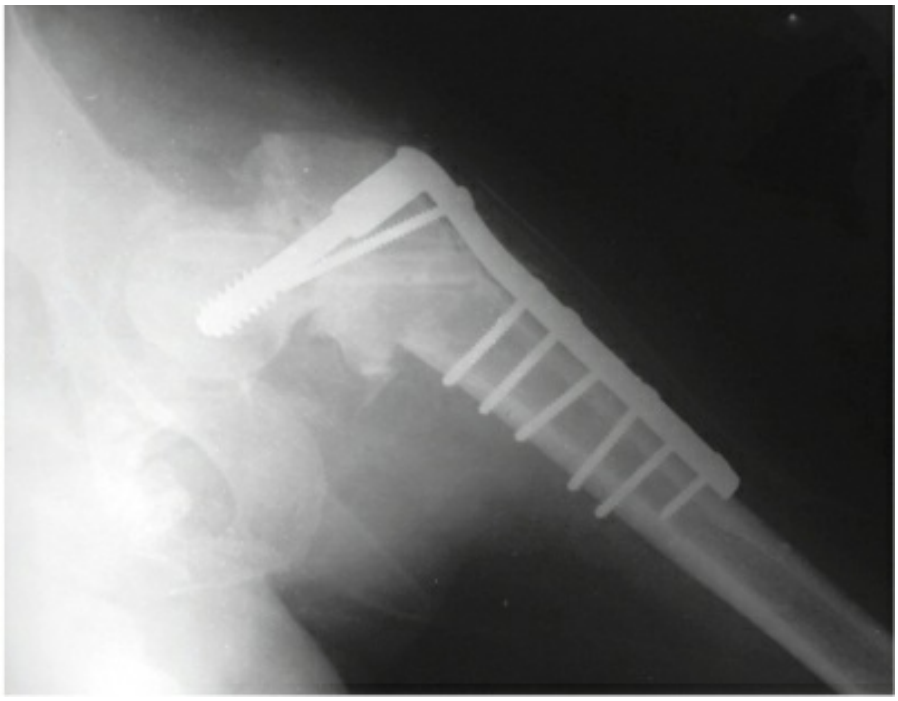

FIG. 13-27 Trochanteric fracture of femur treated by dynamic compression screw.

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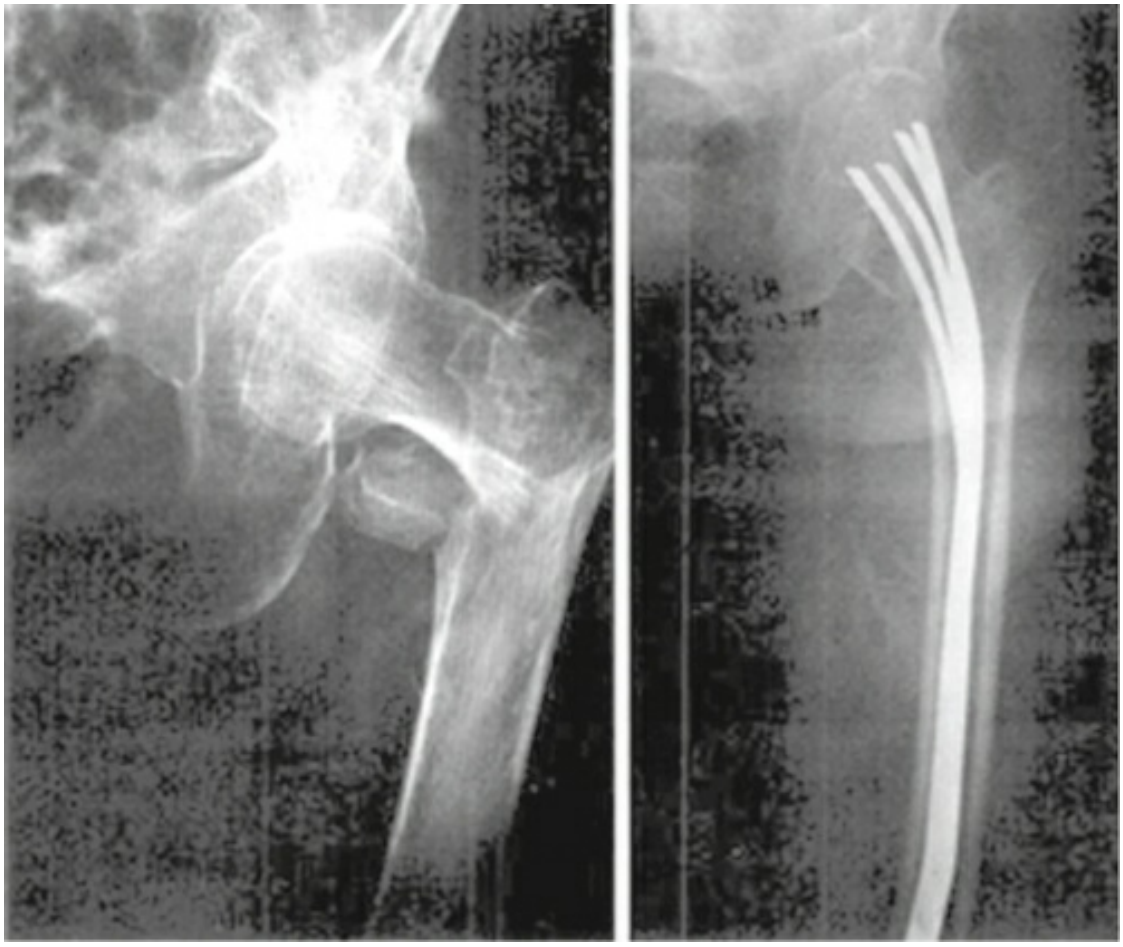

FIG. 13-28 Trochanteric fracture of femur treated by multiple Ender's nail.

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(A)

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(B)

FIG. 13-29 **(A** and **B)** Fixation by proximal femoral nail.

Postoperatively the patient is given only a dressing (no external immobilization). The patient can be made to sit up in bed the next day and the hip is mobilized as soon as the pain permits; full weight bearing, however, is started after about 3 months.

Special precautions in subtrochanteric and intertrochanteric fractures

Do not neglect the possibility of developing the following complications during the immediate postsurgical phase like:

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- Infection
- Blood clots progressing to deep vein thrombosis (DVT)

There is a possibility of complications like malunion, delayed union, nonunion, limb shortening, angular deformity, as well as rotational malunion.

Several factors are responsible for these complications, such as:

- These fractures are extracapsular.
- They occur through the cortical bone.
- There is a large biomedical stress at the site of a fracture.
- Imbalanced pull of the strong muscular attachments to the fractured bones.
- Short external rotators are attached to the proximal head and neck, whereas internal rotators of the hip remain attached to the distal fragment.

Therefore, limb positioning maintaining proper anatomical alignment of the fractured bony ends is of primary importance during the early stage of fracture healing. It has to be ensured with repetitive inspections, guidance to the patient and radiological checks.

Plus point: The bone at the site of the fracture is cancellous in nature, as such, the rate at which the fracture heals is faster and much better as compared to intracapsular fractures.

Complications

1. **Malunion:** Inadequate fixation/immobilization, implant failure or severe comminution often results in malunion. The fracture malunites in coxa vara (Fig. 13-30) which produces shortening and limp.

Treatment: Correction of coxa vara deformity is achieved by

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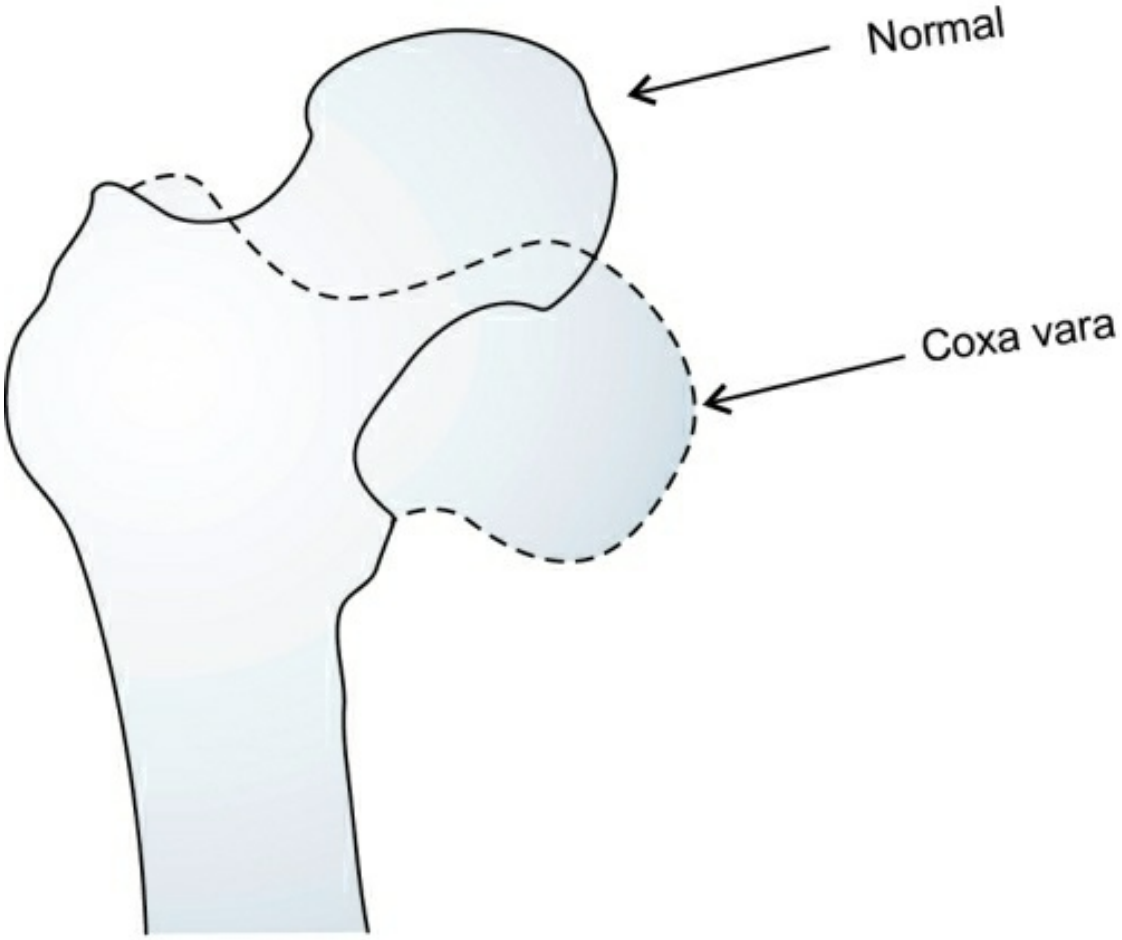
corrective osteotomy and internal fixation.

2. **Nonunion** of trochanteric fractures is extremely rare.

Treatment: Internal fixation with bone grafting.



(A)

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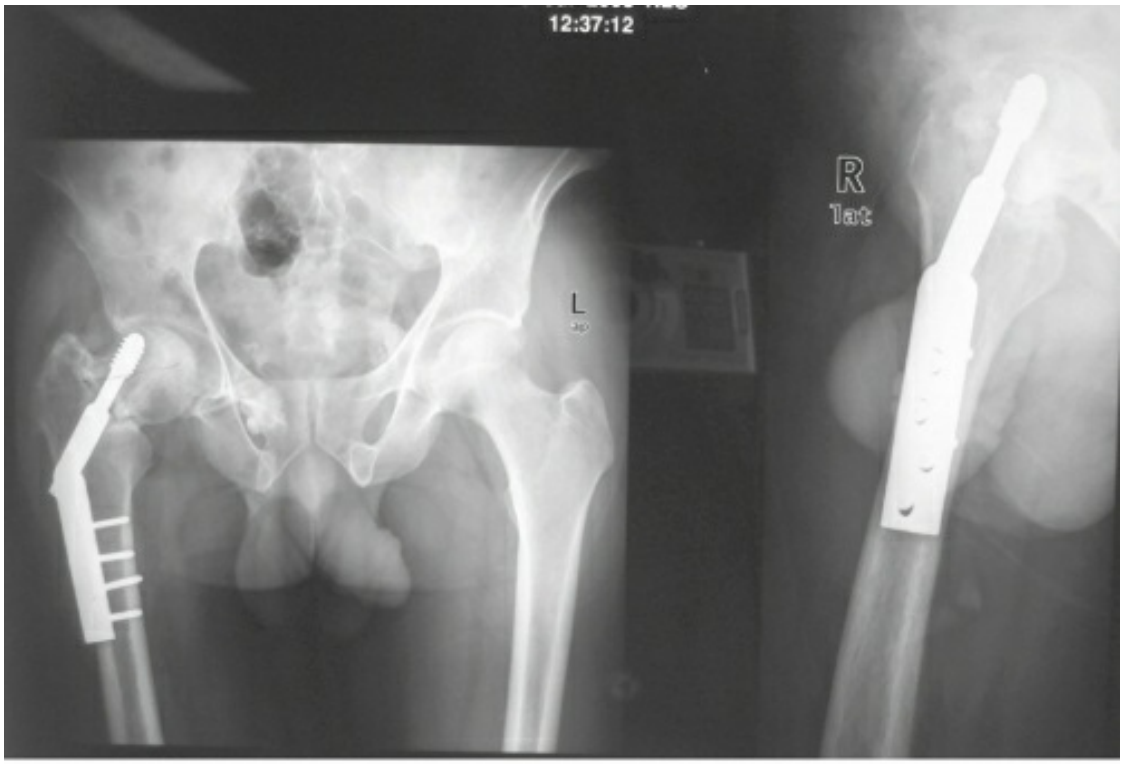

(B)

FIG. 13-30 **(A)** Normal neck shaft angle; coxa vara (dotted line). **(B)** Coxa vara, after fixation.

Physiotherapeutic management

The physiotherapeutic management of trochanteric fractures, treated conservatively or surgically, proceeds on the same lines as described for fracture of the neck of femur.

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CHAPTER
14

Injuries of the thigh

OUTLINE

■ Fractures of the shaft of femur

Fractures of the shaft of femur

Fractures of the shaft of femur occur at all ages and are caused by severe trauma, except in cases where the bone is destroyed and weakened by disease. For example, in children, the femur may be affected by a bone cyst while in the elderly, it may be weakened by a metastatic lesion. Fracture occurring in a diseased bone is called *pathological fracture*. It results following a trivial trauma.

In adults, generally, there is marked displacement of the fragments due to the pull of strong muscles surrounding the femur (Fig. 14-1).

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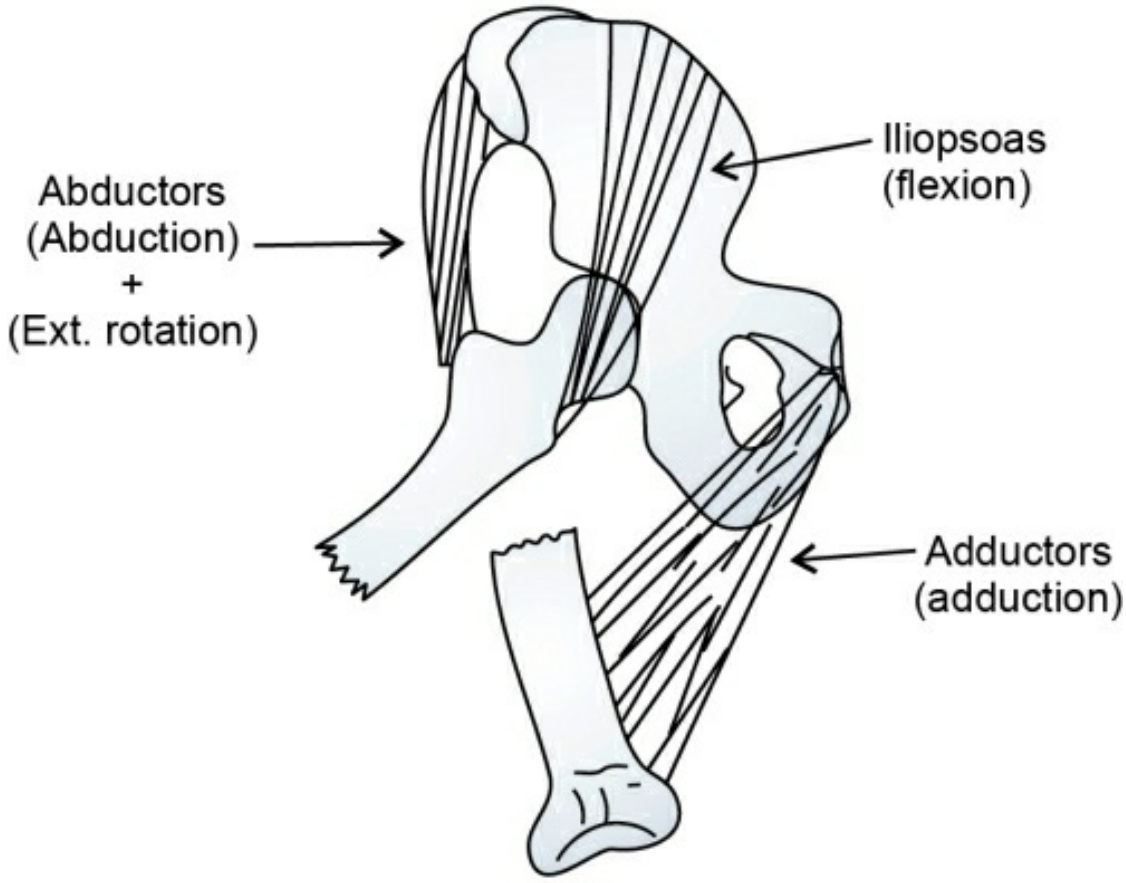

FIG. 14-1 Fracture shaft of femur: displacement of fragments by pull of muscles.

In a case of fracture of the shaft of femur, there is generally, considerable blood loss from the fractured bone ends and also from the traumatized soft tissues. The patient, therefore, may be in a state of shock when first seen.

Treatment

The immediate treatment includes blood transfusion to combat shock, and temporary splintage of the fracture.

Fracture of the shaft of femur can be treated by both conservative as well as operative methods.

Conservative treatment

It depends upon the age of the patient:

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1. *Children under 2 years of age*: Fracture of the shaft of femur in children below 2 years of age is treated by Gallow's traction (see Fig. 4-12) for 3–4 weeks.

2. *Older children*: In older children, this fracture can be treated by any of the following methods:

- Skin traction on pillows (Fig. 14-2)
- Skin traction in a Thomas splint
- Plaster of Paris (POP) hip spica

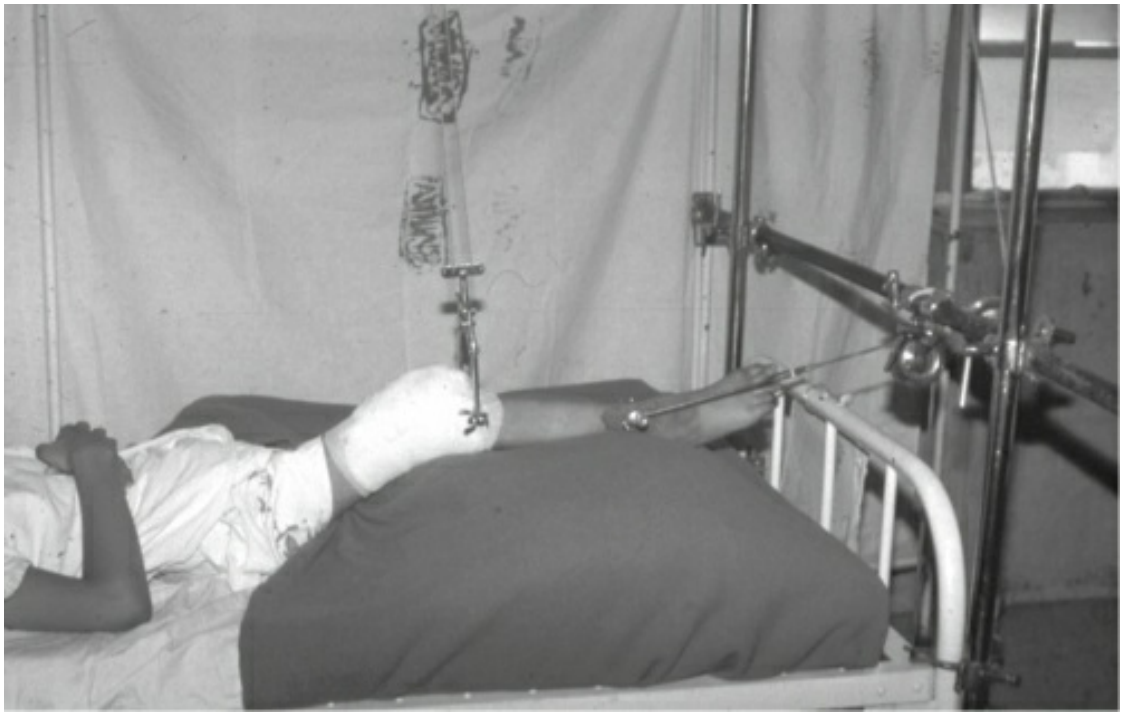

FIG. 14-2 Skeletal traction on pillows.

The period of immobilization is 6–8 weeks.

3. *Adults*: Fracture of the shaft of femur in adults and elderly patients is treated by skin or skeletal traction in a Thomas splint (Fig. 14-3) or a balanced traction over pulleys in a Bohler–Braun splint, Rusell's

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traction (see Fig. 13.25). The period of immobilization is longer, i.e., 12–14 weeks. Methods of traction immobilization, although uniting the fractured bone, are associated with deformities like limb shortening or angular deformities; moreover, long (12–14 weeks) immobilization results in complications.

Functional cast bracing: Fracture of the shaft of femur in adults can also be treated by functional cast bracing. In this method, the fracture is initially treated by traction for about 4 weeks. As the fracture becomes 'sticky' and some callus is seen on the radiographs, a cast brace (Fig. 14-4) is applied. The cast brace permits flexion at the knee joint as well as ambulation.

FIG. 14-3 Skeletal traction in a Thomas's splint.

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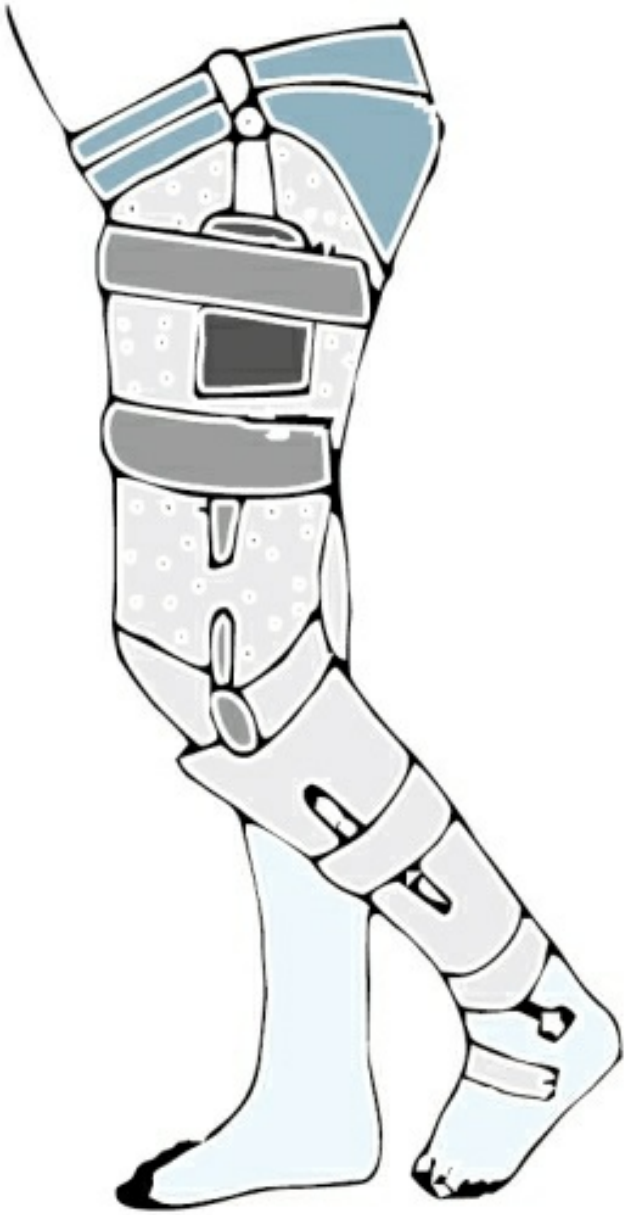

FIG. 14-4 Functional cast bracing.

Operative treatment

1. *Internal fixation*: Open reduction internal fixation of fracture fragments is generally indicated in adolescent, adult and elderly patients. It is rarely indicated in very young children where some amount of angulation and overriding of the bony fragments are acceptable. In young children, these deformities get corrected in the

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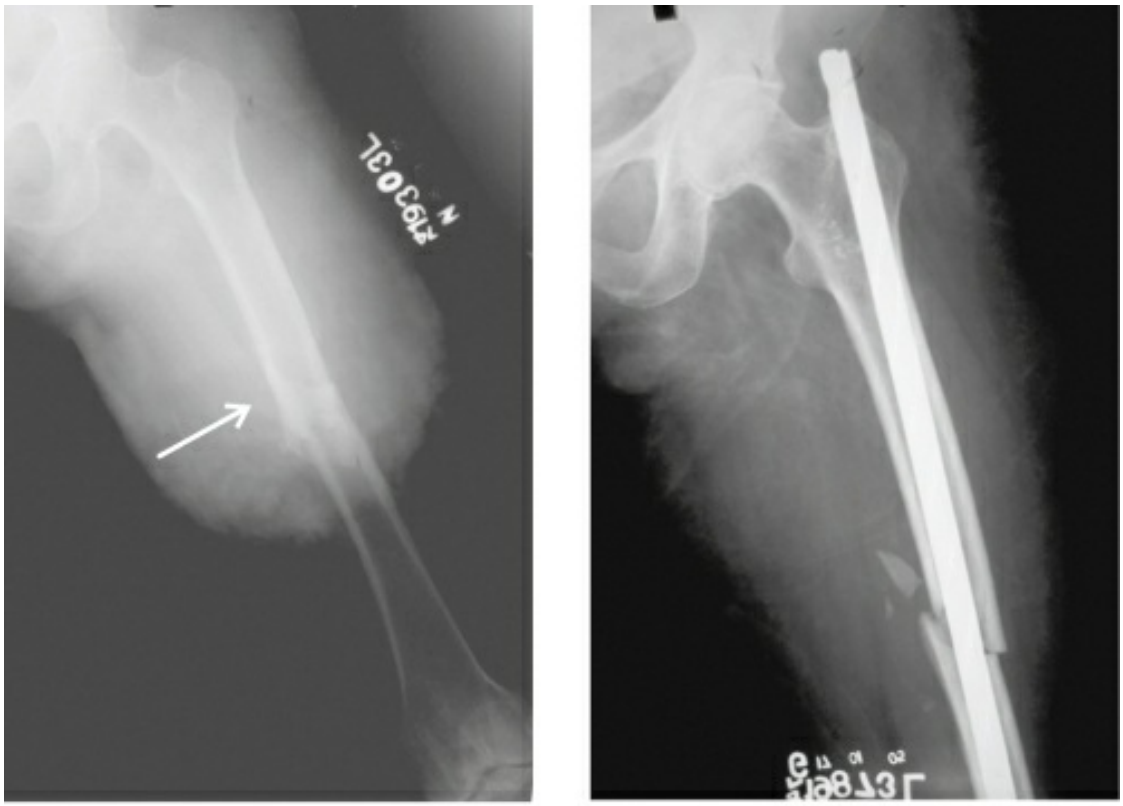
process of remodelling of the bone.

Wherever indicated, the femur is internally fixed with Kuntscher's intramedullary nail (Fig. 14-5) or plate and screws (Fig. 14-6). **Interlocking nail** is a further development over the Kuntscher's nail (Fig. 14-7). An interlocking nail provides rotational stability to the fracture and thereby facilitates fracture healing.

2. *External fixation*: Stabilization of the fracture by external fixator (Fig. 14-8) is ideal for open fractures with contaminated wounds.



(A) (B)

FIG. 14-5 **(A)** Radiograph showing a fracture in the middle of shaft of femur (arrow). **(B)** Internal fixation by a Kuntscher's nail.

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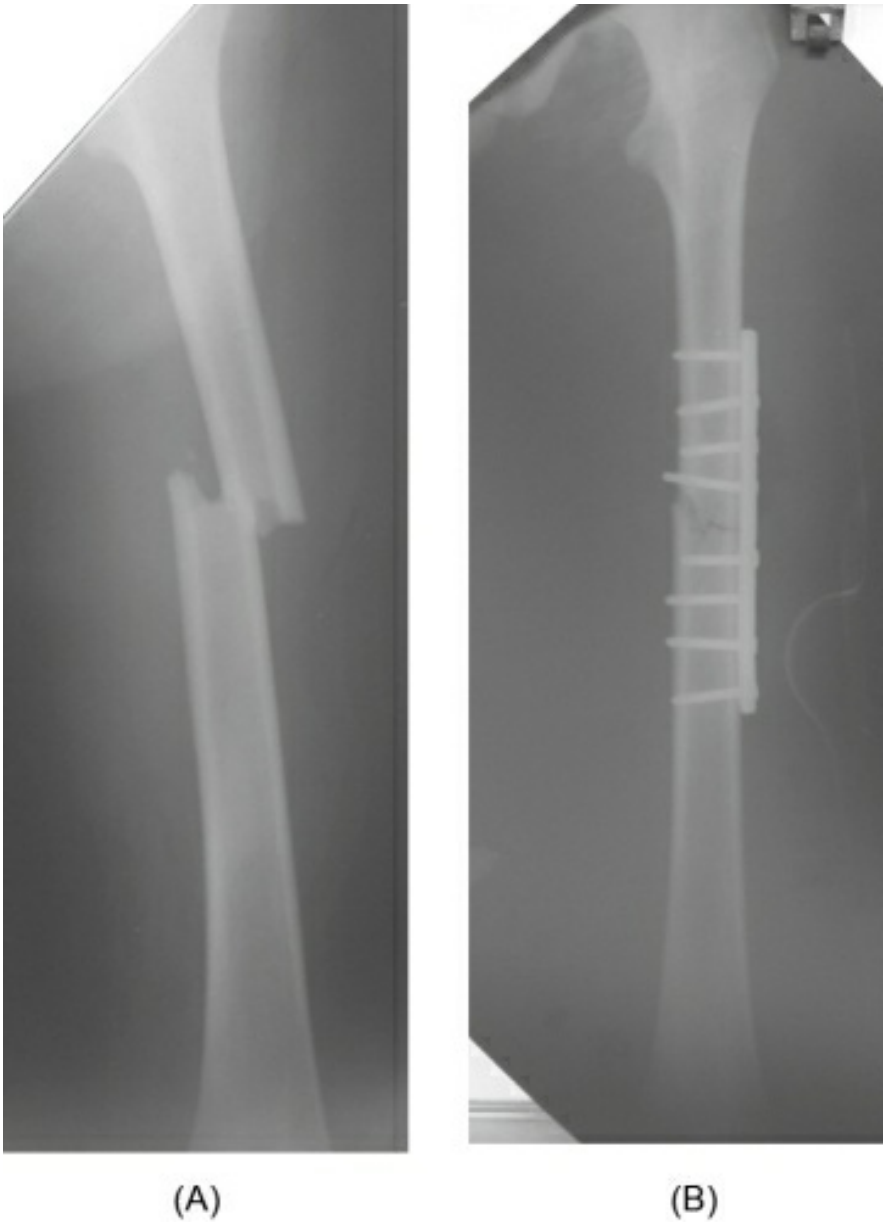

FIG. 14-6 **(A** and **B)** Fracture of the shaft of femur treated by compression plating.

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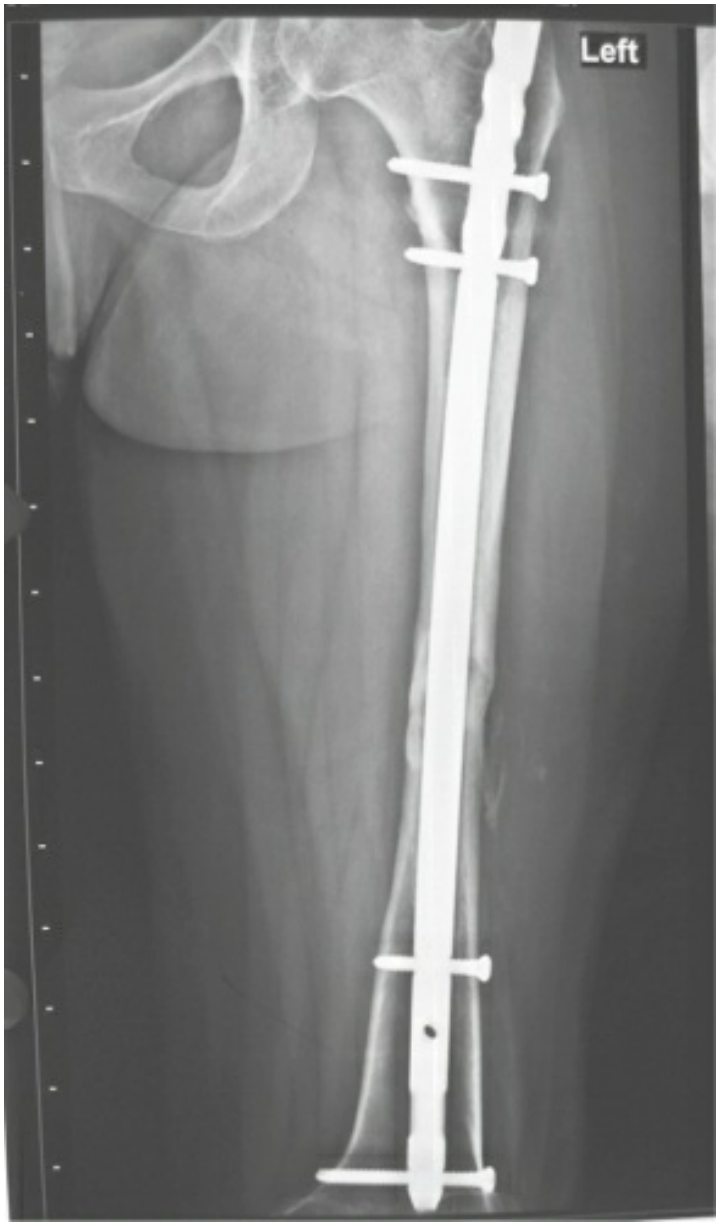

FIG. 14-7 Fracture of the femur treated by interlocking nailing.

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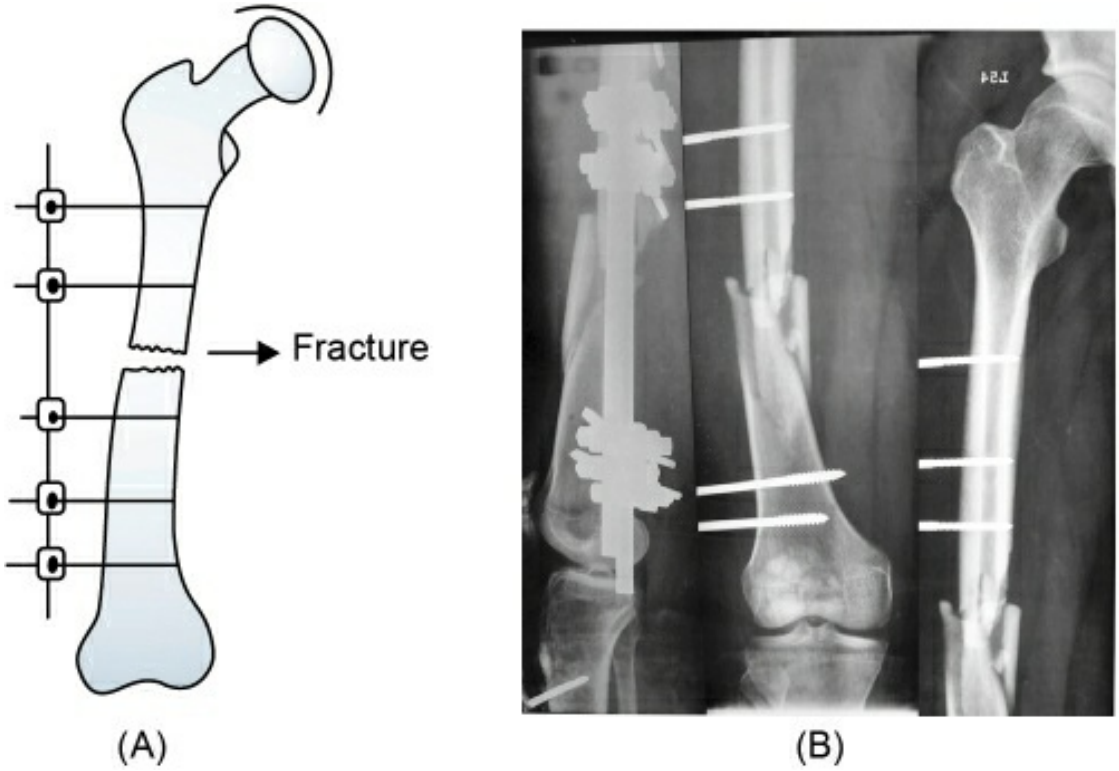

FIG. 14-8 Fracture of the shaft of femur treated by external fixator. **(A)** Line diagram, **(B)** as seen on X-ray.

Advantages of operative treatment

- Period of hospitalization and recumbency is less.
- Generally, no external immobilization is needed and hence knee mobilization can be initiated early (after 2 weeks). Although, weight bearing should be started only after the radiographic evidence of sound union is obtained, i.e., after 2–3 months.

Complications

1. *Injury to vessels and nerves*: Although rare, a sharp bony fracture fragment can cause injury to the femoral artery and femoral and sciatic nerves. In such a situation, it requires urgent repair.

2. *Infection*: An open fracture is likely to get infected. Infection during

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surgery can also lead to chronic osteomyelitis of the femur.

3. *Delayed union and nonunion*: If a fracture of the shaft of femur is treated with inadequate immobilization, it can go into delayed union or nonunion. Other common causes of nonunion include infection and interposition of soft tissues between the fracture fragments.

Delayed union or nonunion is treated by open reduction, internal fixation and bone grafting.

4. *Malunion*: Improperly treated fractures can unite in a malposition resulting in shortening and deformity of the limb.

Malunited fracture can be treated by corrective osteotomy. The bone is internally fixed with nail or plate.

5. *Knee stiffness*: Varying degrees of knee stiffness commonly result after femoral shaft fractures. The possible causes are as follows:

- Prolonged immobilization of the knee.
- Adhesions of the quadriceps muscle to the bone and callus at the fracture site.
- Intra-articular and peri-articular adhesions of the knee joint.

Knee stiffness can be treated by intensive knee mobilization programmes. Severe degree of knee stiffness can be treated surgically by an operation – quadricepsplasty. In this operation, lengthening of the quadriceps muscle is carried out. Postoperatively, intensive knee mobilization is required, initially in a Thomas splint with the Pearson knee attachment.

These days, knee stiffness can also be treated by arthroscopic surgery. In this operation, the adhesions inside the joint are broken

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arthroscopically.

Physiotherapeutic management

Early physiotherapy during immobilization follows the same pattern as described for trochanteric fractures. The skeletal traction here plays an important role as there is likelihood of marked displacement of the fractured ends because of the strong muscular action. In fracture of the upper third of the shaft of femur, the proximal fragment is flexed, abducted and externally rotated due to the actions of iliopsoas, glutei and short hip external rotators, respectively; the distal fragment is adducted due to the actions of strong adductors.

In fracture of the mid shaft region, the proximal fragment is flexed by the iliopsoas and drawn inwards by the adductors. The distal fragment is tilted backwards by the lower part of adductor magnus and is drawn upwards by the hamstrings and rectus femoris.

When the fracture is treated by skeletal traction, as the period of traction extends up to 12 weeks, early knee mobilization, which is important, can be initiated with traction and split bed (Fig. 14-9). Early initiation of isometrics to the quadriceps is essential to gain early control of quadriceps for knee flexion.

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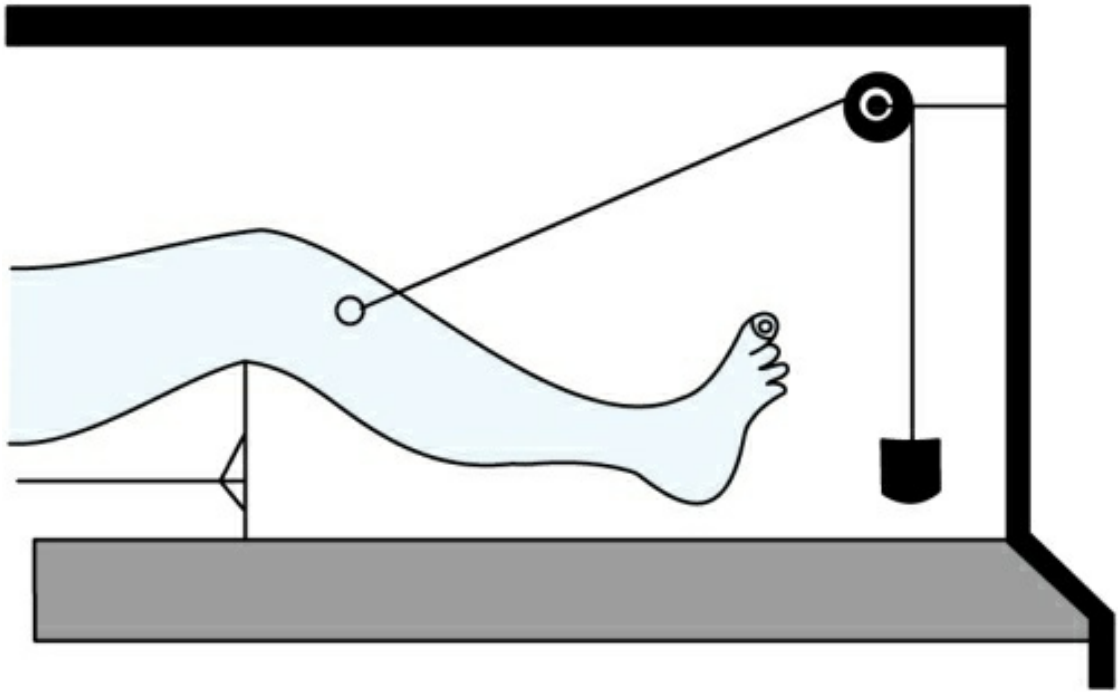

FIG. 14-9 Early knee mobilization with maintenance of traction.

When treated by intramedullary nail, mobilization of the hip and the knee can be initiated early, by 2–3 weeks. Early return of quadriceps strength and control is emphasized to achieve independent SLR by 2–3 weeks when fibrous union is established. Partial weight bearing can be initiated by 6–8 weeks and full weight bearing by 12 weeks.

Rest of the treatment programme is on the same lines as described for the trochanteric fractures treated by internal fixation.

Note: Since these types of fractures are usually associated with extensive soft tissue injury, training isometrics is difficult and painful, but can be made effective by training to simultaneously contract the same muscle groups on both the sides (e.g., bilateral static quadriceps contractions) or hams contractions.

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CHAPTER 15

Injuries of the knee

OUTLINE

- Supracondylar fracture of the femur
- Intercondylar fracture of the femur
- Physiotherapeutic management of supracondylar and intercondylar fractures of the femur
- Fracture of the patella
- Acute dislocation of the patella
- Recurrent dislocation of the patella
- Dislocation of the knee
- Fractures of the tibial condyles
- Intercondylar fractures of the tibia

Supracondylar fracture of the femur

The fracture line is just proximal to the femoral condyles. The distal fragment is pulled backwards by the pull of the gastrocnemius muscle. The sharp edge of the fracture fragment can injure the popliteal artery (Fig. 15-1). The fracture is often comminuted depending upon the severity of the force.

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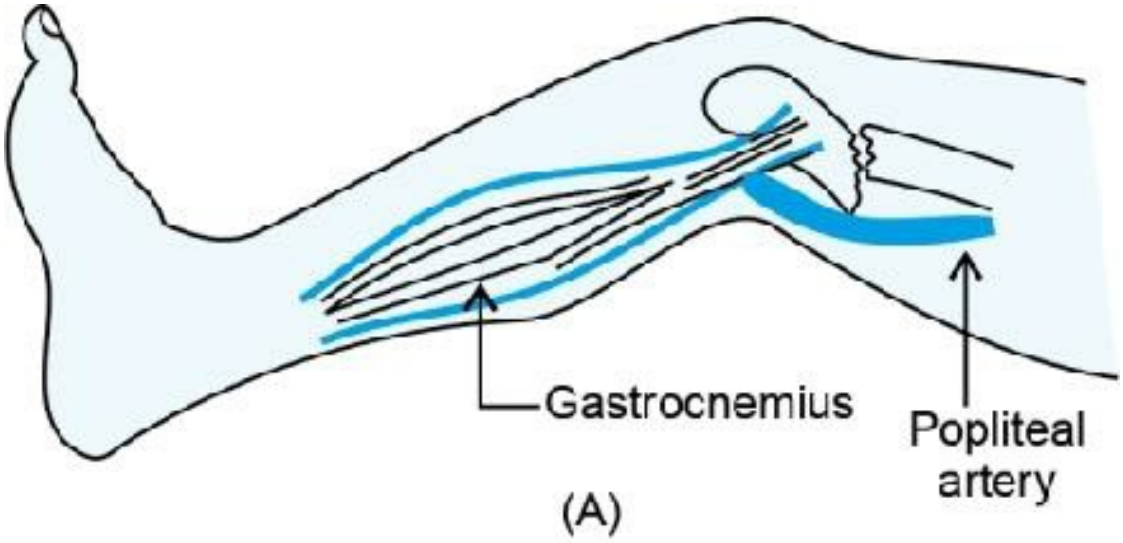

(A)

(B)

FIG. 15-1 **(A)** Pull of the gastrocnemius angulates the distal fragment posteriorly and may cause injury to the popliteal vessels (diagrammatic representation). **(B)** Radiograph showing the fracture with posterior

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displacement of the distal fragment.

Treatment

This fracture can be treated by conservative as well as operative methods.

Conservative methods

The fracture is reduced under general anaesthesia and the limb is immobilized in a Thomas' splint. Skeletal traction is applied through the upper end of the tibia and the knee is maintained in 30 degrees of flexion using a Pearson knee attachment (Fig. 15-2). The limb is immobilized for 8–12 weeks.

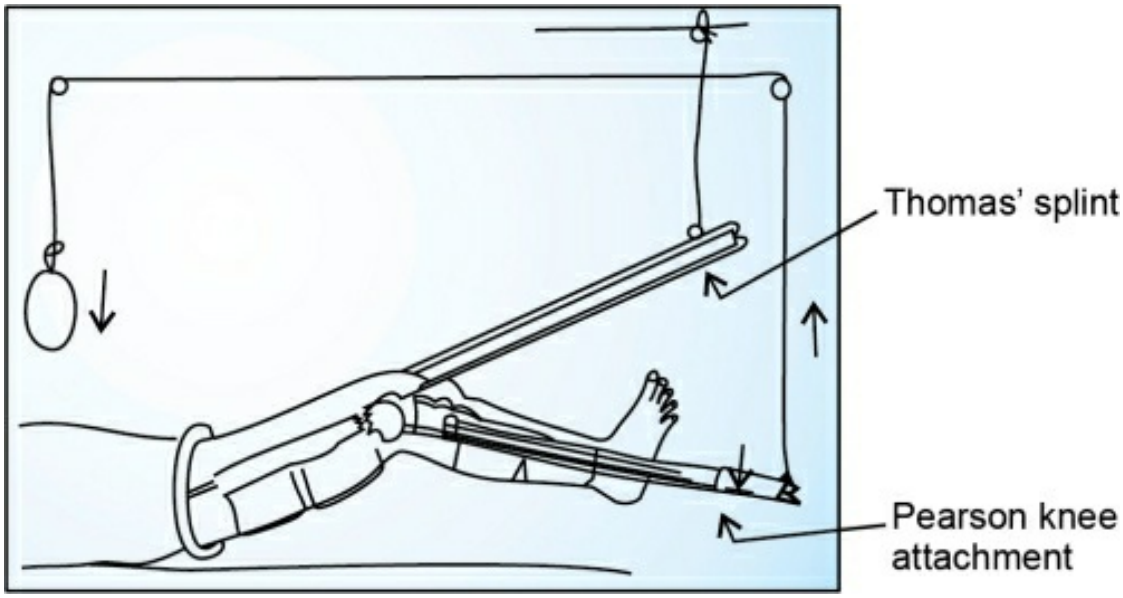

FIG. 15-2 Fracture of the distal femur: treatment by skeletal traction through upper tibial pin. Pearson knee attachment to the Thomas' splint facilitates movement at the knee joint, which the patient can do himself.

Operative methods

Surgery is indicated in cases where closed reduction fails or injury to the popliteal artery necessitates repair. The fracture is reduced by

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operation and fixed by a condylar blade plate (Fig. 15-3), a dynamic compression screw (DCS) (Fig. 15-4) or an intramedullary supracondylar nail (Fig. 15-5). Various other fixation devices are also available. Postoperative mobilization can be started after 2 weeks. However, weight bearing is started after about 3 months.

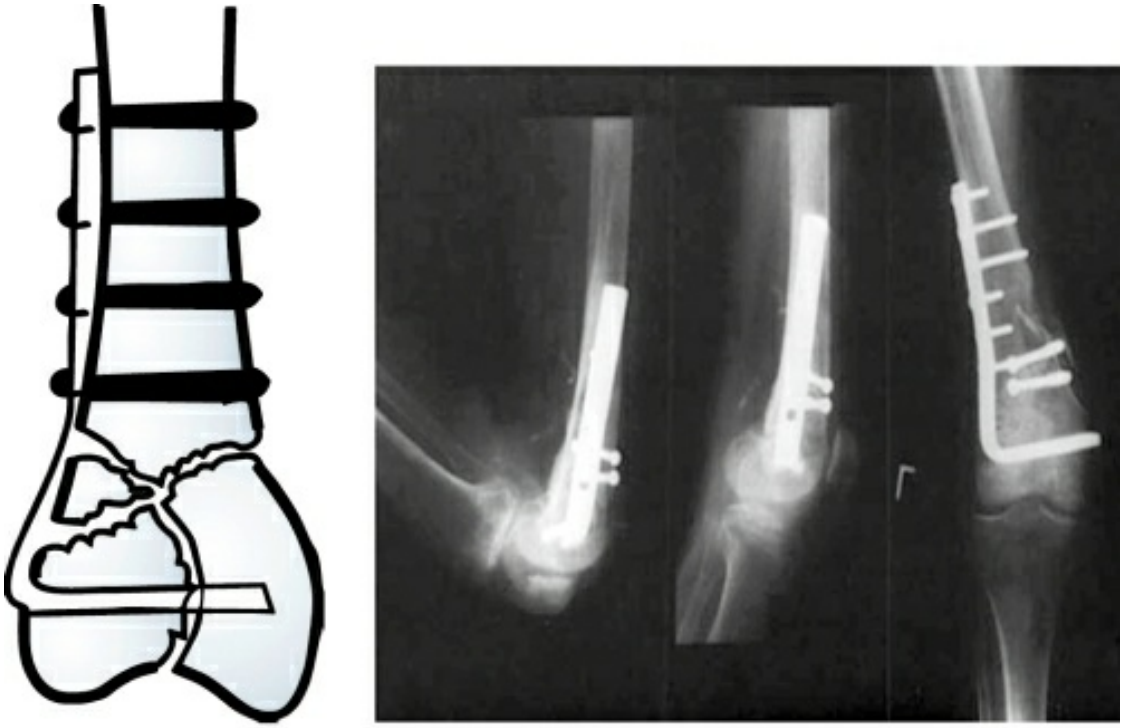

FIG. 15-3 Treatment by condylar angled blade plate. **(A)** Line diagram. **(B)** As seen on a radiograph.

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FIG. 15-4 Treatment by dynamic compression screw (DCS).

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FIG. 15-5 Treatment by intramedullary supracondyler nail.

Complications: The complications include malunion, nonunion and knee stiffness. The treatment of these complications is the same as that for fracture of the shaft of the femur. Injury to the popliteal artery, described earlier, is a serious complication encountered in this

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fracture. Repair of the artery or grafting is indicated urgently in such cases. The fracture is also fixed internally.

Intercondylar fracture of the femur

It generally occurs as a result of severe trauma. Either single or both condyles may be fractured. When both condyles are fractured, the fracture line may pass through the condyles resulting in a T- or Y-shaped fracture (Fig. 15-6). Since it is an intra-articular fracture, it is usually associated with haemarthrosis.

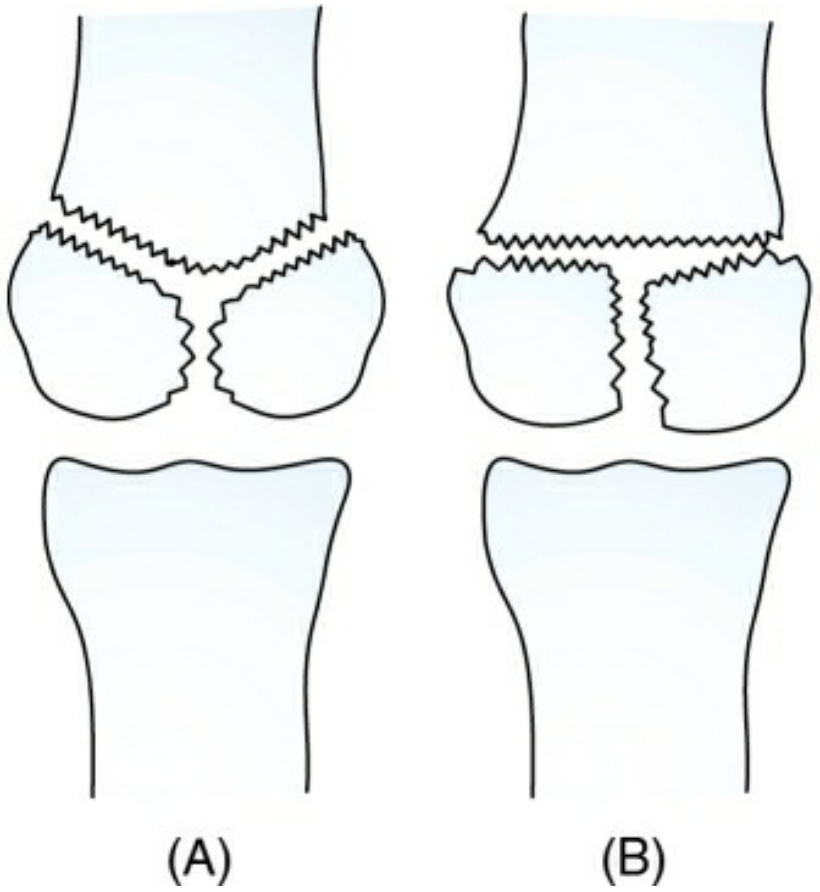

FIG. 15-6 Intercondylar fracture of femur. **(A)** Y-shaped fracture. **(B)** T-shaped fracture.

Treatment

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It can be treated by conservative or operative methods.

Conservative treatment

The plan of treatment is the same as for supracondylar fractures of the femur. Skeletal traction is applied through the upper tibia and is maintained for 6–8 weeks. Knee mobilization is started after 6–8 weeks.

Operative treatment

In all intra-articular fractures, accurate reduction of the fracture, thereby achieving congruity of the articular surfaces, is essential. Therefore, if the fracture is not too comminuted, open reduction and internal fixation of the fracture is indicated. Internal fixation is achieved by multiple screws, Kirschner wires or blade plate. Knee mobilization is started early, i.e., after 2 weeks only.

Complications

- Injury to the popliteal neurovascular bundle, especially injury to the popliteal artery needs immediate repair.
- Postoperatively, there is a danger of infection to the superficially placed implants. This needs careful monitoring.
- Knee stiffness, osteoarthritis of the knee joint and malunion are possible late complications.

Physiotherapeutic management of supracondylar and intercondylar fractures of the femur

The common problems with these injuries:

1. *Gross effusion of the knee*

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2. *Knee stiffness* – due to adhesions and involvement of the articular surfaces

3. *Knee instability* – the fracture, especially a comminuted one, may be associated with injuries to the soft tissues including ligaments; unless the soft tissue repair and bone architecture are properly restored, instability and stiffness of the knee are common features

4. *Reflex inhibition of the quadriceps* (extensor lag) – due to quadriceps insufficiency

Right from the initial period, it is absolutely essential to plan appropriate physiotherapeutic measures to control these four complications. Therapeutic measures are employed to minimize effusion; and acquire early ROM at the knee while maintaining reduction and emphasis on the early and strong isometrics to the quadriceps.

Initially, when the fracture is treated with skeletal traction, the following programme is instituted:

1. Limb elevation, pressure bandage and isometrics to the quadriceps and glutei are performed.

2. Strong ankle and toe movements are given.

3. Gradual knee mobilization is started after a week or 10 days. It may be started as a relaxed passive movement preceded by thermotherapy or cryotherapy. Self-controlled mobilization by continuous passive motion (CPM) is very effective. Early mobilization improves and maintains the tone and strength of the quadriceps besides facilitating gliding planes of quadriceps mechanism.

4. Self-assisted relaxed knee swinging with the patient sitting at the edge of the bed and supporting the operated leg by the good one is the ideal technique of mobilization.

5. Non–weight-bearing crutch walking should be initiated to make the

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patient ambulatory.

6. By 4–6 weeks, comfortable ROM of knee flexion beyond 90 degrees should be attained, with minimal effusion and full extension at the knee.

7. All the programmes should be made vigorous to gain further range and strength.

8. Partial weight bearing is initiated by 9 weeks following surgery and the patient is given proper re-education in walking.

9. Full weight bearing is permitted by 8–12 weeks. Proper gait training, ambulation and functional training are initiated.

10. Early knee mobilization and early weight bearing with cast brace has been reported by Borgen and Sprague (1975) for open or closed supracondylar and intercondylar fractures. Cast brace with polycentric hinges is applied between 3 to 6 weeks (see Fig. 14.4). Standing and walking in parallel bars and knee movements are begun on the next day after applying the brace.

Fracture of the patella

Patella is the largest sesamoid bone in the body situated in the strong quadriceps tendon. It increases the efficiency of the extensor mechanism of the knee by increasing the leverage. It has an articular surface which articulates with the intercondylar groove at the lower end of the femur. The patella may be fractured due to (1) a direct injury or (2) an indirect injury.

1. A direct injury can cause an undisplaced crack fracture of the patella or a comminuted 'stellate' fracture of the patella (Fig. 15-7).

2. An indirect injury results in a transverse fracture of the patella with displacement of fragments (Fig. 15-8). The displaced fragments are treated by tension band wiring (TBW). This is caused by forced

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passive flexion of the knee when the quadriceps muscle is in a state of contraction. The fracture fragments are pulled apart by the pull of the quadriceps muscle. Active extension of the knee, in these fractures, is impossible as the extensor mechanism of the knee is ruptured. A major direct trauma can cause a comminuted fracture (Fig. 15-9).

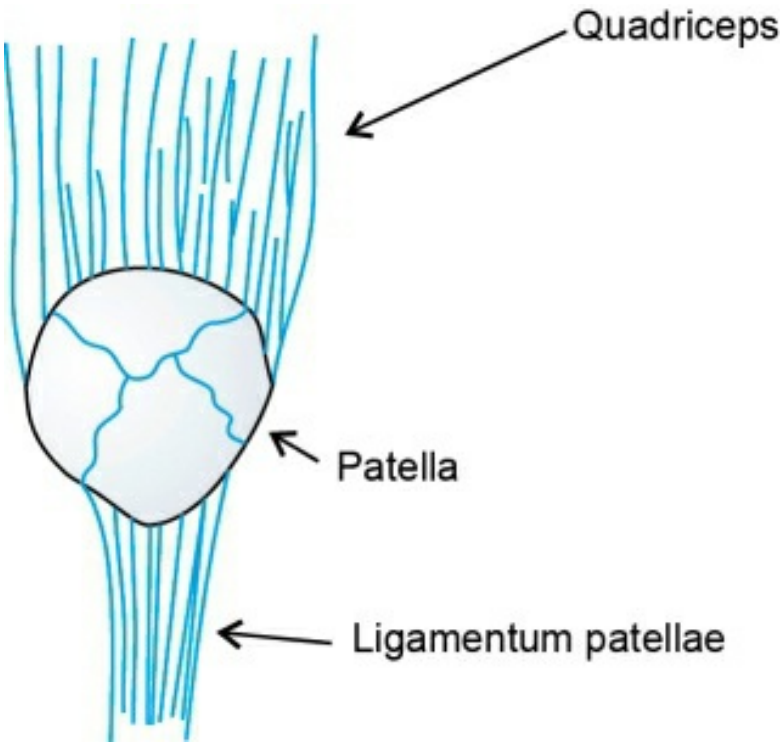

FIG. 15-7 Fracture of patella: stellate fracture.

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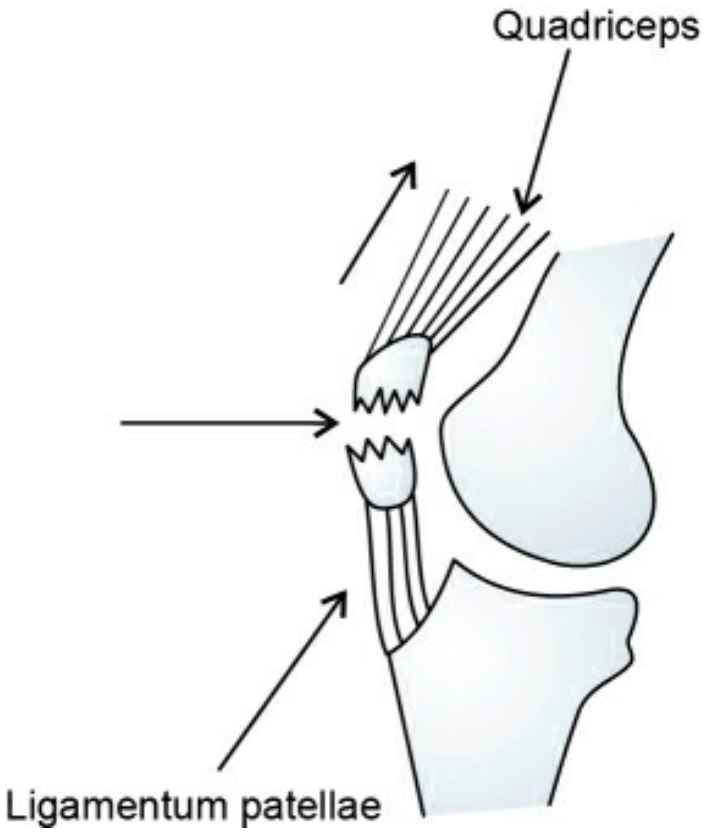

FIG. 15-8 Transverse fracture.

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FIG. 15-9 Comminuted fracture.

Diagnosis

The patient will have pain and tenderness over the patella in cases of undisplaced fractures of patella, while in displaced fractures, there is haemarthrosis and inability to actively extend the knee joint. A radiograph would confirm the type of fracture.

Treatment

The treatment can be (a) conservative or (b) operative.

Conservative treatment

An undisplaced fracture (crack or stellate type) is treated by a POP cylinder or an above-knee POP cast (Fig. 15-10) for 4 weeks. It must be remembered that the extensor mechanism should be intact.

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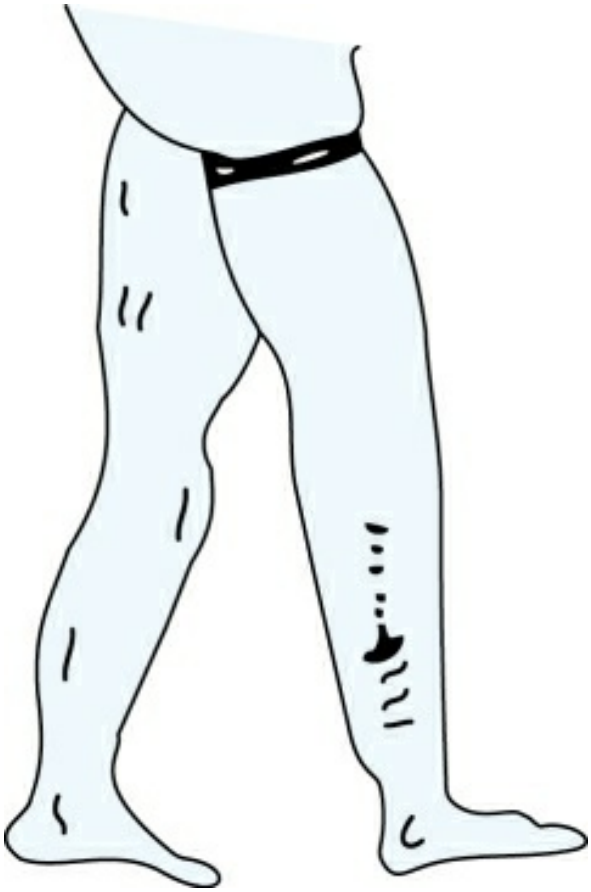

FIG. 15-10 Stellate or undisplaced fracture treated by walking POP cylinder.

Operative treatment

It is always indicated in transverse displaced fractures and rarely, in undisplaced fractures where the extensor mechanism is torn. The following surgical procedures are commonly employed:

1. *Internal fixation:* A transverse fracture is fixed internally either by a screw or by TBW (Fig. 15-11). The extensor mechanism is also repaired. An above-knee POP cast is applied for 4–6 weeks after which knee mobilization is started.

2. *Excision of the patella*: In severely comminuted fractures where internal fixation cannot be done or in elderly patients, who show signs of osteoarthritis, the patella is excised partially or completely (partial

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or total patellectomy) (Fig. 15-12) and quadriceps mechanism is repaired. The period of postoperative immobilization is 5–6 weeks.

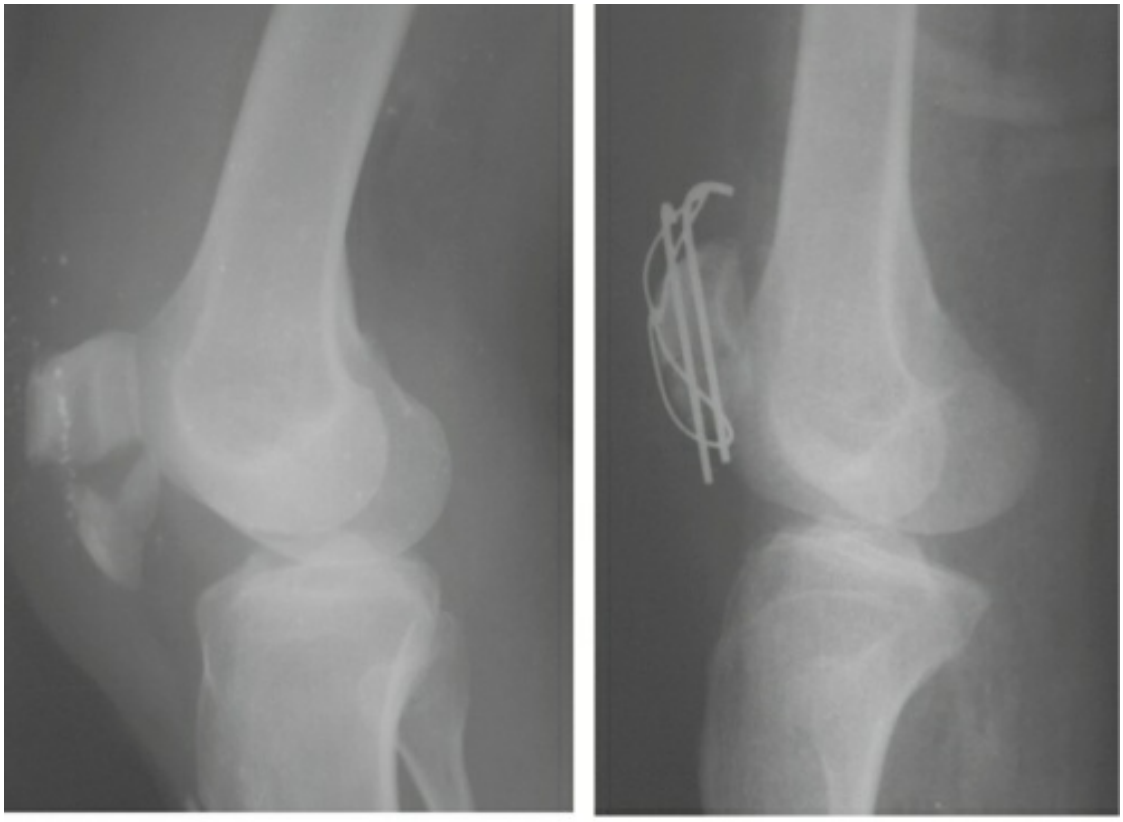

FIG. 15-11 **(A and B)** Displaced fracture of patella treated by tension band wiring.

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FIG. 15-12 Comminuted fracture treated by excision of patella, and repair of the quadriceps mechanism.

Physiotherapeutic management

The basic principles of physiotherapy:

1. To reduce effusion, pain and inflammation.

2. To provide effective quadriceps mechanism.

3. To regain maximum possible ROM of flexion–extension.

All efforts are concentrated to get the quadriceps mechanism re-established at the earliest.

Undisplaced fractures: It is usually treated in a plaster cast applied

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for 3–4 weeks.

1. Static quadriceps contractions are initiated early in the plaster. Similarly, begin with assisted SLR early, although not strong enough to provoke pain. Repetition of SLR and holding it for 10 s, the POP slab itself provides good assistance as well as resistance.

2. Weight bearing and crutch walking is started immediately the next day and the patient resumes work in 3–4 days.

3. The POP cylinder cast is removed after 4–6 weeks and knee flexion is initiated as relaxed passive movement, with or without CPM.

4. Knee flexion may be preceded by thermotherapy or cryotherapy and made vigorous to attain early movement.

5. Correct weight bearing and gait pattern should be re-established to avoid limp. Full function should be regained by 8–12 weeks.

Displaced fractures: These are usually treated by internal fixation by TBW or screw fixation. It is also treated by patellectomy.

Physiotherapeutic management (TBW treatment): The basic objective of physiotherapy is to attain mobile and strong knee with emphasis on the return of a strong quadriceps mechanism.

The obvious advantages of this procedure are as follows:

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1. The surgical procedure is not as extensive as patellectomy.

2. The patella is retained with its muscular attachments.

3. The period of immobilization is short.

These factors allow early mobilization of the knee, which is important to regain strength and mobility.

(a) *Preoperative evaluation and education:* Due to the presence of pain and haemarthrosis, accurate assessment is not feasible. Therefore, the postoperative regime of physiotherapy should be explained on the normal side.

(i) The physical requirements of the patient's routine and work should be assessed in relation to the knee.

(ii) The adjacent joints should be examined to rule out any dysfunction.

(b) *Postoperative regime (1–10 days)*: The limb is immobilized in a posterior plaster cast or in a pressure bandage.

(i) The limb encased in a plaster cast should be elevated over pillows. If pressure bandage is applied, the pillows should be so arranged that there is no sudden slipping of the limb. Even a slight sudden flexion at the knee should be avoided.

(ii) Diapulse may be given over the cast or bandage.

(iii) Vigorous ankle and toe movements and relaxed

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passive movements to the hip should be given.

(iv) Direct isometrics to the quadriceps should be deferred for 3–4 days. Indirect isometrics can be initiated by pushing down the whole leg against the mattress, a small and soft pillow under the knee or with strong and sustained ankle dorsiflexion.

(v) Graduated assisted SLR can be started by 3–4 days, but it should not be painful.

(vi) Non–weight-bearing crutch walking to be initiated as soon as it is painless.

Mobilization (10 days onwards): The stitches are out by 10–14 days. This is the vital period to regain knee ROM as well as strength in the quadriceps and hamstrings. The pain is usually due to the setting in of retropatellar degenerative changes. Therefore, physiotherapy should be directed towards strengthening of quadriceps and ROM of the knee avoiding undue strain on the repaired extensor mechanism.

1. Mobilization should be initiated within a small range either by CPM apparatus or as a relaxed passive movement.

2. Strong isometrics to the quadriceps by the use of a wedge or self-assisted exercise by using the web between the thumb and index finger (Fig. 15-13), repeated every hour, are important.

3. Self-assisted stretching of the knee in the range of flexion

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as well as terminal extension with knees hanging at the edge of the bed is ideal.

4. Gradual weight bearing to be initiated after 6 weeks, in parallel bars with correct methods of weight transfers and gait. It should be progressed to a cane. The whole regime of management should be made progressive with progressive resistive exercise (PRE) and prone kneeling.

The patient must regain adequate knee ROM and muscle power by 6–8 weeks. It takes between 8 and 12 weeks to gain full ROM. However, mild extensor lag may continue for about 6 months (Dudani & Sancheti, 1981).

Comminuted fracture: treated by patellectomy

First week: Strong ankle and foot movements with the leg in elevation are started immediately.

The surgical incision and the sutured ligamentum patellae may be painful initially while doing isometrics to the quadriceps. Therefore, mild indirect contractions to the quadriceps should be initiated by putting a soft wedge under the knee. Feeble static contractions to the quadriceps should be ensured. Patients usually use the gluteus maximus for the quadriceps. Isometrics to quadriceps at this painful stage are possible only when the patient has had adequate preoperative training.

Electrical stimulation can be used as an adjunct to re-educate the quadriceps contractions.

Assisted SLR with enough assistance to initiate the lift

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should be started at the earliest, without much discomfort.

Second week: Partial weight-bearing gait training should be added, making the previous programme or exercise more vigorous.

Mobilization

1. As the soft tissue healing is adequate to begin gradual mobilization in a small range in patients treated by bandage, self-assisted small arc passive movements are ideal to initiate mobilization.

2. Controlled CPM or relaxed passive movements are extremely effective at this stage.

Third week onwards:

1. Assisted active movements to be initiated with graduated weight-bearing gait training.

2. In patients treated with posterior splint, the splint should be removed intermittently for exercises and reapplied for walking.

3. In patients treated with POP, non–weight bearing facilitates them to go back to work as the POP cylinder is continued up to 6 weeks.

4. Vigorous exercise programme needs to be given to patients treated by 6 weeks' immobilization as the knee joint is considerably stiff and painful.

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5. Hydrotherapy is an effective measure to achieve mobility and strength.

6. PRE has to be carried out intensively to strengthen the quadriceps, hamstrings and the ligaments of the knee joint.

7. Proper gait training and functional positions are guided.

8. The results are generally good and an adequate range of motion and strength returns by 8–12 weeks after surgery.

FIG. 15-13 Self-assisted or resisted isometrics to isolated quadriceps by using the web between the thumb and the index finger.

After patellectomy there is an urgency to concentrate maximally on quadriceps strengthening procedures. Initiating isometrics at the earliest opportunity and regularly monitoring the strength are essential to strengthen the quadriceps.

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Acute dislocation of the patella

The patella always dislocates laterally. The injury occurs in a semiflexed knee with the relaxed quadriceps muscle. The patella is forced laterally.

Treatment

The patella may be pushed back into its place easily. However, the reduction may have to be done under general anaesthesia. An above-knee POP cast is given for 3–4 weeks after which the knee is mobilized.

1. Gentle isometrics to the quadriceps are initiated as early as possible. Limb encased in a cast is pressed downwards by placing a pillow under the foot which indirectly initiates static contractions in the quadriceps (Fig. 15-14).

2. SLR by the physiotherapist, fully supporting the weight of the limb, also helps in initiating isometrics to the quadriceps besides improving hip control and strength.

3. PWB crutch walking can be started as soon as pain is reduced.

4. Vigorous exercise to improve the extensor mechanism and procedures to mobilize the knee are begun on removal of the cast and progressed. Full knee ROM and adequate control of knee mechanics should be regained by 6–8 weeks.

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FIG. 15-14 Early initiation of isometrics to quadriceps and gluteus maximus and minimus by pressing pillow downwards and to the side of fracture by blocking with a soft pillow.

Recurrent dislocation of the patella

In recurrent dislocation of the patella, the patient has repeated episodes of dislocation of the patella. The patient is usually asymptomatic between the attacks.

In habitual dislocation of patella, the patella dislocates with every flexion of the knee, but reduces spontaneously as soon as it is extended.

In either type of dislocation, the patella always dislocates to the lateral side. The causes of recurrent dislocation of patella include laxity of the ligaments, weak musculature, poorly developed lateral femoral condyle and small or abnormally placed patella.

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Clinical features

Recurrent dislocation of the patella may occur with/without injury. The patella dislocates laterally with severe pain. *Apprehension test* may be positive which is when the patella is pushed laterally and the knee is flexed, the patient resists this manoeuvre.

Treatment

Surgical operation is the only effective treatment for recurrent dislocation of the patella. The basic principle of surgical operation is realignment of the quadriceps mechanism, so that the patella is prevented from dislocating laterally when the knee is flexed. However, in adults, there may be an associated osteoarthritis of the knee joint and therefore, the patella is removed and the quadriceps mechanism is repaired.

Postoperative regime

Postoperatively, an above-knee POP cast is given for 4–6 weeks, after which the knee is mobilized.

Physiotherapy following surgery

During immobilization (4–6 weeks)

1. Strong toe movements and active hip movements to be started as early as possible.

2. On the second postoperative day, non–weight-bearing crutch walking can be initiated.

3. Indirect isometrics to the quadriceps should be initiated in the form of assisted SLR (Fig. 15-15) or by pushing the leg encased in the cast downwards on the mattress in supine lying. Direct weak isometrics to the quadriceps should be begun inside the cast within the limits of discomfort.

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FIG. 15-15 SLR assistance is provided by physiotherapist posteriorly just proximal to the ankle joint by one hand, and below the knee by the other.

Mobilization

1. Gradual knee mobilization is begun in a small range ideally by CPM, relaxed passive movements or as self-assisted (using normal leg) knee swinging.

2. Hydrotherapy in the form of whirpool is extremely useful at this stage.

3. Assisted SLR to be initiated.

4. Self-resistive hamstring exercises and sessions of endurance training in the maximum extension position of the knee should be emphasized.

5. Knee orthosis may be used, as a protective measure for 8–10 weeks

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while walking, till the patient regains full active extension and 70–90° of flexion.

6. Quadriceps and hamstrings co-contractions could be beneficial in achieving good control of movements.

7. Isokinetic exercises are valuable means of improving endurance. The exercises should be progressed to resistive exercises.

By 10–12 weeks, body resistive squats may be begun with brief periods of jogging, running and light sports.

The physiotherapeutic management following patellectomy is described earlier.

Dislocation of the knee

It is a rare injury caused by considerable violence. The cruciate and collateral ligament(s) are usually torn.

Treatment

The dislocation is reduced under general anaesthesia as an emergency. Open reduction may have to be performed, if closed reduction fails. Repair or reconstruction of the torn ligaments may also be required. An above-knee POP cast is worn for 12 weeks.

Physiotherapeutic management

Following closed reduction: Initially the limb is rested on a back splint with knee in 15 degrees of flexion.

1. Ankle and toe movements are checked along with the sensory status to exclude injury to the popliteal nerve.

2. Circulation in the foot is examined to exclude injury to the popliteal artery.

3. Vigorous ankle and toe movements with leg in elevation are given

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to reduce swelling.

4. When the swelling has subsided, POP cast is applied for 12 weeks.

Following surgical reconstruction (during immobilization)

1. Isometrics to the quadriceps and glutei are emphasized right from the first day, besides points 1, 2 and 3 described earlier, after closed reduction.

2. Non–weight-bearing crutch walking to be started on the second or third day.

3. Assisted SLR to be begun by 1 week and progressed to voluntary SLR by the patient.

4. Gradual weight bearing can be initiated with plaster as soon as the patient can perform SLR; and can be progressed to full weight bearing.

Mobilization: The nature of injury and long period of immobilization poses two main problems:

1. Stiff and painful knee

2. Instability of the knee with increased anteroposterior glide or lateral wobble

Therefore, extra efforts are needed to concentrate on mobilization as well as controlled stabilization of the knee. The maximum range as well as endurance is to be regained at the earliest. It proceeds on the same lines as described for patellectomy. However, manipulation under GA may become necessary to assist further mobilization when the knee is not yielding to routine exercises.

Fractures of the tibial condyles

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Fractures of the medial or lateral tibial condyles occur as a result of varus or valgus strain respectively. Fracture of the lateral condyle of tibia, also called 'bumper fracture', is more common and occurs following an injury by the bumper of a car on the lateral aspect of the knee joint (Fig. 15-16). These fractures are usually associated with injury to the collateral ligaments on the opposite side. Fractures of the lateral condyles are occasionally comminuted fractures with marked depression of the tibial plateau (Fig. 15-17A and B).

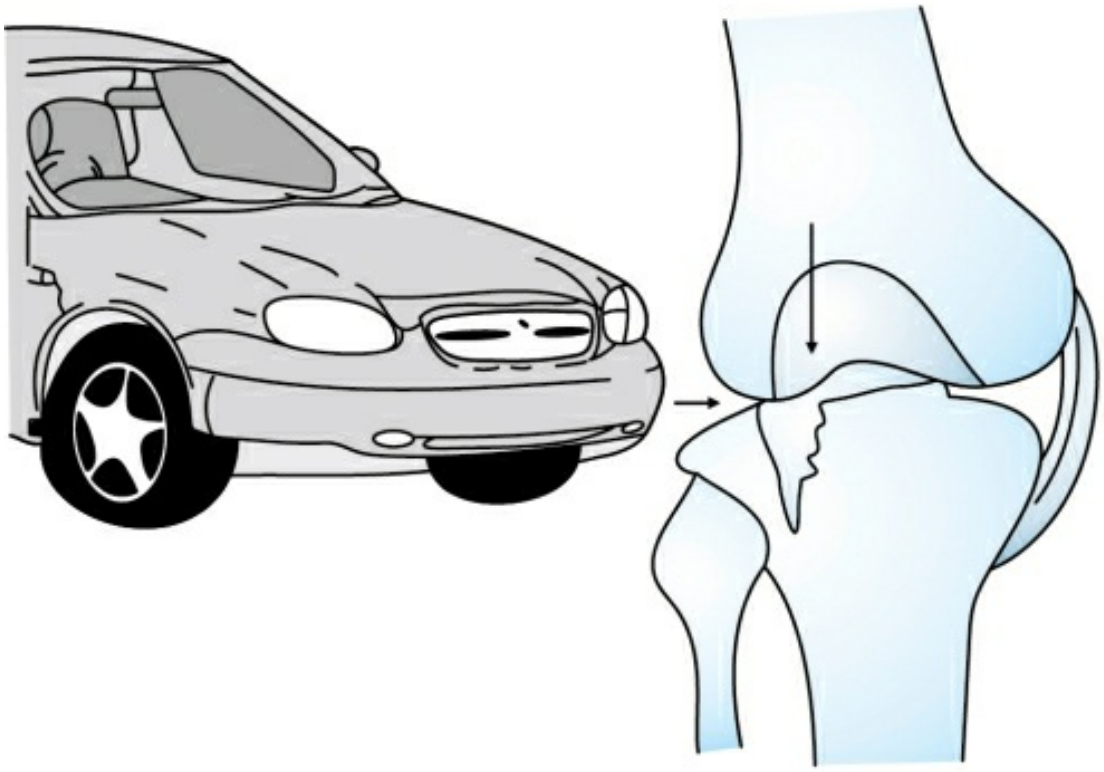

FIG. 15-16 Fracture of the lateral condyle of tibia resulting from injury by bumper of the car.

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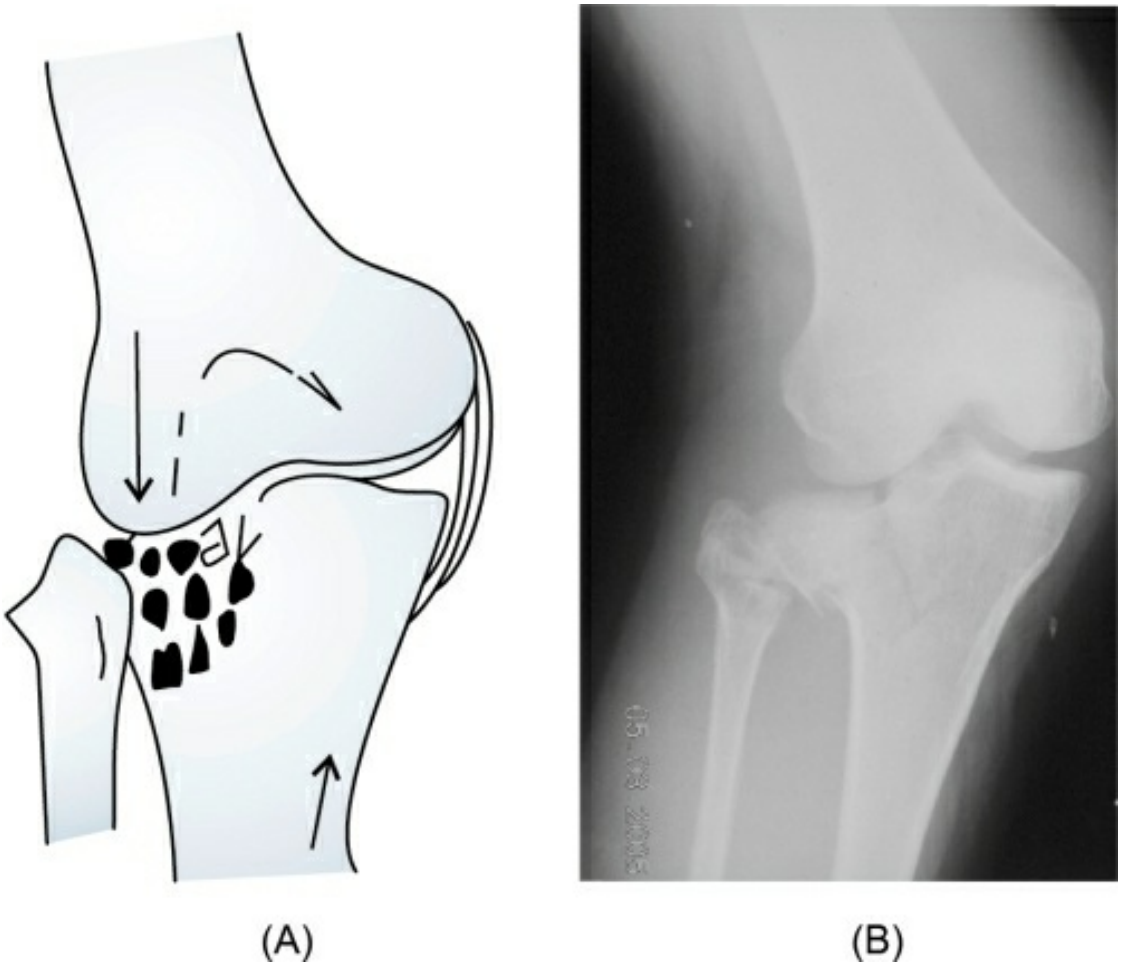

FIG. 15-17 Comminuted fracture. **(A)** Diagrammatic representation with marked depression, and **(B)** as seen on a radiograph of the lateral plateau.

Following an injury, the patient presents with a painful, swollen knee with haemarthrosis of the knee joint.

Treatment

Conservative treatment

Plaster immobilization: This method is indicated only in undisplaced fractures. An above-knee plaster cast is applied for 3–4 weeks. Knee mobilization is started after removal of the plaster. Weight bearing, however, is allowed after 3 months.

Traction: This is a simple and commonly employed method of

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treatment for displaced fractures. A below-knee skin traction or skeletal traction through the tibia is given for 3 weeks. After 3 weeks, the knee is mobilized. However, weight bearing is started after the union is consolidated, usually after 3 months. The disadvantage of this method is prolonged immobilization. However, generally good results, in terms of knee movements, are obtained by this method.

Surgical treatment

Open reduction and internal fixation of this fracture is ideally indicated in grossly displaced and/or fractures where the tibial plateau is depressed due to impact by the lateral femoral condyle. In the latter situation, the tibial plateau is elevated and the fracture is fixed by a special type of plate (Fig. 15-18). Bone grafting is also required to support the tibial plateau.

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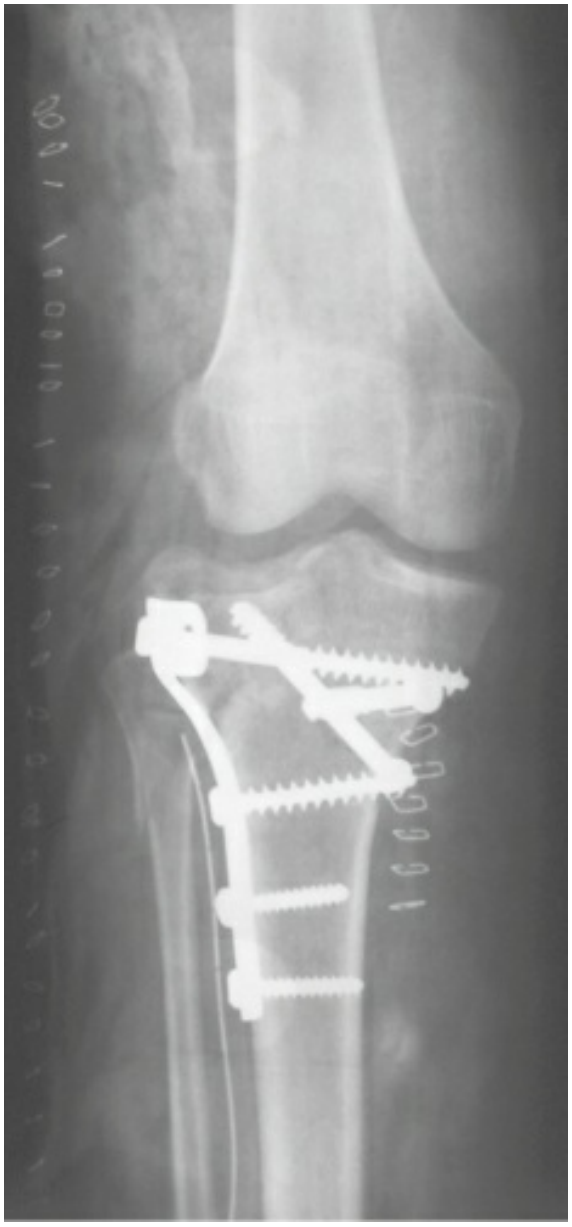

FIG. 15-18 The fracture fixed with plate and screws. Note that the depression in the lateral tibial plateau has been corrected by surgery.

Undisplaced fracture can be treated by a long screw. Postoperatively, knee movements can be started after 1 week but weight bearing is allowed after 3–4 months.

The patient may have some limitation of knee movements in severely displaced and/or comminuted fractures in spite of open reduction and internal fixation.

In grossly displaced or comminuted fractures, open reduction with

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internal fixation is done. Knee mobilization can be initiated early during the second postoperative week. Mobilization procedures need extra emphasis and should be repeated often in spite of discomfort to achieve early functional range of motion. Fractures often result in stiff knee due to severe articular damage.

Physiotherapeutic management

Undisplaced fractures which are treated by conservative methods do not pose any specific problems.

During immobilization

- Early initiation of isometrics to the quadriceps and hamstrings is important.
- Vigorous toe movements in POP immobilization; and ankle and foot movements in patients treated with traction are repeated often.
- Assisted SLR can be initiated early in patients treated with plaster immobilization as soon as it is painfree.
- Non–weight bearing to be initiated on axillary crutches to encourage early ambulation on the third or fourth postoperative day.

Mobilization

- Knee mobilization is of vital importance and with correct methods of mobilization, early return of near normal to normal mobility is restored. Suitable electrotherapeutic modality, CPM and relaxed passive movements are instrumental.
- While mobilizing, the knee joint should be carefully examined for the possibility of genu valgum, especially in fractures of the lateral tibial condyle.

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- Regaining early extension is important to avoid extra stress leading to osteoarthritic changes and poor gait.

- Strengthening procedures for the quadriceps and hamstrings are equally important. They need special emphasis in view of the expected osteoarthritic changes. The damaged articular surface of the tibial condyle often remains irregular.

- If the union of the fracture is acceptable, graduated partial weight bearing may be started after 10 weeks – from two axillary/elbow crutches and progressed to one crutch, to one cane and no aid, by 12 weeks.

- Other ambulatory activities and gait training should be added. Medial shoe insert or wedge may be necessary in patients with residual genu valgum deformity to relieve compression at the lateral compartment of the knee joint.

Intercondylar fractures of the tibia

A fracture through both the medial and lateral condyles of tibia occurs following a force that pushes the femoral codyles on the tibial plateau, e.g., fall from a height. It results in a T- or Y-shaped fracture through the tibial condyles. It is a rare injury.

Treatment

Conservative treatment

The fracture fragments are reduced under anaesthesia and the limb is immobilized by skeletal traction applied through the lower end of the tibia. The traction is maintained for 4–6 weeks and then the knee is mobilized. Full weight bearing is permitted after 3 months.

Operative treatment

Open reduction and internal fixation of the fractured fragments is achieved with the help of screws or special plates. Postoperatively,

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knee mobilization is started after 1 week or 10 days, but weight bearing is allowed after 3–4 months.

Physiotherapeutic management proceeds on the same lines as described for fractures of the tibial condyles.

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CHAPTER 16

Injuries of the leg

OUTLINE

■ Fracture of the tibia and fibula (fractures of both bones of the leg)

Fracture of the tibia and fibula (fractures of both bones of the leg)

These are common injuries and result mainly from road traffic accidents. As the tibia is a subcutaneous bone, its fractures are often open (compound) fractures.

An angulatory force produces a transverse or short oblique fracture (Fig. 16-1); rotational force produces a spiral fracture and direct blow to the tibia can result in a comminuted fracture.

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FIG. 16-1 Fracture of the shafts of tibia and fibula.

Treatment

An open wound, which can be extensive, poses a problem in the management of these fractures. However, these injuries can be treated

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by any of the following methods:

1. *Plaster*: The fracture is manipulated under general anaesthesia and an above-knee POP cast is applied. Static quadriceps exercises are begun as soon as pain permits. Non–weight-bearing crutch walking can be started after 2 weeks. Union of the fracture may take 3–6 months. Weight bearing is allowed only after the union is consolidated.

2. *Functional cast bracing*: Relatively stable transverse fractures of the tibia may be treated by an above-knee POP cast for the initial 3–4 weeks. The plaster is then changed into a patellar tendon bearing (PTB) cast (Fig. 16-2). This allows knee mobilization and early weight bearing.

3. *Traction*: Severely comminuted fractures can be treated by skeletal traction applied through the lower tibia or calcaneum (Fig. 16-3). The traction is maintained for 10–12 weeks.

4. *Operative treatment*: It is indicated when closed reduction fails or the fracture is displaced in the plaster. Open reduction is performed and the fracture is internally fixed by plate and screws or intramedullary nail (Fig. 16-4). These days, fracture of the tibia is treated by closed interlocking nailing (Fig. 16-5). After surgery, knee mobilization is started after a week or two. Weight bearing, however, is allowed after 3 months.

5. *External fixation*: The tibia is fixed with two or three pins passed transversely in the tibia on either side of the fracture (Fig. 16-6). It is indicated in severely comminuted fractures and where there is marked soft tissue damage. This method facilitates care of the wound and the patient can walk with the help of crutches (non–weight bearing).

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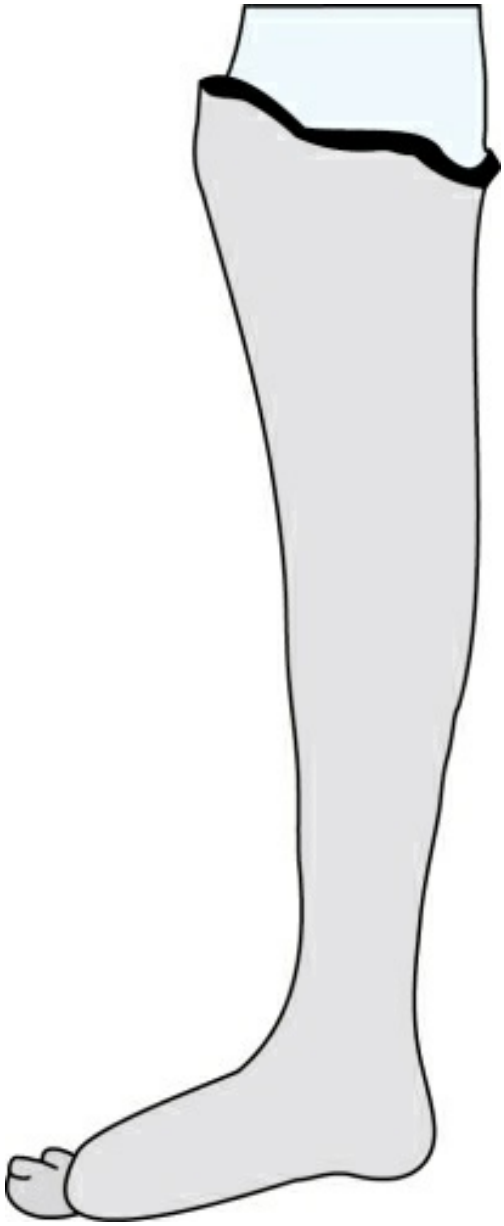

FIG. 16-2 Patellar tendon bearing (PTB) cast.

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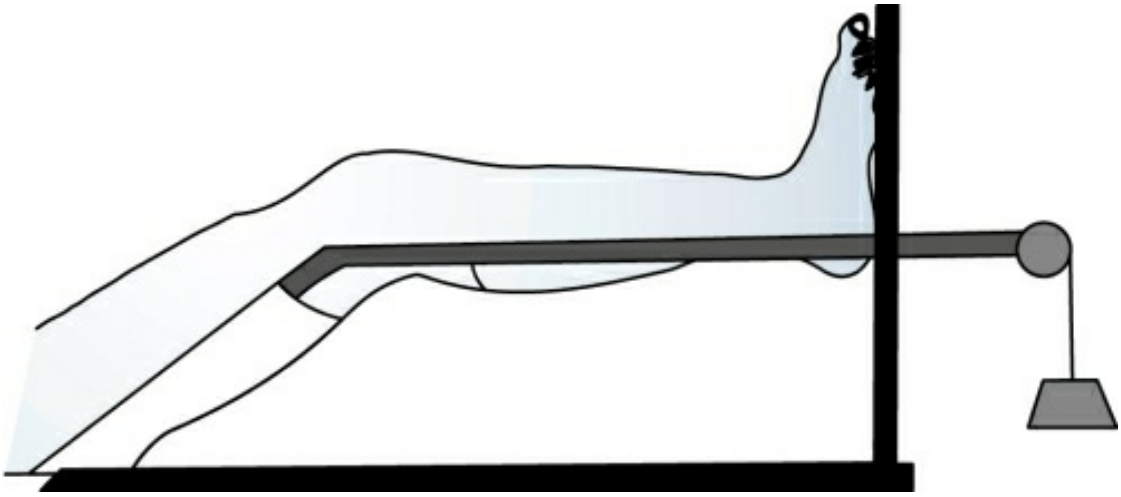

FIG. 16-3 Skeletal traction through calcaneum.

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FIG. 16-4 Treatment by compression plating of the tibia.

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FIG. 16-5 Fracture of tibia treated by interlocking nailing.

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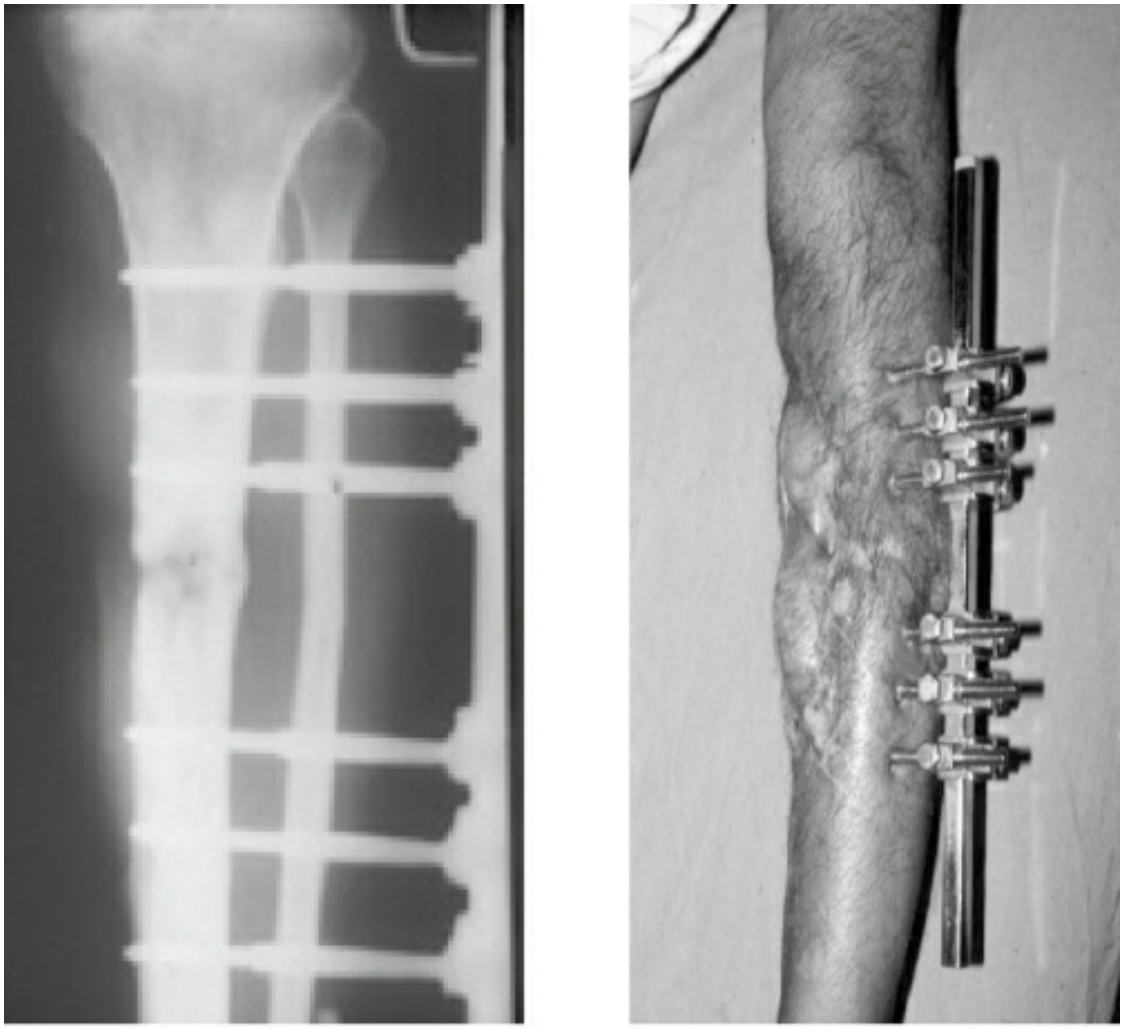

FIG. 16-6 **(A and B)** Fracture of tibia treated by an external fixator.

Complications

1. *Infection*: As already discussed, open fracture of the tibia and fibula are quite common. The bone is likely to get infected and may develop osteomyelitis.

2. *Injury to the vessels:* The popliteal artery may be injured in fractures of the upper third of the tibia. The artery needs to be repaired urgently.

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3. *Compartment syndrome*: In a closed fracture, bleeding from the fractured bone ends causes a rise in the pressure in the fascial compartments of the leg. This, in turn, leads to muscle ischaemia. A tight plaster may also have the same effect. Removal of the tight plaster or surgical decompression of the tight compartment is the treatment.

4. *Delayed union and nonunion*: Undue delay in union or failure to unite (Fig. 16-7) necessitates bone grafting operation along with internal fixation of the fracture.

5. *Malunion*: It may cause angulatory deformity and/or shortening of the leg (Fig. 16-8). It may also predispose the patient to osteoarthritis of the knee and/or ankle *joints.*

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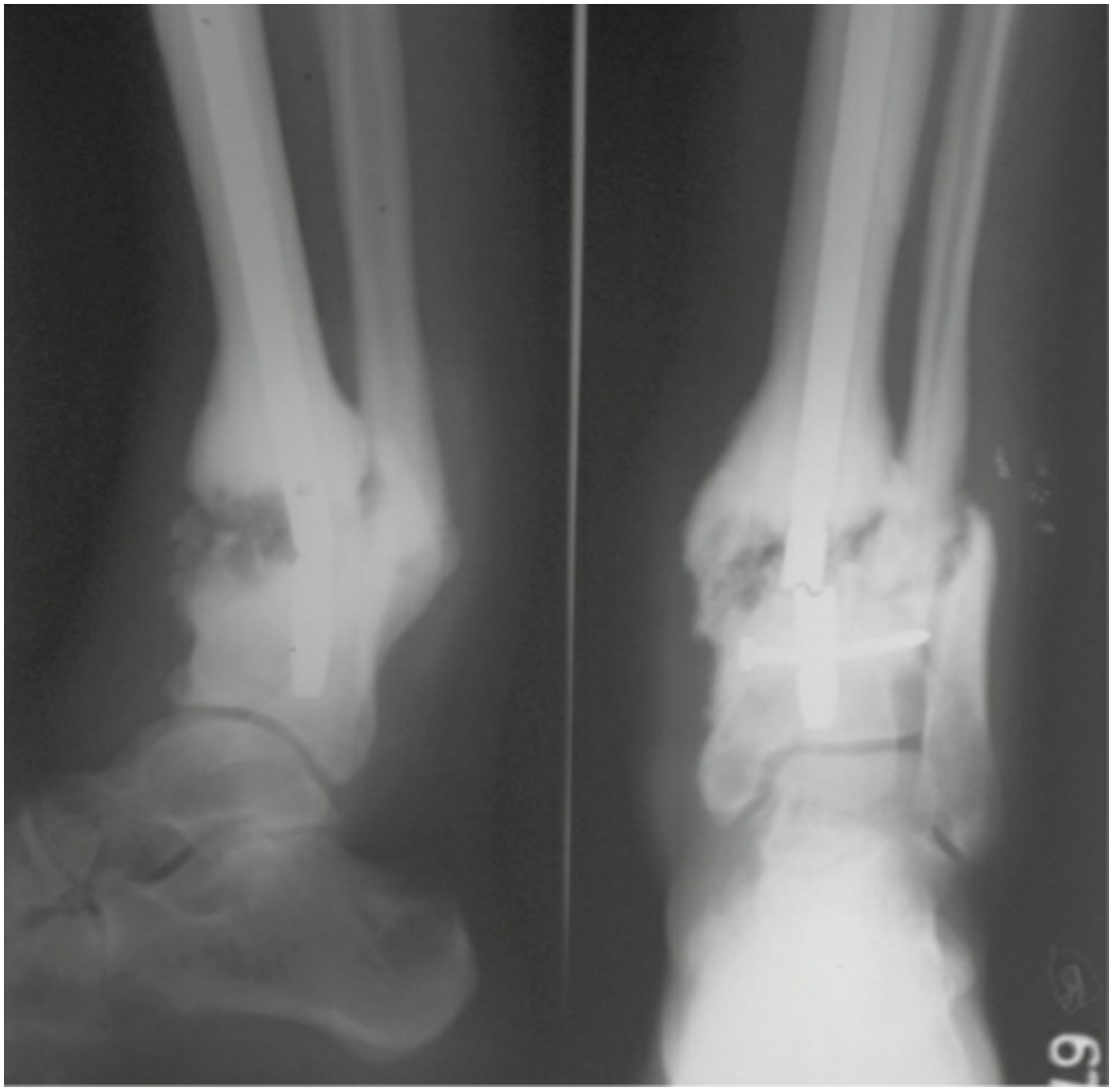

FIG. 16-7 Nonunion of the fracture of tibia and fibula.

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FIG. 16-8 Malunion of the fracture of tibia and fibula resulting in angulation.

Physiotherapeutic management

Objectives

- Restore normal ROM at the knee and ankle joint – if not normal, at least the functional ROM, i.e., 0–110 degrees at hip and knee; at the

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ankle, dorsiflexion of 0–10 degrees and plantar flexion of 0–20 degrees each

- Improve the strength, power and endurance in the muscles around the ankle and toes and in the inverters and dorsiflexors
- Offer stability in all ambulatory activities and the near-normal pattern of gait

Expected problems

- Infection – high incidence of compound fractures and in subcutaneous location, the fracture is susceptible to infection
- Limb shortening – as a result of overlapping or malunion
- Malunion precipitating early osteoarthritis changes
- Joint stiffness – due to the fear of pain, tendency of not moving the knee as well as ankle joint; it is a common expected problem
- Delayed union or nonunion – failure of bony union is common in about 10% cases which may need surgical intervention
- Occasionally, preventable complications like claw toes, fat embolism may be seen

Fractures treated by plaster: Immobilization of the knee, ankle and foot leads to stiffness of these joints and weakness of the muscle groups around them. Strengthening of these muscles takes priority over other measures. The following measures are adopted:

1. Isometrics to quadriceps, hamstrings
2. Assisted SLR
3. Repeated strong and resistive movements to toes

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4. Resisted as well as strong isometrics to the glutei

5. Knee mobilization to be initiated and made vigorous as soon as pain permits

6. Vigorous self-passive stretching exercises to be guided to regain mobility at the foot and ankle

7. Non–weight-bearing crutch walking to be initiated as soon as leg hanging in standing becomes painless – to facilitate going back to work and performing daily activities (about 2 weeks)

8. Full weight bearing to be initiated on the radiographic evidence of fracture union (usually 3–6 months)

9. Correct walking and functional guidance

Fractures treated by traction: Due to the prolonged immobilization in skeletal traction (usually 10–12 weeks), the chances of the knee becoming stiff are quite high. Isometrics, therefore, need maximum attention. Rest of the programme is the same as described for fractures treated by plaster.

Fractures treated by cast bracing: When the stable transverse fractures of tibia are initially treated by POP cast for 4–6 weeks, the physiotherapeutic programme is the same as for fractures treated by plaster. The above-knee POP cast is then replaced by functional PTB plaster; it allows early mobilization and weight bearing. Therefore, early return to fully active life is facilitated. However, vigorous programmes for knee mobility, strength and endurance are to be emphasized.

Fractures treated by surgery: Here the knee mobilization can safely be

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started by the end of 2 weeks. This facilitates regaining knee mobility and a strong extensor mechanism.

Partial weight bearing can be initiated by 8 weeks, if not very painful, and full weight bearing by 12 weeks.

Fractures treated by external fixation: These fractures are usually comminuted and associated with extensive soft tissue damage. The wound is watched for infection, etc. Vigorous exercises to the ankle, toes, glutei, quadriceps and hamstrings play an important role in improving circulation of the whole limb and also the injured area facilitating an early healing.

The patient should be given confidence and assistance in early standing and non–weight-bearing crutch walking with the leg in external fixator by 2 weeks.

Management of complications

1. *Infection:* Keen observation, wound care and improvement of circulation to the limb are important measures to avoid or reduce infection.

2. *Compartment syndrome:* Haemorrhage, oedema or tight plaster may result in ischaemia leading to fibrosis or even gangrene (like VIC). Therefore, a proper watch is kept on the symptoms of ischaemia like increase of pain, swelling, pallor, absence of distal pulse in the foot and blueness of the toe nails.

3. *Delayed union and nonunion:* Fracture of the lower third of tibia is prone for nonunion due to poor blood supply to this area. Therefore, in such fractures, the circulation can be improved by vigorous exercises to adjacent joints.

4. *Malunion:* Improper reduction of the fracture or loss of reduction in plaster can lead to malunion. Detection of the cause and its early

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correction is necessary. Limb shortening due to overriding is compensated by exact shoe raise to prevent osteoarthritis. Malunion with angulation may need early osteotomy to avoid osteoarthritis.

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CHAPTER
17

Injuries of the ankle and the foot

OUTLINE

- Fractures around the ankle
- Hind foot fractures
- Fracture of the talus
- Fracture of the calcaneum
- Midfoot fractures
- Forefoot fractures
- Fractures of other tarsal bones
- Fracture of the metatarsals
- Fatigue or stress fracture of the metatarsal
- Fractures of phalanges

Fractures around the ankle

Classification

- Malleolar fractures or adduction–abduction fractures
- Hind foot fractures – fracture of the calcaneum and talus
- Midfoot fractures – fracture of the navicular, three cuneiform bones

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and cuboids

- Forefoot fractures:
- Fracture of the proximal phalanx of the great toe
- Fracture of the phalanges of the 2nd to 5th toes
- Fractures of the 1st to 4th metatarsals
- Fractures of the 2nd to 5th metatarsals
- Fracture of the base of the 5th metatarsal C joints fracture
- Metatarsal inversion injury – on a plantar flexed ankle

Malleolar fractures (or adduction–abduction fractures)

Fractures around the ankle are produced by forced adduction or forced abduction of the foot, often associated with an element of rotation or vertical compression.

Forced abduction produces rupture of the medial ligament of the ankle, fracture of the medial malleolus or fracture of both malleoli (Fig. 17-1).

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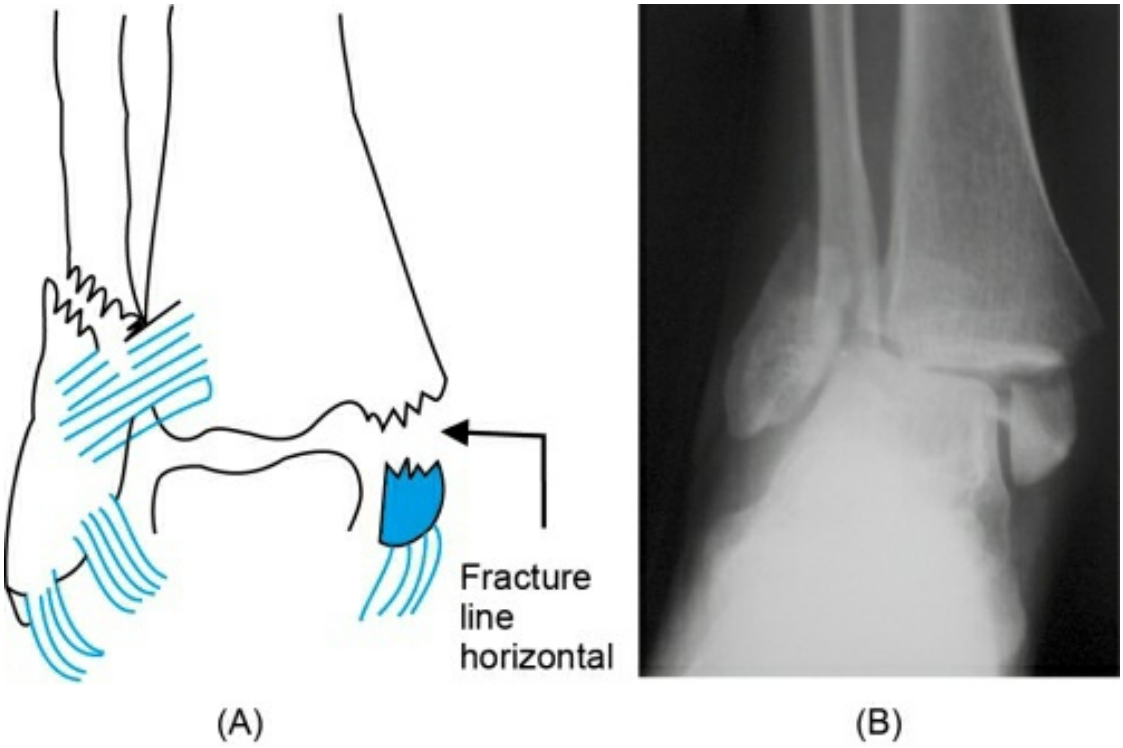

FIG. 17-1 Abduction injury. **(A)** Fibular fracture at the syndesmosis, and **(B)** as seen on radiograph. Note the horizontal fracture line in the medial malleolus.

Forced adduction produces rupture of the lateral ligament, fracture of the lateral malleolus or fracture of both the malleoli (Fig. 17-2).

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FIG. 17-2 Adduction injury fracture of the medial malleolus with a vertical fracture line.

When both malleoli are fractured, it is also called *Pott's fracture*.

Treatment

The main objective of the treatment is to restore the alignment of ankle mortice by accurate reduction of the fractures.

The treatment can be conservative or operative.

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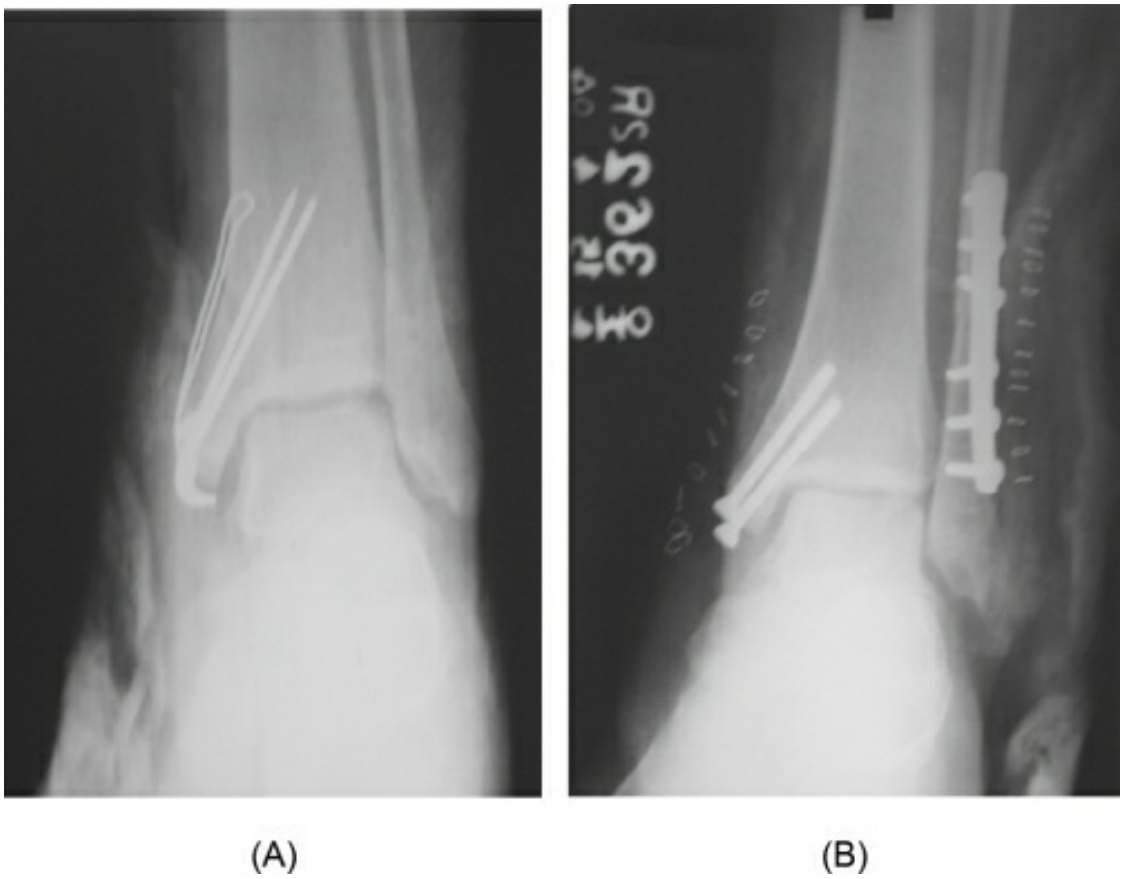
Conservative treatment

The fracture is manipulated under general anaesthesia and immobilized in a below-knee plaster cast for 6–8 weeks. The ankle may be mobilized after 8 weeks; however, weight bearing is allowed only after about 12 weeks.

Operative treatment

Open reduction internal fixation is indicated where closed reduction has failed or the fracture gets redisplaced in the plaster or the fracture is grossly displaced. The fractures of medial and lateral malleoli are fixed internally by a screw or tension band wiring. The fracture in the fibula can also be fixed by a plate (Fig. 17-3).



(A) (B)

FIG. 17-3 **(A)** Fracture of the medial malleolus fixed by tension band wiring. **(B)** Fracture of the medial malleolus fixed by malleolar screws while the fracture of the lateral malleolus is fixed by plating.

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Complications

1. *Malunion:* It leads to distortion of the ankle mortice and deformity. In later years, osteoarthritis may set in.

2. *Nonunion:* It is common with fracture of the medial malleolus. Internal fixation by a screw or tension band wiring with bone grafting is the treatment.

3. *Joint stiffness:* It results following prolonged immobilization and oedema. It can be prevented by accurate reduction of the fracture and adequate physiotherapy as early as permissible.

Physiotherapeutic management

Objectives

- To restore the maximum passive range of movements of the ankle, subtalar, metatarsophalangeal (MTP) and interphalangeal (IP) joints (Table 17.1).
- Acceptable form has to be associated with increased strength and endurance of the muscle groups acting over the ankle, subtalar, MTP and IP joints.
- Steadiness and stability in standing, performing functions and while doing ambulatory activities without limp.
- Concentrated exercise training session for the intrinsic muscles.

Table 17-1

Standard Normal and Functional Range of Ankle and Foot Movements

Movements	Normal ROM	Functional ROM
Ankle dorsiflexion Ankle planters	0–20 0–45	5–10 0–20

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flexion Foot inversion Foot everton	0–35 0–10	0–25 0–10

Expected problems

- Lingering heel pain on weight bearing results in a permanent limping gait.
- Later on, subtler joint osteoarthritis changes are observed.
- Flattening of the foot area and weight-bearing pain results in uneven stepping and a limp.

Physiotherapy management

Fractures treated with a short leg brace

- Check the cast to ensure full ROM at the knee and MTP joints.
- Begin early active movements to the toes.
- Keep leg elevated to prevent oedema.

8–12 weeks after removal of the cast

- Active relaxed free rhythmic movements are guided to be performed in warm water.
- Self-assisted passive, active, resistive and most importantly self-passive stretch-hold to improve ankle dorsi- and plantarflexion are concentrated to get maximum ROM in these two movements.

Weight bearing

- Graduated weight bearing is initiated in parallel bars, walking aids or crutches to eliminate limp to the maximum with cast.
- Full weight bearing after 12 weeks.

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Fractures treated by conservative management

During immobilization

- Limb elevation
- Strong repeated movements for the toes, knee and the hip.
- Diapulse may be applied over the POP cast.
- Non–weight-bearing crutch walking can be initiated on the second or third day.

During mobilization

1. *Early passive mobilization:* Early initiation of relaxed passive range of motion exercises is important. The patient should be made well conversant to practise them often. This can be done best by the patient sitting in a chair with the back supported. The distal portion of the affected leg rests just over the knee on the sound thigh. The ankle and foot, which are free to move, are grasped by the patient using both hands. Full range relaxed passive movements of the ankle and foot can be improved effectively (Fig. 17-4) with repetitive efforts with the use of HP or warm water immersions.

Relaxed passive movement in the maximum possible range, especially circumduction, causing minor discomfort but not pain are ideal to begin with (Cyriax, 1978). The passive movement should not be so forcible as to overstretch the fibrils that are gaining longitudinal attachment within the healing breach; nor should they be so gentle as to fail to disengage those fibrils that are gaining abnormal transverse adherence. Deep friction massage is also useful in preventing adhesions.

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2. *Thermotherapy*: If there is no oedema, thermotherapy is advisable. It increases capillary permeability, promoting the reabsorption of extravasated fluid and dissolution of organized haematoma, helping early healing (Griffin and Karseli, 1978).

3. *Early muscle strengthening*: Exercises to strengthen all the muscles should also be started as early as possible. The technique may be the same as described for early mobilization, except that the movements are active in this exercise. It can be made self-resistive also, if there is no pain. The movements should be taken to the maximum range, with isometric holding at the end of the range. As the exercises are self-resistive, the degree of resistance can be controlled to the level of pain and discomfort.

While strengthening the muscles the patient should be told to concentrate more on the muscles of the anterior and lateral compartments of the leg which are usually weaker as compared to those of the posterior compartment.

Exercising the toe flexors and intrinsic muscles should not be neglected, to maintain the tone and strength of the foot arches. In fact, active slow circumduction with toes tightly clenched is a simple and more effective exercise.

4. *Stretching exercises* (Fig. 17-5): It is important to stretch the posterior calf muscles. This needs prolonged gradual relaxation of the calf. It can be done by keeping the forefoot on a block or a book and pushing the heel down with the knee straight in standing, or with the knee bent to 90 degrees in sitting; putting a downward pressure over the knee with a block or a book placed under the forefoot. In standing, the body weight presses the heel down and stretches the gastrosoleus.

5. *Re-education in weight bearing*: Proper placement of the injured limb, gradual weight bearing and the normal pattern of gait are to be progressed in stages. Weight bearing is started after 12 weeks.

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6. *Speedy movements*: Gradual initiation and progress to more vigorous exercises like toe walking, heel walking, spot jogging and single leg hopping.

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FIG. 17-4 Self-assisted relaxed passive movements of the ankle and foot.

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(A)

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(B)

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(C)

FIG. 17-5 Self-assisted calf stretching in **(A)** sitting, **(B)** standing and **(C)** step standing.

Fractures treated by open reduction and internal fixation

The period of cast immobilization after surgery is usually less, about 3–4 weeks. Therefore, mobilization can be started early. Gentle relaxed passive movements as well as self-assisted procedures followed by thermotherapy should be started.

The rest of the physiotherapeutic regime is the same as described

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for the conservative approach. However, SWD or US is contraindicated due to the metallic implants used for internal fixation.

Pilon fractures of the tibia

Pilon fractions of the tibia consist of comminuted fractures of the distal tibia including the distal tibial articular surface. There is usually a fracture of the distal third of the fibula also (Fig. 17-6). This fracture usually results from a high-energy trauma due to road traffic accidents or fall from a height. It is also usually associated with considerable swelling and ecchymosis in and around the ankle joint.

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(A)

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(B)

FIG. 17-6 **(A and B)** Preoperative X-rays of Pilon fracture of tibia. Note the fracture of fibula also.

Treatment

The swelling and oedema around the ankle (due to injury) necessitates elevation of the limb and waiting for a period of about 1 week for the swelling to subside.

Initially the fracture may be treated by an external fixator for stabilization. Subsequently, the fractures are treated by open

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reduction and internal fixation (Fig. 17-7).

FIG. 17-7 Pilon fracture treated by open reduction and internal fixation.

Hind foot fractures

Injuries of the talus

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Talus is an important tarsal bone which is a part of both the medial and the lateral longitudinal arches of the foot. Majority of the talar surface is intra-articular and it has no musculotendinous attachments. The blood supply to the body of talus is precarious since it passes through the neck of the talus. A fracture through the neck of talus, therefore, may cause avascular necrosis of the body of talus if not treated properly.

Injuries of the talus are rare and result from a fall from height or forced dorsiflexion injury to the ankle.

The talus may be fractured through its body or neck (Fig. 17-8) or may be dislocated from the ankle mortice without a fracture.

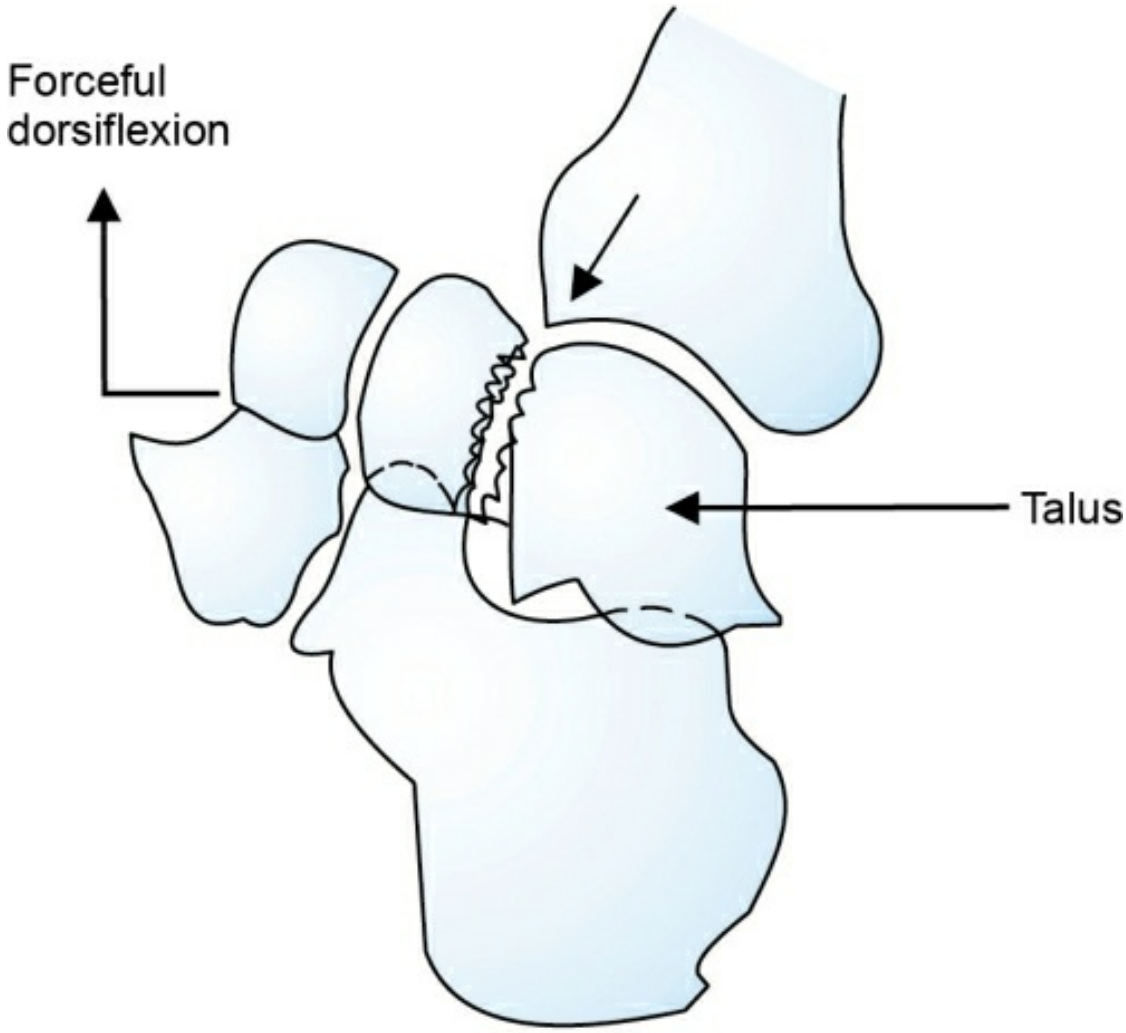

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FIG. 17-8 Fracture of the neck of talus.

Treatment

Conservative treatment

The fracture or dislocation is manipulated under general anaesthesia and immobilized in a below-knee plaster for 6–8 weeks. The ankle is then mobilized; however, weight bearing is allowed only after 3–4 months.

Late neglected cases, where closed reduction cannot succeed, are treated by skeletal traction applied through the calcaneum.

Operative treatment

Open reduction of the fracture or dislocation is indicated where closed reduction fails or the fracture is widely displaced. The fracture is fixed internally by Kirschner wires or screws (Fig. 17-9).

FIG. 17-9 **(A and B)** Pre- and postoperative radiographs of fracture of talus treated by fixation by screws.

Postoperatively the limb is immobilized in a below-knee plaster for 8–10 weeks.

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Complications

Avascular necrosis: Fracture through the neck of talus or dislocation can cut off blood supply to the body of talus. This subsequently leads to avascular necrosis of the talus. It may cause osteoarthritis in later years which may require ankle arthrodesis.

Physiotherapeutic management

The physiotherapeutic programme for the cases treated by conservative as well as surgical methods is the same as described for abduction and adduction injuries of the ankle.

The problem associated with this fracture is the shortening of the tendo-achilles, resulting in limitation of dorsiflexion. It makes floor squatting impossible due to the restricted range of anterior tibial excursion on the foot. Therefore, the patient needs to be taught an alternate method of floor squatting. This method includes the fractured leg to be maintained in forward position so that the pelvis can be lowered down more on the sound limb (Fig. 17-10).

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FIG. 17-10 Floor squatting with the fractured leg forward.

To avoid this, concentrated exercise is necessary to get maximum early dorsiflexion. If the patient regains good range of dorsiflexion, floor squatting can be attained by stabilizing the body weight on the sound limb to avoid excessive stretching and pain in the affected foot. As the pain reduces, it can be progressed to near normal floor squatting.

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Fracture of the talus

Physiotherapy management

Objectives

- To restore full ROM of ankle and the foot.
- To restore strength and endurance of all the muscle groups moving the ankle and foot.
- To restore functional tasks such as floor squatting, and pre-injury sports and recreational activities.

Expected problems

As a result of the possibility of complications such as infection, nonunion, delayed union, malunion and AVN, and posttraumatic osteoarthritis. They may lead to the following:

- Painful limping
- Inability to sustain standing, perform flexor – squats, brisk walks or sports
- Shortening/contracture of tendoachilles (TA)

Physiotherapy for conservatively managed patients

- Keep limb in elevation and begin active full range movements for the MTP and IP joints.
- Initiate active knee movements as soon as pain is reduced.
- 3rd day – supported standing, non–weight-bearing walking with crutches.

On the removal of immobilization:

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- Under warm water, small-range active free movements to subtalar and ankle joints are guided, for home treatment.
- Self-assisted, gentle self-stretch-hold techniques are guided to improve the ambulation – prolonged period of NWB (8–10 weeks) JROM.
- Graduated steps to progress towards PWB by 8–10 weeks, independent ambulation (FWB by 12 weeks)

Physiotherapy for surgically treated patients

- Patients treated by ORIF
- Most procedures involved are similar to that for conservatively managed patients
- Ambulation – PWB can be safely started by 4–6 weeks and full weight bearing by 8–10 weeks
- Guidance and short training and practice may be needed to perform lower limb activites

Fracture of the calcaneum

Applied anatomy of calcaneum

Calcaneum is a large tarsal bone which articulates anteriorly with the cuboid. It forms the posterior pillar of both the arches, and plays an important role in the transmission of body weight in all weight-bearing activities. The centre of the calcaneal tuberosity lies lateral to the line of the weight-bearing axis; therefore, the fracture lines usually run obliquely from the superolateral to the inferomedial aspect.

Tuber joint angle

The normal angle between the superior articular surface of the

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calcaneum and the upper surface of calcaneal tuberosity is 35–40 degrees.

Fracture of the calcaneum results from a fall from height. The calcaneum is pushed up against the talus and gets crushed.

Basically two types of fractures occur:

1. **Extra-articular fracture:** Fracture of the calcaneum where the subtalar joint is not involved (Fig. 17-11).

2. **Intra-articular fractures:** Fracture of the calcaneum involving the subtalar joint. Here the fracture line extends into the subtalar joint (Fig. 17-12). Osteoarthritis of the subtalar joint may develop a few years later.

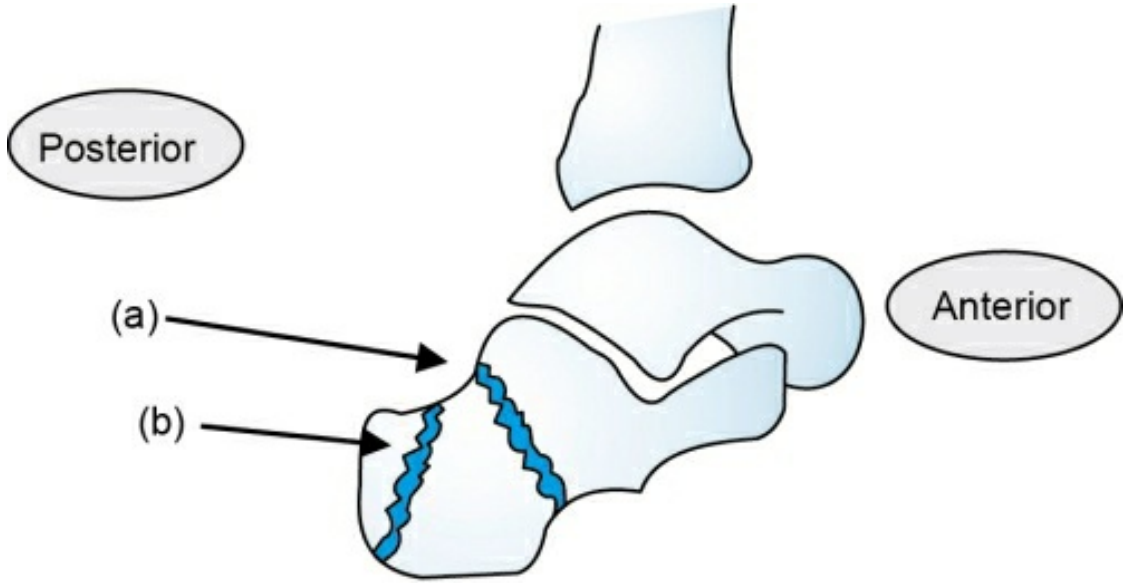

FIG. 17-11 Extra-articular fractures of the calcaneum: **(a)** – through the posterior part of the body, and **(b)** – fracture of tuberosity.

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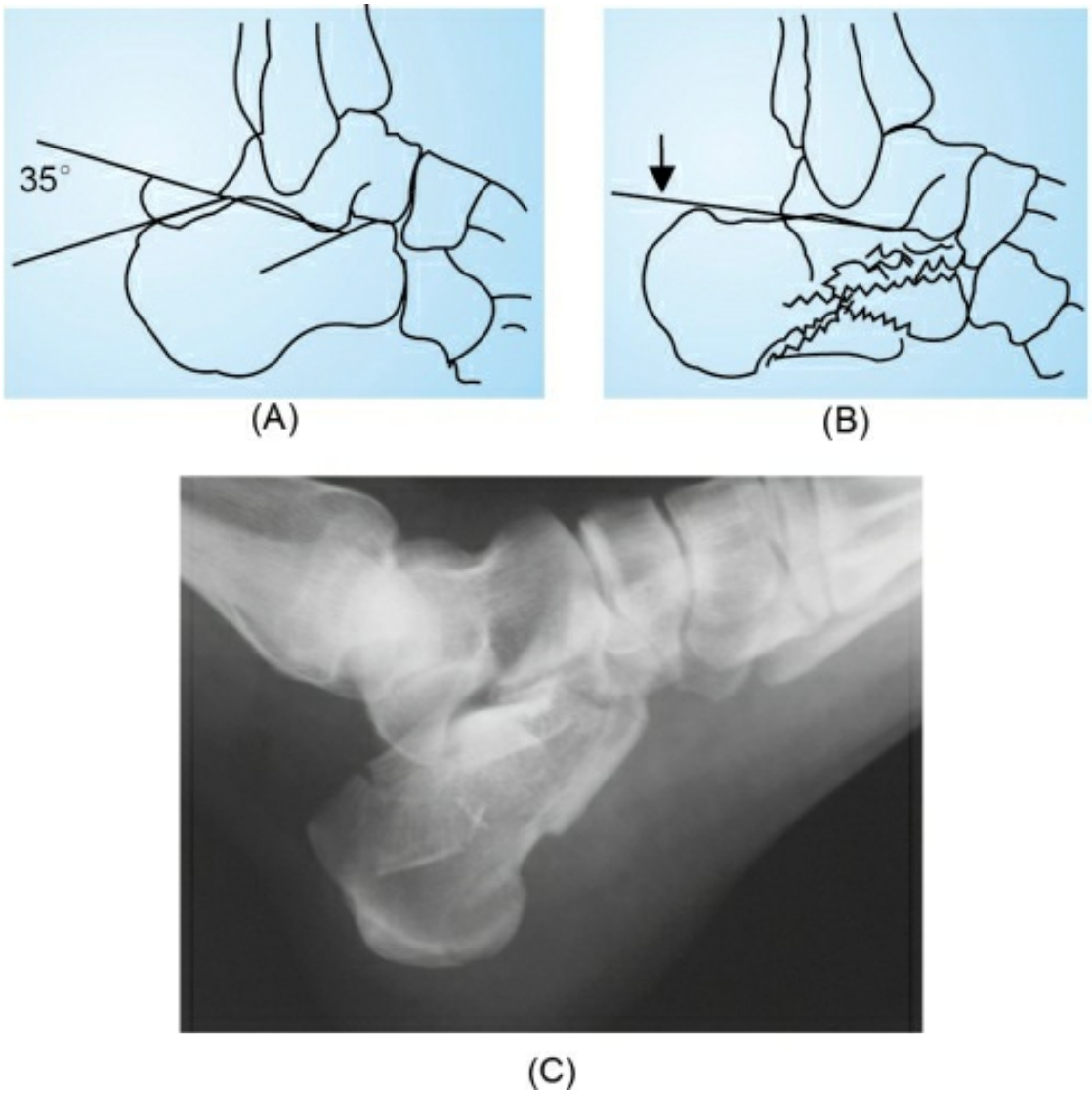

FIG. 17-12 Tuber joint angle: **(A)** normal, **(B)** in a comminuted fracture of the calcaneum, the tuber joint angle is either obliterated or reduced, and **(C)** a comminuted fracture of the calcaneum, as seen on radiograph.

Clinical features

- Severe pain and tenderness over the heel.
- The heel appears broader from behind.
- There might be ecchymosis at the heel.

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■ Inability to bear any weight on the fractured foot.

Treatment

Fractures of the calcaneum can be treated by the following methods:

1. *POP cast*: A below-knee POP cast is applied for 3–4 weeks, after which the foot is mobilized and gradual weight bearing is started.

2. *Open reduction and internal fixation*: Displaced and/or comminuted fractures are treated by open reduction and internal fixation by special plates (Fig. 17-13).

3. *Arthrodesis:* Some surgeons prefer to treat severely comminuted fractures of the calcaneum by primary arthrodesis of the subtalar joint in view of the inevitable secondary osteoarthritis of the subtalar joint.

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FIG. 17-13 Fracture of the calcaneum fixed by a special plate.

Complications: The following complications are commonly seen, mainly due to the inability to accurately reduce the fracture in most of the cases and also due to the type of fracture (whether involving the subtalar joint).

1. Persistent pain in the heel and joint stiffness.

2. Osteoarthritis of the subtalar joint, which may need arthrodesis.

Physiotherapeutic management

It proceeds on the same lines as described for adduction and abduction injuries around the ankle. However, the following modifications are necessary to deal with the common problems following this fracture.

1. *Persistence of pain while resuming weight bearing*: Therefore, partial weight bearing should be deferred to 8 weeks. A cane may be necessary to avoid painful weight bearing for a prolonged period. Appropriate thermotherapy should be given just before standing.

2. *Specificity of gait*: Both the phases of gait are usually painful. Therefore, initial gait training may need modification to minimize the period of walking cycle at the cost of ideal gait.

3. *(a) Subtalar joint stiffness*: If not mobilized early, it leads to marked limitation of eversion and inversion of foot. Therefore, early mobilization of these movements is emphasized, especially when the articular surface is fragmented and driven down in the body of calcaneum which itself is crushed.

(b) *Limitation of dorsiflexion:* Immobilization leads to limitation of ROM of dorsiflexion, and the related problems, as discussed in the fracture of talus.

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Physiotherapy management

First 2 weeks

- Active full ROM moments to the toes and MTP joints.
- Position leg and foot in elevation.
- Partial weight bearing may be started for muscular and cuboids bone fractures.
- Remaining fractures are not allowed weight bearing.

By second week

- Isometric (light and slow speed) may be begun for all the muscle group covering ankle and foot.

By 6–8 weeks

- Make isometric strong and sustained.
- Free active small ROM exercise begun for all the four major groups around the ankle in warm water.
- Begin PWB for Lisfranc injuries.

Eight weeks onwards

- Guide and supervise self-resistive mode of exercise for all the four major muscles group
- Gradual progressive weight bearing is initiated.

Midfoot fractures

Fractures of other tarsal bones

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Fractures of the tarsal bones other than the talus and the calcaneum are relatively rare.

Treatment

These fractures do not require manipulation and are treated in a below-knee POP cast for 3 weeks.

Physiotherapeutic treatment

Fractures of other tarsal bones not associated with crushing injuries do not pose difficulties. Routine measures of physiotherapy are adequate to deal with these types of fractures. Vigorous exercises to the intrinsic muscle should be emphasized right from the initial stages.

Fracture of the metatarsals

Fracture of the metatarsal usually occurs due to fall of a heavy object on the foot or in roadside accidents. The base of the fifth metatarsal may be fractured by sudden pull of the peroneus brevis muscle, due to forced inversion and plantar flexion of the foot (Fig. 17-14).

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FIG. 17-14 Fracture of the base of the fifth metatarsal bone.

Treatment

Conservative treatment.

For *undisplaced or minimally displaced fractures*: The treatment of choice is conservative. The foot is immobilized in a below-knee POP cast for 3–4 weeks. Mobilization and gradual weight bearing is then started.

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Operative treatment.

Grossly displaced fractures are fixed internally by Kirschner wires (Fig. 17-15) or screws. Postoperatively a below-knee POP slab is given for 2–3 weeks after which mobilization is started. Weight bearing is allowed after 4–6 weeks.

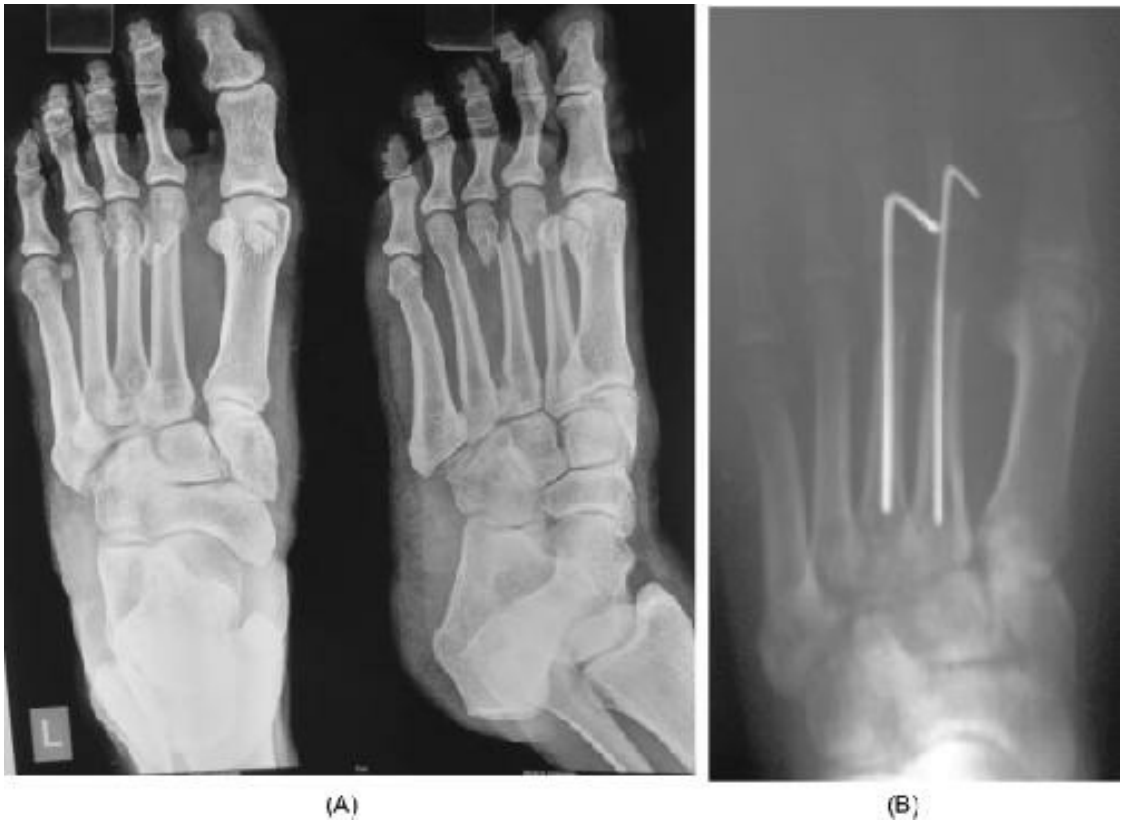

FIG. 17-15 **(A)** Grossly displaced fractures of the 2nd and 3rd metatarsal bones. **(B)** Internal fixation by K-wire.

Physiotherapy management

Objectives

- To restore normal JROM of ankle joint, subtalar joint, and MTP and IP joints.
- To increase strength, power and endurance of the long flexors and

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the extensors of the toes (intrinsic muscles), evertors and invertors of the foot.

Expected problems

- Painful restriction of full and strong ROM of the toes to facilitate floor gripping required for balance and gait.

- In the commonly encountered fractures of the 1st and 5th metatarsals, the time of bone healing is longer (6–8 weeks) as compared to the other forefoot bones (4–6 weeks), extending the period of bone tenderness and inability for weight bearing.

The management of fractures of metatarsal bones proceeds on the same lines as described for the tarsal bones. However, the possibility of damage to the anterior transverse arch of the foot must be remembered. Efforts to get vigorous contractions in the intrinsic muscles at the earliest should not be neglected. During mobilization, Faradic foot bath may be necessary to enforce active intrinsic exercises.

Flat foot exercises, proper weight transfers to the foot and gait training may be necessary.

Full function should be restored by 5–6 weeks.

Fatigue or stress fracture of the metatarsal

Prolonged walking in persons not accustomed to it may give rise to a hairline fracture in the metatarsal tie (march fractures). There is no history of trauma; the patient starts feeling pain spontaneously at the site of the fracture on walking with acute tenderness and swelling. The common site of this fracture is the shaft or neck of the second or third metatarsal bone (Fig. 17-16).

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FIG. 17-16 Stress fracture: radiograph showing a faint fracture line in the neck of the second metatarsal with exuberant callus (arrow).

Treatment

As the fracture heals spontaneously with abundant callus formation, the treatment is only symptomatic. In certain cases where the pain is severe, immobilization in a below-knee walking plaster for a period of 4 weeks may be necessary. No specific physiotherapeutic measures are needed to treat these fractures.

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Forefoot fractures

Fractures of phalanges

Satisfactory alignment is preserved even in comminuted fractures of phalanges. It needs no rigid immobilization, only protection from injury has to be ensured. Soft woolly dressing for 2 weeks followed by active physiotherapy is adequate.

Physiotherapy during week 1 and 2

- For stable phalange fractures – free active movements for MTPs.
- For fractures of 1st MT, sesamoid and 1st phalanx – no ROM or strengthening exercise.
- No weight bearing for the fractures of 1st and 5th MTs, first phalanx and sesamoid bone.
- Weight bearing can be initiated for stable fractures of other metatarsals.

By the end of 2 weeks, graduated weight bear can be initiated keeping pain as the main guiding factor.

- After 2nd week – PWB for 1st and 5th MT, sesamoid fractures.
- By 6–8 weeks – active full ROM exercise to all the toes, ankle and foot.
- By 8–12 weeks – full weight bearing is safe.
- Session of standing on the fractured leg alone.
- Guidance to perform self-resistive exercises to the long toe flexors along with self-stretch-hold technique is important. Increase the vigorousity all exercises programmes

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gradually.

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CHAPTER 18

Common paediatric and adolescent musculoskeletal disorders and fractures

OUTLINE

- Fractures in children
- Common paediatric and adolescent musculoskeletal disorders

Musculoskeletal disorders in children and adolescents can be basically classified into three categories:

1. Congenital – since birth

2. Developmental or acquired – during the growth period due to nontraumatic diseases (infective, viral, metabolic diseases)

3. Traumatic – fractures, subluxation, dislocation, or due to repetitive microtrauma

Whatever may be the cause, the earliest possible identification remains a major factor for effective management.

Both the paediatric orthopaedic surgeon and the paediatric physiotherapist play a decisive role in the process of early detection, more so in a congenital variety of musculoskeletal diseases.

The complete programme of management of such cases is discussed

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in detail in the relevant chapters.

Overall common musculoskeletal disorders seen in children and adolescents, their salient features and major principles of management are described in the following sections.

Fractures in children

Fractures in children differ from those in adults due to bone peculiarities and the pattern of bone healing.

1. Relative weakness of the physis of the longitudinally growing bone makes them susceptible to epiphyseal injuries.

2. The periosteum in children's bones is attached loosely to the bone and gets stripped off easily by the collection of haematoma under it. This haematoma turns into exuberant callus – a characteristic in children.

3. Periosteum is thick and attached loosely to the cortex, whereas bones are pliable. Bending of bones rather than breaking occurs, resulting in an incomplete fracture of one cortex only, called *greenstick fracture* (Fig. 18-1).

4. The intact periosteum may buckle resulting in buckle or torus fracture close to the physeal plate or the joint (Fig. 18-2).

5. Periosteum being highly cellular heals fast, quickly gets remodelled and corrects angulation or overriding amazingly; however, it fails to correct rotational misalignment.

6. Remodelling is better in younger children and in fracture which is in the region of metaphysis and close to the growing end.

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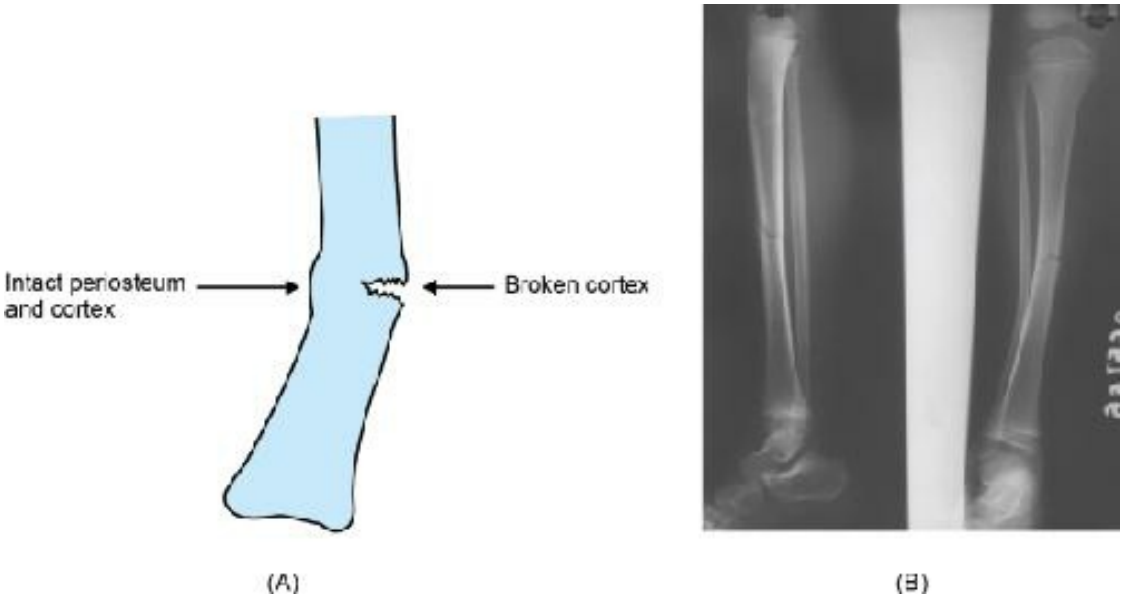

FIG. 18-1 Greenstick fracture. **(A)** Diagrammatic representation. **(B)** Greenstick fracture of tibia as seen on radiograph.

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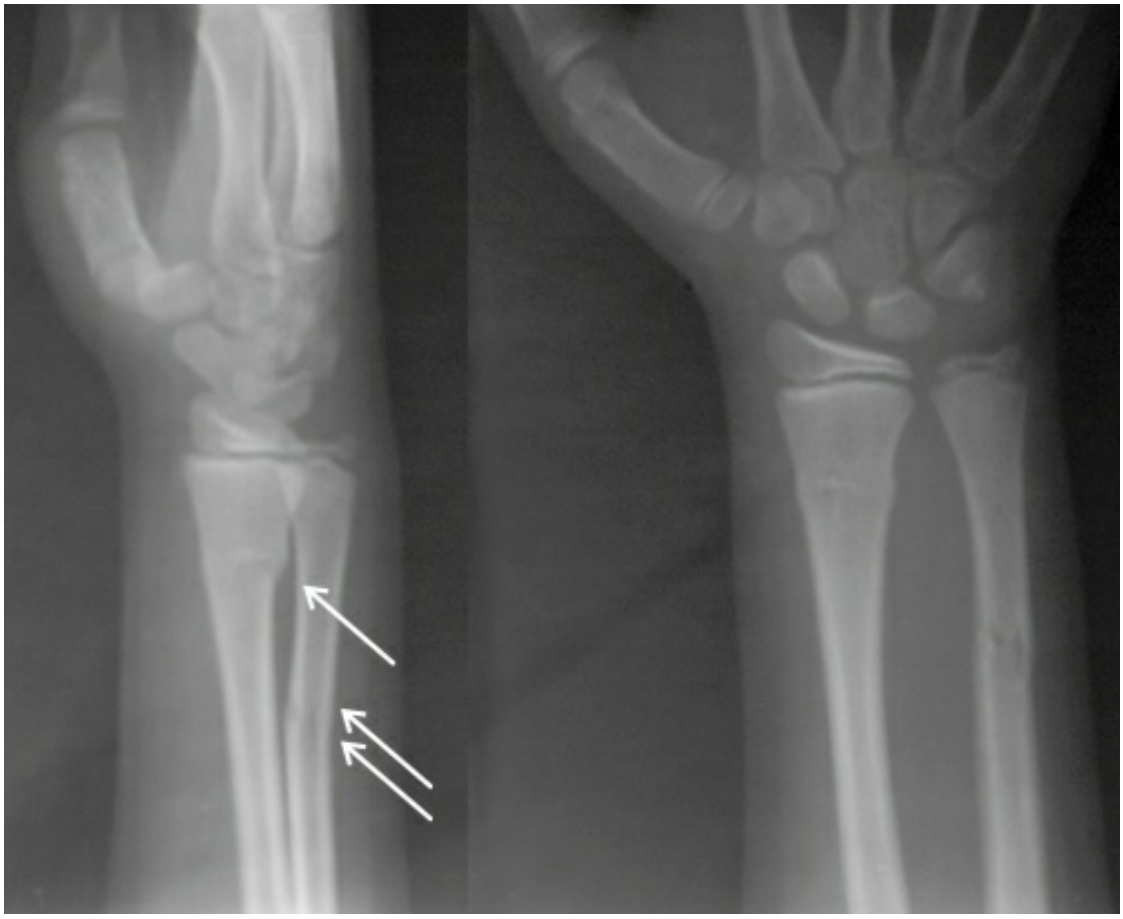

FIG. 18-2 Torus fracture of lower third of radius (single arrow). Note the greenstick fracture of the ulna (double arrows).

Causes of fracture in children

- Fall and sports injuries: 20–25%
- RTAs: 10–15%
- Birth injuries: fractured clavicle, humeral shaft or shaft of femur
- Pathological fractures: osteomyelitis, fibrous dysplasia, osteogenic imperfecta, rickets, bone cyst (Fig. 18-3), etc.

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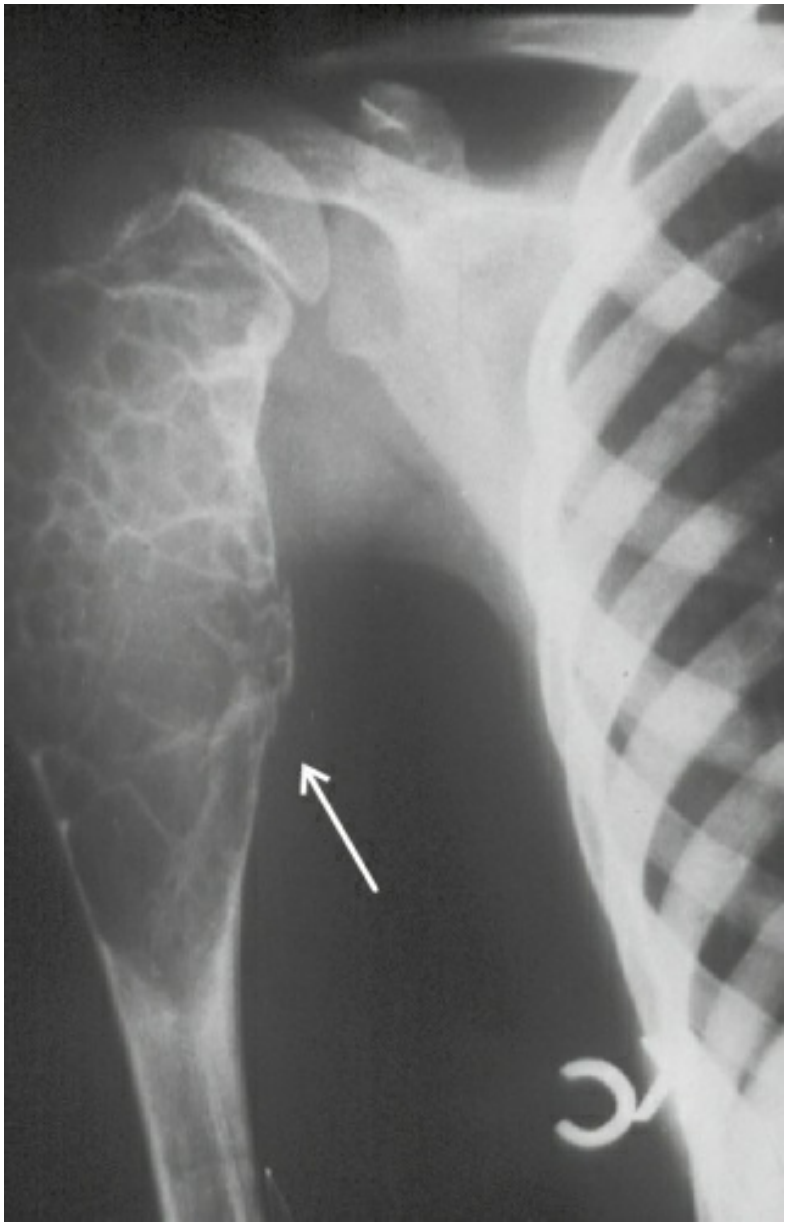

FIG. 18-3 Pathological fracture of humerus in an aneurysmal bone cyst. Note the break in the cortex (arrow).

Common types of fractures in children

Greenstick fracture

- Fractures of a single cortex usually occur in the forearm bones following a bending strain

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■ One cortex gives way while the other remains intact. (Fig. 18-1)

Treatment: Greenstick fracture is treated by closed reduction and POP cast immobilization. Sometimes an incomplete fracture is converted into a complete fracture to correct angulation. It is then immobilized.

Torus or buckle fracture

Axial compressive force causes a torus fracture where the periosteum remains intact and buckles, but the cortex is broken.

Treatment: Treatment is done by immobilization in a plaster cast.

Epiphyseal injuries

Physis is the weakest region that gives away easily resulting in epiphyseal injuries (Table 18-1).

Table 18-1
Five Types of Epiphyseal Injuries

Type I	There occurs complete separation of the epiphysis from the metaphysis without a break (Fig. 18-4 A,B) – commonly occurs at the lower end of radius
Type II	Physeal separation along with a triangular piece (avulsion) of metaphysis (Fig. 18-4C) – common at lower radial and tibial epiphysis
Type III	Fracture involving epiphysis running along the growth plate (Fig. 18-4E) – common at the epiphysis of medial malleolus
Type IV	The fracture line runs through the epiphysis as well as through the metaphysis (Fig. 18-4F,G) – commonly seen at the lateral condyle of humerus
Type V	Vertical compression of epiphysis and the physis, resulting in complete loss of growth potential of the bone (Fig. 18-4H) – common at the lower tibial epiphysis

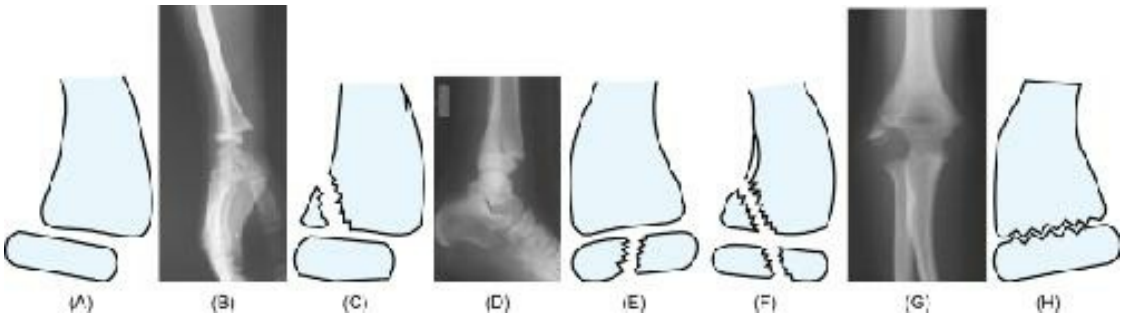

FIG. 18-4 Epiphyseal injuries: **(A)** Line diagram of type I injury. **(B)** Type I

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epiphyseal injury of lower end of radius as seen on radiographs. **(C)** Line diagram of type II injury. **(D)** Type II epiphyseal injury of the lower end of tibia. Note the displacement of the epiphysis along with the metaphyseal fragment. **(E)** Type III epiphyseal injury. **(F)** Line diagram of type IV injury. **(G)** Type IV epiphyseal injury of lateral condyle of the humerus as seen on an X-ray. **(H)** Type V epiphyseal injury (diagrammatic representation).

Classification of epiphyseal injuries: The classification of epiphyseal injuries has a prognostic significance in respect to the potential of growth disturbances. The Salter–Harris classification that has the five types explained in Table 18-1 is commonly used (Salter, 1963).

Treatment: Epiphyseal injuries need accurate reduction to minimize subsequent growth inequalities. Undisplaced injuries are treated by POP case immobilization while displaced injuries need open reduction and interval fixation (ORIF) by K-wires.

Complications

- Epiphyseal injury can cause the following:
  - Growth arrest – leading to limb length shortening
  - Unequal bone growth – partial injury to the epiphysis results in unequal growth and angular deformity at the related joint
  - Overgrowth – may occur due to excessive growth stimulation (e.g., common at the fracture of shaft of femur)
  - Injury to nerves/vessels – for example, injury to the brachial artery in injury to the distal humeral epiphysis
  - Compartment syndrome – similar to fractures, epiphyseal injury can also cause compartment syndrome

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Common paediatric and adolescent musculoskeletal disorders

Developmental dysplasia of the hip

Developmental dysplasia of the hip (DDH) was earlier called congenital dislocation of the hip (CDH). The change in terminology came with the understanding that the hip joint may be normal or mildly subluxated, dislocating gradually during the early years of life. In adolescence, it can be diagnosed easily by physical examination and X-ray. Sometimes, mothers can also make out that the hip is not in position due to altered gait.

Treatment is immobilization by special orthosis. Surgery may be required in the form of open reduction and osteotomy of the pelvis or femur for proper containment of the femoral head. See the 'Congenital Dislocation of the Hip' section in Chapter 30, on Deformity, for further details on DDH.

Legg–calve–perthes disease

Legg–Calve–Perthes disease is the idiopathic osteonecrosis or AVN of the femoral head and is commonly seen in the age group of 5–7 years. The child complains of pain in the groin, which may radiate down to the knee; the child walks with an antalgic gait. The early sign is limitation of internal rotation of the hip; later on, the all movements of the hip become stiff.

Investigations

The diagnosis is made by an X-ray and MRI. Treatment is rest to the limb, which may be given by bracing the limb in abduction. Surgery may be necessary.

Details in Chapter 35, see section Perthes Disease.

Slipped capital femoral epiphysis

The posteroinferior displacement of the proximal femoral epiphysis of femur is known as slipped capital femoral epiphysis. It is a

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developmental condition common in adolescents. The main symptoms are stiffness of the hip joint with weakness of abduction of the hip. There is a tendency to keep leg externally rotated; passive internal rotation is painful. Limb shortening is present and the displacement diagnosis is easily made by X-rays. The treatment is to stop weight bearing. Surgery is done for stabilization of the slipped epiphysis by pins and screws. If the slip is severe, then femoral osteotomy is done to achieve the correction of the slip.

Disorders of the knee

Osgood–schlatter disease

Osgood–Schlatter disease is again an adolescent disorder commonly seen at the age of 10–15 years. There is traction apophysis of the tibial tubercle, with symptoms of localized knee pain or tenderness. There may be anterior knee pain while running or jumping.

Treatment

Although it is a self-limiting disease, relieved within 12–18 months, subjects are given rest and NSAIDs, with precautions to avoid running and jumping for some time.

Sinding–larsen–johansson syndrome (jumper's knee)

This syndrome has symptoms similar to those of Osgood–Schlatter disease but is painful, and tenderness is present over the inferior pole of the patella. This is also a self-limiting disease, relieved within 3–12 months.

Genu varum and genu valgum

Deformity is visible in both the cases so diagnosis is easy to make. Physiological deformity of 10–15 degrees gets corrected in 12–18 months and 3–4 years for genu varum and genu valgum, respectively. However, all the cases are not resolved, so monitoring is necessary.

Treatment

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Mothers can be taught to apply repeated gentle stretches in both cases. It persists up to puberty; thereafter, surgery (osteotomy) is required.

Disorders of the foot

Calcaneal apophysitis (sever disease)

It is common before the fusion of apophysis (9 years in girls and 11 years in boys). Repetitive microtrauma at the tendo-Achilles, tendon–bone junction results in apophysitis, with localized heel pain at the Achilles tendon insertion and there is a limp.

Treatment

The disorder is self-limiting, relieved within 6–12 months. Rest to the limb with NSAIDs and gentle passive stretching is the treatment of choice with heel pad application. If there is severe pain, the POP cast may be given.

Disorders of the neck

Congenital muscular torticollis

It is a unilateral contracture of the sternocleidomastoid at birth or within the first 2 months. It may be due to intrauterine malpositioning of the head or intrauterine vascular insult resulting due to scanning or imaging.

Treatment

Mothers are educated to apply multiple gentle stretching throughout the day. Adjustable moulded cervical collar is also given in some cases to maintain the position. In resistive cases, surgical release is beneficial before the age of 3 years.

Klippel–feil syndrome

This is an abnormality of the cervical spine due to incomplete segmentation of vertebrae which is congenitally present. It varies from the fusion of two to all vertebrae. Physically, the subject has a short

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neck with low posterior hairline. Clinically, there is limitation of neck ROM.

Treatment

Generally not reported in the smaller age group and there is no specific treatment.

Disorders of the shoulder

Anterior dislocation or subluxation

It is the most common disorder in children that occurs during sports. It has a tendency for recurrence.

Treatment

Treatment is done by immobilization in a sling and later on a vigorous strengthening programme to prevent recurrence.

See the 'Anterior Dislocation' section in Chapter 5 for further details.

Sprengel deformity

This happens during the development stage when normally the scapula descends but in this case, one or both scapulae fail to descend. Diagnosis can be made by palpation of the scapula and limitation of the ROM of the scapulothoracic joint.

Treatment

Surgical releases may be necessary.

Disorders of the elbow

Subluxation of the head of radius

Subluxation of the head of radius is commonly seen in toddlers with trival trauma. Diagnosis is with the help of X-ray.

Treatment

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Close reduction is done by flexing the elbow with supination of the forearm.

Throwing injuries

Apophysitis

Due to repetitive throwing in sports, sometimes, there is apophysitis of the medial epicondyle of humerus. There are complaints of pain only.

Treatment

This is treated by rest and NSAIDs, and by stopping sports for at least 6 weeks.

Osteochondritis of capitulum

This is again because of repetitive action of the arm. Pain, swelling, tenderness and limitation of range of movement at elbow involving capitulum on the lateral side of elbow are the common symptoms.

Disorders of the back

Scoliosis

This is a deviation of the curvature of spine laterally and is pain free. It is more common up to the age of 10 years. It can be congenital, idiopathic or neuromuscular. Diagnosis is made on the basis of physical examination and X-rays.

Scoliosis with thoracic deformity is prone to cardiac abnormalities and with lumber deformity, it is prone to gastrointestinal or renal abnormalities.

Treatment

Lateral curve <20 degrees is only treated by positioning and is observed on regular check-up. A curve between 20 degrees and 40 degrees requires bracing for at least 23 h a day.

More than 40 degrees curves are cases for surgical fusion or spinal

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instrumentation, strengthening, postural exercises and postural re-education.

Scheuerman disease

This is common in adolescents in the age group of 14–17 years. It involves familial osteochondrosis of the thoracic spine. This is a typical deformity of rigid thoracic kyphosis due to anterior vertebral wedging and compensatory lumbar hyperlordosis. There may be tightness of the hamstring muscle.

Treatment

Concentrate on mobility and postural exercises to the spine along with Milwaukee brace. When the curve is >70 degrees, surgery is the correct option.

Spondylolisthesis

It is seen in young athletes when sport requirements include repetitive hyperextensions of the lumber spine putting mechanical stress on the pars interarticularis. In X-ray, forward slipping of the fifth lumbar vertebrae over S1 is commonly seen. There is flattening of the normal lumbar curve. A toe touch test is positive. Tightness of the hamstring muscle is also there. Nerve compression may or may not be present.

Treatment

Acute injury may require immobilization in a body jacket. Special spinal brace is given in mild-to-moderate slipping. In cases of severe slipping, surgery is required. Postural mobility and re-education exercises are done later on.

Cerebral palsy

It is a crippling disease of CNS either due to faulty development of the CNS, prenatal birth anoxia, injury due to application of forceps or postnatal causes like head injury, meningitis or encephalitis. Major symptoms are delay in the milestones from head control to walking and speaking. Spasticity and ataxia–athetosis are the major features,

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which may be associated with mental retardation and speech defects.

Treatment

Treatment requires strengthening and endurance exercises for the whole spine, abdominal and extremities also. Passive movement and PNF techniques are given to prevent deformities and to develop the normal pattern in the brain.

It also requires multispecialty care including occupational therapy, speech therapy and orthopaedic treatment for correction of or release of tenderness. Long-time tireless efforts should be made to bring the child to a level of self-care. In severe cases, mothers have a major and important role.

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CHAPTER 19

Prevention of fractures

OUTLINE

■ Major causes of fractures
■ To overcome and reduce the miseries due to avoidable or preventable fractures

Is it ever possible to prevent fractures?

Certainly not, however, the incidence of fractures can be brought under control. It requires planned efforts on a large scale at various levels, mainly the authorities from departments like public health, transport, education, information and broadcasting, housing and construction, press and media and last but not the least 'WE OURSELVES'.

What is a fracture?

Fracture is a break in the continuity of a bone.

Why does the bone break?

1. A healthy bone breaks when it encounters a violent force or a trauma, which exceeds the tenacity of that bone.

2. Certain healthy bones have a tendency to partially break as a result of a summation of stereotype small microtraumas. It is called a *stress fracture* (commonly seen in sports personnel who put sustained stress on a certain bone, also in policemen, nurses or soldiers who perform

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standing duty for long hours).

3. Another variety of fractures is known as *pathological fractures*, which occur in a bone weakened due to a disease, a yields even to a small or trivial injury.

The possible causes of pathological fracture can be as follows: deficiency in the process of bone formation and consolidation or imbalance between the process of bone resorption and bone formation, where the former exceeds the latter.

Major causes of fractures

- Direct or indirect trauma
- Bone weakened by infective, metabolic, developmental bone disease or bone tumours

Direct or indirect trauma

Fractures in the normal bones due to direct or indirect trauma are a major problem which requires multiprong action as mentioned earlier.

Stress fractures

These are fractures occurring due to stereotype stress overload commonly seen in professions involving long standing hours (e.g., nurses and policemen). They are also seen in sportspersons usually involving leg and foot bones. They can be prevented by the following measures:

- Intermittent breaks in the continued activity
- Comfortable footwear
- Being watchful during games for any pain or discomfort
- Regularly performing conditioning exercises to the susceptible

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musculoskeletal complexes

Fractures due to pathological bone disorders

- Prevention of the nutritional deficiencies by vitamin D_3 and calcium supplements
- Prevention of osteoporosis or a loss of bone density in elderly men and postmenopousal women by vitamin D, calcium supplements and appropriate therapy, respectively
- Adopting lifestyle with regular exercise

Younger women

Injuries can be prevented by being watchful and remaining physically fit. Generally, women with a craze to achieve a paper-thin figure go for crash dieting and lose body weight dangerously. They develop malnutrition and become susceptible to fractures following even a mild-to-moderate trauma (anorexia nervosa). Therefore, women and even men should not strive only for an outward ideal physical form, but also be physically fit.

Senior citizens

The incidences of fracture are commonest amongst senior citizens following a fall which happens to be the single common cause. Regular intake of vitamin D supplements may reduce the incidence of fractures in these people.

However, there are certain other causative factors that are associated with old age and may be responsible for a fracture. They are as follows:

- Progressive demineralization of bones
- Poor vision and loss of hearing
- Lack of movement control, coordination and balance

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- Overall state of disorientation and confusion, etc.
- Above all, general debility and weakness and which is made worse when associated with central nervous system (CNS) lesion.

To overcome and reduce the miseries due to avoidable or preventable fractures

The primary approach is to educate the masses on the safety precautions to prevent fractures. They should be provided with guidance on the rules and regulations to be observed strictly to avoid accidents (RTAs). Provide better facilities to the public for safe performance of work and other activities of the daily routine. At the same time, strictly curb and punish individuals indulging in wrong attitudes, especially during driving.

Prevention of fractures is a huge proposition and is possible only with a team approach. The following government departments can play a vital role in dealing with each and every fracture-prone situation:

1. Department of transport
2. Department of information and broadcasting
3. Department of housing and construction
4. Department of health and social welfare
5. Department of education

Example: Since a majority of fractures occur due to road traffic accidents, a safe transport system can play a vital role in the prevention.

Transport department

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- Providing public transport services which are safe.
- Strict discipline in driving, issuing driving licences, etc.
- Curbing strictly the use of mobiles, smoking or drunken driving.
- On the spot strict punishment for defaulters.
- At the same time, condition of the roads and road signals should be well maintained.

Department of information and broadcasting, press and media

- Repeatedly projecting the hazards of undue hurry and carelessness by story-based films, road demonstrations, etc.
- Emphasize the importance of healthy exercise-oriented lifestyle.
- Films on early detection of infective diseases, metabolic bone diseases like rickets, osteoporosis, tuberculosis and bone tumours.
- Emphasize the dangers of wrong methods of excessive weight reduction to achieve paper-thin figure.
- Emphasize the dangers of obesity as well.

Department of housing and construction

- Safety measures at the site of construction to prevent accidents.
- Provide ideal steps of small height with railings on both sides.
- Entrance should have slope with a railing.
- The floor in toilets, bath and under the water basin should not be slippery.

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- Adequate space in rooms to move about freely.
- Avoid door steps in between rooms.

Department of health and social welfare, and preventive medicine

- Extensive training of peripheral health workers to detect pathological fracture-prone diseases early.
- Peripheral centres should have adequate supply of vitamins and nutrients.
- Availability of specialists services intermittently at peripheral centres.

Educational institutes and parents

Educational institutes and parents should cultivate an active lifestyle by extra emphasis on sports, PT with regular monitoring.

Role of physiotherapy in fracture prevention

- Physiotherapists can play a major role by encouraging all acquaintances and friends, and in fact, every one they meet to get habituated to an active lifestyle by highlighting the health benefits of exercise. While treating patients for some other cause, the physiotherapist must practically get them interested in an exercise-filled lifestyle, preferably by self-demonstration.
- Provide guidance on safer physical activity performance, strictly avoiding fracture-prone behavioural attitudes.
- Discourage elderly people from instant sitting up from the lying down position, standing and starting to walk. These manoeuvres may cause postural hypotension resulting in giddiness and a tendency to fall.

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- Concentrate and emphasize on practicing and achieving momentary body balance on a single leg. It will go a long way in improving the body balance in ambulation or while performing activities while standing. It is possible only with the long sessions of balance training. It may cause sudden giddiness leading to a fall.

- Never turn or roll your neck instantly while walking.

- Safe and well-balanced wide–based (steps) gait training provides stability to the gait. It can be achieved by giving special training in the gym.

- Correct methods of transfers in bed, standing, sitting over with a pause in between the stages to restore perfect balance before the next stage of a particular activity is begun.

- Provide necessary assistive aid to facilitate good balance while performing functional activity. Generally, using a cane is never accepted wilfully by any individual. Therefore, it is essential to convince them of the benefits of a cane, at the same time, pointing out to them the consequences of not using the cane.

- Before the patient is discharged, home visit is a must to check:

- The house entrance has a slope or small steps with railings.

- The indoor as well as the outdoor areas are well lit.

- Walking area and room floors are clear of obstacles (e.g., not too many furniture items), loose carpeting, and have even flooring without steps in between rooms.

- No soapy and slippery flooring in toilets and bathrooms (common places of falls).

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- Furniture items are of the correct height.
- Lamp switch and telephone are placed so that they are operable from the bed itself.

Footwear safety

- Nonskid soles
- Narrow heels or toe areas
- Ensure close fitting of footwear before initiating standing or ambulation.

Exercise training programme

There are two basic modes of exercise training depending upon the degree of physical fitness.

1. Structured exercise training – ideal for younger age group with good exercise tolerance and the absence of cardiorespiratory anomaly, as it involves rather vigorous and continuously performed exercise.

2. The second or lifestyle exercise programme or exercise lifestyle programme which does not require continued exercise but is in vigorous bouts in between.

Exercise prescription for the structured exercise programme (table 19-1)

Table 19-1

General Characteristics of Structured Exercise Programme

Exercise Specificity	Initial Stage of Beginning Exercise	Progression of the Exercise
Type and mode [a]	Aerobics (dynamic)	Make vigorous by adding resistive mode
Intensity	40–60% of HR_{max}	60–70% of HR_{max}; if possible 70–85% HR_{max}

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Duration	5–15 min session	Gradually work up to 20–30 min per session or if feasible > 30 min
Frequency	Twice a week	At least three times a week; may be increased up to 5 times a week

[a]Must include impact loading of the spine and the lower limbs (e.g., jogging, spot running, brisk or marathon type of walk) to improve BMD and prevent osteoporosis. Cardiac clearance and exercise tolerance must be obtained before beginning this type of exercise training.

Exercise lifestyle training programme

Individuals who cannot perform exercises continuously for 30 min may change to three bouts of exercise with each bout lasting for 10 min, else incorporate the CRC type exercise, activities of daily routine so that the heart rate reaches the level of training heart rate range of 60% of HR_{max}.

This requires purposely planning a bout of performing that particular activity vigorously to reach the HR to the training level.

- Create an opportunity to have a brisk walk in between your daily schedule (e.g., parking vehicle away from the place of work and performing a brisk walk to and from the office.
- Make it a point not to use elevators, rather prefer brisk stair climbing. In fact, purposely try to repeat stairs at every opportunity.
- While watching TV, during the ad breaks, stand up and do some brisk exercises like spot marching, vigorous arm and lower limb movements. DO NOT KEEP MUNCHING while watching TV.
- Try to remain maximally active during leisure time.
- Avoid playing long, sedentary games.
- Get habituated to play at least one brisk outdoor game at least thrice a week.
- During long periods of sitting, perform antigravity arm movements overhead or sideways; stand and perform brisk antigravity hip

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movements.

■ Never ask for even a glass of water, please go and get it yourself.

In short, plan and make it a point to remain physically active as much as possible and whenever feasible. Major requirement is to make each and every physical activity as brisk as possible.

Last but not the least:

Do not forget that you are the best controller of your body.

So avoid:

■ Undue hurry while performing physical activity.

■ Never indulge in:

■ Drunken driving

■ Smoking while driving

■ Using mobile during driving

■ Driving too fast or attempt wrong hurried overtakes

■ Likewise catching or alighting from a moving train or bus

■ Go for complete medical checkup after 40 years of age

■ Healthy diet

Go for healthy exercising lifestyle and minimize incidences of avoidable fractures.

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CHAPTER 20

Emergency management of a polytrauma patient

OUTLINE

- Management at the site of accident
- Management in the hospital
- Pattern of orthopaedic injuries
- Disaster management

The rapid increase in the number of automobiles, technologies and industries, and above all speedy lifestyle, has resulted in an alarming increase in the incidence of acute polytrauma. Polytrauma may also damage the vital organ systems in the thoracic, abdominal and pelvic viscera with serious consequences or even death.

Table 20-1 shows the trimodal distribution factors of death following acute polytruama and preventive measures.

Table 20-1
Trimodal Distribution of Fatal Peaks, Possible Causative

Fatal Peak	Cause – Common Organ System Damage	Prevention
First peak of immediate death (50%)	Severe injury to the brain, spinal cord, heart, lungs or major blood vessels	Only possible by educating masses on preventive safety measures on RTAs
Second, intermediate peak of early death; Few hours after the injury (30%)	Occurs commonly due to airway disruption or failure of the respiratory mechanism	Possible with immediate initiation of resuscitation (ABC of life supports)

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Third or late peak of delayed death (20%)	Due to failure of multiorgan systems or sepsis	Possible with appropriate early measures (hospital care)

Objectives of management

- Preserving life by instant application of manual resuscitation
- Careful handling of the patient during transfers from the site of accident to a safe place and early transfer to a hospital or multidisciplinary health care facility
- Appropriate therapeutic measures to promote recovery – therefore, correct quick assessment and control of the vital parameters (e.g., adequacy of respiration, cardiac function, shock, unconsciousness, excessive blood loss need immediate attention)

The management of acute polytrauma patients is discussed in two sections: (i) at the site of the accident, and (ii) at the hospital.

Management at the site of accident

1. **Get one of the bystanders to call for ambulance and police.**

2. **Safe transfer**: Correct lifting and shifting of person from the site of the accident should never be done alone. Take help of at least two bystanders, guide them on how to protect damaged areas (e.g., in cervical injury) and prevent further damage during the transfer.

3. **Area of transfer**: Patient should be placed on a well-ventilated, even and hard surface. Loosen tight clothing worn by the patient if required. Place the neck in slight extension so that the nostrils point upwards, to ensure unobstructed ventilation; also get help to clear the crowd close to the patient.

4. **After safe transfer perform a quick survey of lethal injuries:**

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(a) *Respiration*

(b) *Circulation*

(c) *Control of haemorrhage or excessive bleeding*

Whenever injury to the cervical spine is suspected, immobilize and support the cervical spine with makeshift arrangement (e.g., conventional cervical collar or wrapping the neck with available cloth or rigid support).

Excessive uncontrolled bleeding may result in patient going into shock with its typical symptoms and signs (Box 20-1).

(d) *Examination of neurological function*

i. The level of consciousness to be assessed objectively by Glasgow coma scale (GCS) (Table 20-2)

ii. Pupillary response

iii. Voluntary limb movements

Table 20-2
Glasgow Coma Scale

1. *Eye opening*	(E)
• Spontaneous eye opening	4
• Opening eye in response to verbal command	3
• Opening eye in response to pain	2
• Does not open the eye at all	1
2. *Verbal response*	(V)
• Oriented	5
• Disoriented	4
• Inappropriate words	3
• Incomprehensible sounds	2

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• No response	1
3. *Motor response*	(M)
• Obeys commands	6
• Localized pain	5
• Withdrawal (pain)	4
• Flexion (pain)	3
• Extension (pain)	2
• No response	1

BOX 20-1

SIGNS AND SYMPTOMS OF SHOCK

- Unconsciousness
- Profuse sweating
- Tachycardia
- Pale appearance
- Hypotension

Once the patient is stabilized, conduct quick survey of the lethal injuries of the whole body from head to toe.

Conducting quick survey of other lethal injuries

Head and cervical spine injuries

Open skull injuries should be covered by clean cloth. Conduct neurological examination. In suspected cervical fractures or dislocation, temporary stabilization of neck is of vital importance.

Injury to the chest and thorax

Open chest injuries should be covered with a clean cloth with application of firm pressure over the open wounds. Development of flail chest or pneumothorax is an emergency and should be prevented by quick restoration of breathing.

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Injury to the abdomen

Intra-abdominal injury is an emergency as such and needs careful examination. Rigid abdomen suggests blunt injury and may inflict damage to the vital organs like liver or spleen. Open abdominal injuries should be covered with a clean cloth and application of a firm pressure.

Injury to the pelvis

Pelvic compression and distraction test should be employed; a positive test eliciting severe pain is indicative of pelvic fractures.

In pelvic injuries, there is always a likelihood of internal haemorrhage and damage to the intrapelvic organs like kidneys, bladder and genitourinary system. Suprapubic swelling indicates injury to the bladder, scrotum or perineal haematoma indicating urethral rupture.

Injury to the spine

Rigid motionless holding of the neck indicates serious injury to the cervical spine confirmed by the level of consciousness (GCS).

Acute tenderness over the spinous processes and rigid holding of the thoracic and lumbar spine are indicative signs of fractures at these sites with graduated onset of paraparesis.

Injuries to the limbs

Typical signs of localized pain, swelling, tenderness, limb positioning, bony deformity (or malalignment) and loss of function due to a sudden increase of pain indicate the presence of fracture.

Whenever limb fracture or dislocation is suspected, immediate rigid splinting and immobilization should be applied by whatever material available (e.g., using folded newspaper or an umbrella (Fig. 20-1).

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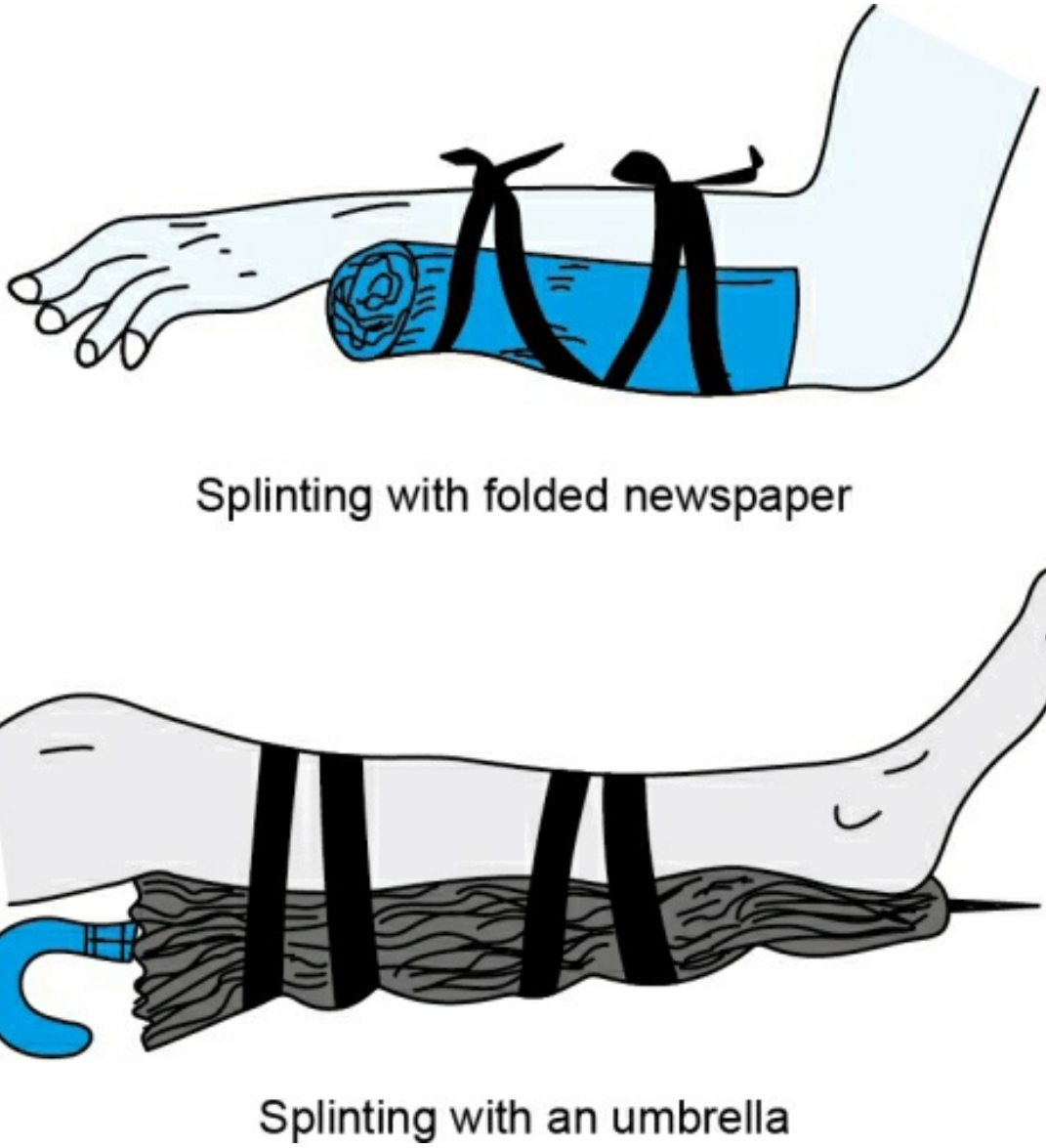

FIG. 20-1 Emergency splinting (a first step in fracture management). Emergency splinting with any object is a must to prevent further damage to the soft tissues by fractured bony ends.

Remember

Treating fracture is not an emergency. Restoration of airways and circulatory function is the first priority along with immediate arrangement to transfer patient to a multidisciplinary facility centre.

Management in the hospital

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As soon as a patient is brought to the hospital emergency, accurate quick survey is done of the whole body to find out the lethal injuries needing immediate attention and care. Meanwhile, measures like IV antibiotics, analgesics, tetanus toxoid, wound care and debridement should be undertaken to prevent infection and reduce pain.

Restoration of breathing

- Airway clearance
- Mechanical suction of secretions from oropharynx
- Endotracheal intubation
- Oxygen inhalation
- Presence of flail chest or pneumothorax
- Needs immediate attention
- Ventilator

Restoration of circulation (cardiac function) and treatment of shock

- Once the cardiac function is restored by resuscitation, restore adequate circulating blood volume by the following:
- Start IV fluids.
- Perform compatible blood transfusion.
- Control external bleeding by local pressure and limb elevation.
- Start immediate vascular repair or grafting if become necessary.

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Assessment of neurological dysfunction

- Level of consciousness
- Pupillary response
- Voluntary limb movements

Assessment of abdominal injuries

Closed abdominal injuries are assessed by the following:

- Sonography at substernal, right and left subcostal, and suprapubic regions
- Immediate exploration and repair of open abdominal injury

Immediate surgery

Immediate surgical procedure may be needed for head, chest and abdominal injury patients.

This is followed by the management of other body systems like digestive system, excretory system and, lastly, fracture management.

Pattern of orthopaedic injuries in polytrauma

Orthopaedic injuries are always associated with various types of injuries to the soft tissues surrounding the bones and joints.

- Head, cervical spine, and maxillofacial injuries
- Lower rib fractures with injuries to liver, spleen and kidney
- Injuries to the lumbar spine and intra-abdominal injuries with damage to the organ systems in the abdominal viscera
- Pelvic fractures with injuries to the genitourinary system (e.g., kidney, bladder, urethra) with excessive bleeding
- Lower limb fractures

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- Multiple fractures in a single limb

Definitive orthopaedic treatment

Orthopaedic care at the site of injury

- Apply makeshift support to maximally immobilize the areas of fracture or dislocation, e.g., cuff and collar, paper roll or umbrella to support lower limbs and conventional cervical collar by wrapping available cloth.

- Applying localized pressure over the bleeding points and covering the open wounds with clean cloth.

Orthopaedic care at the hospital

Once the patient's condition is stabilized, a detailed survey is conducted to know the extent of orthopaedic injuries along with radiographic investigations.

After initial wound care, fractures are treated with internal fixation. Soft tissue repair or reconstructions like vascular, neurological repair, grafting, tendon transfers, suturing are done along with the proposed management of bony injuries (e.g., fractures or dislocations).

Disaster management

Calamities like earthquake, downpours, war, railway accidents and terrorist attacks result in mass injuries of varying intensity and there are always an inadequate number of care-taking personnel.

As such the patients are sorted out and categorized on the basis of the severity of involvement into four major categories, and referred to four groups according to the severity of injuries.

Triage sort

Category I: Critical, needing immediate intervention, e.g., patients with airway obstruction or injuries to the large blood vessels

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Category II: Urgent but can wait for some time, e.g., open fractures

Category III: Less serious injuries, not endangered by delay

Category IV: Severe injury, survival not likely in spite of intervention

Treatment is carried out as per the individual needs.

In the triage, a survey is done to divide the dead and the individuals who are ambulatory into separate groups. The general plan of management of a polytrauma patient is depicted in Table 20-3.

Table 20-3
General Plan of Management of a Multitrauma Patient

At the Site of the Accident	At the Hospital
Instant cardiopulmonary resuscitation in the event of cardiac or respiratory failure	Restore haemodynamic stability by aggressive CPR, oxygen inhalation, defibrillation, using ventilator, etc.
Safe transfer to protected area	Send blood for
Airway and circulatory stabilization; control of blood loss; examination for shock	• Grouping • Cross matching • Clotting
Neurological examination for • Level of consciousness • Pupillary response • Voluntary limb movements	Control excessive blood and fluid loss by establishing adequate circulating blood volume by • IV line for fluid, plasma or blood as required • Starting central venous pressure measurement • Controlling external bleeding points by local pressure
Temporary closure of open injuries (at the chest, abdomen, or pelvis) by clean cloth	• Emergency surgical repair or reconstruction for extensively damaged vital visceral organ systems and vessels
Early identification of serious injuries needing immediate attention • Faciomaxillary injuries • Thoracic injuries: • Flail chest • Pneumothorax • Lacerations involving cardiac and large vessels • Closed abdominal and pelvic injuries	Definitive orthopaedic care • Radiographic investigations of suspected damaged bones and joints • Sonography • Substernal region • Subcostal region • Suprapubic region • Closed reduction of fractures or open reduction with internal fixation along with soft tissue repair
Bleeding	• Immobilization

Role of physiotherapy

Physiotherapists can provide valuable assistance in various ways.

Adequate expertise in the following:

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- Identifying serious injuries and their priorities
- Carrying out the procedure of saving life using CPR and basic life supports
- Managing patients with uncomplicated injuries
- Emergency chest physiotherapy
- Providing immediate splintage, correct posture of the body and the injured part.
- Active assistance in conducting various assessment procedures (e.g., quick neuromuscular evaluation)
- Adopting measures to prevent possible ensuing complications as a result of wrong handling, positioning, injury itself, or following reduction and immobilization by intermittent monitoring to encourage functionally oriented early mobilization after the stabilization of injury
- Education of public on emergency life-saving procedures

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CHAPTER 21

Infections of the bones and joints

OUTLINE

- Osteomyelitis
- Acute haematogenous osteomyelitis
- Exogenous osteomyelitis
- Chronic osteomyelitis
- Subacute osteomyelitis
- Osteomyelitis in HIV disease
- Skeletal tuberculosis
- Tuberculosis of the spine (Pott disease)
- Tuberculosis of the hip joint
- Tuberculosis of the knee joint
- Tuberculosis of the ankle joint
- Tuberculosis of the shoulder joint
- Tuberculosis of the wrist joint
- Tuberculous osteomyelitis
- Pyogenic arthritis (septic arthritis, infective arthritis, suppurative arthritis)
- Acute septic arthritis of infancy (Tom Smith arthritis)
- Gonococcal arthritis
- Syphilitic infection of the bones and joints

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■ Fungal infections of the bone

Like any other tissue in the body, bones are also infected by microorganisms. The common bone infections are as follows:

Common Microorganism	Bone Infection
Staphylococcus aureus	Osteomyelitis
Mycobacterium tuberculosis	Tuberculosis
	Pyogenic arthritis (septic-arthritis)

Osteomyelitis

Infection of the bone and bone marrow by pyogenic organisms is called *osteomyelitis*. It may be acute or chronic.

The most common causative organism is *Staphylococcus aureus*. The other organisms are *Streptomyces albus*, streptococci, pneumococci, *Escherichia coli*, etc. *Mycobacterium tuberculosis* may also cause osteomyelitis, which is discussed separately.

Microorganisms may enter and infect the bone by any of the following three routes:

■ Haematogenous route: Most common entry through the bloodstream, common in children (osteomyelitis)

■ Direct route: Directly through the neighbouring infected tissue (septic arthritis)

■ Exogenous route: Through open fracture, open wound, surgical incision, etc.

Acute haematogenous osteomyelitis

Acute haematogenous osteomyelitis is mostly caused by *S. aureus*. *Streptomyces albus* or streptococcus may be responsible for a mild type

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of infection.

Even mild skin infection like a boil or tonsillitis may be a predisposing factor.

Acute osteomyelitis generally follows a history of trauma. It occurs most commonly during the period of active growth, i.e., between 3 and 16 years of age. The causative organisms spread through the bloodstream from the original focus such as tonsils, respiratory tract and intestines to the bone.

The long bones of the lower limbs are commonly involved, the upper end of the tibia and the lower end of the femur being the most common sites. The upper end of the femur may be involved in infancy.

The initial focus of infection is usually the metaphysis because of the following reasons:

- It is highly vascular.
- The sharp looping of the nutrient artery (hairpin bend; Fig. 21-1) is an ideal site as it slows down the circulation encouraging the harbouring of bacteria.
- A recent trauma may result in reduced tissue resistance because cell destruction due to haemorrhage helps in localizing infection in the metaphysis.
- Other factors like reduced immunity, anoxia, vasospasm, defective phagocytosis and anaemia may aggravate the infection.
- The organisms multiply, set up inflammatory exudate and result in abscess (pyogenic) formation.
- The pus enters various sites of the bones like the medullary canal and the periosteum through the Haversian canals (Fig. 21-2).

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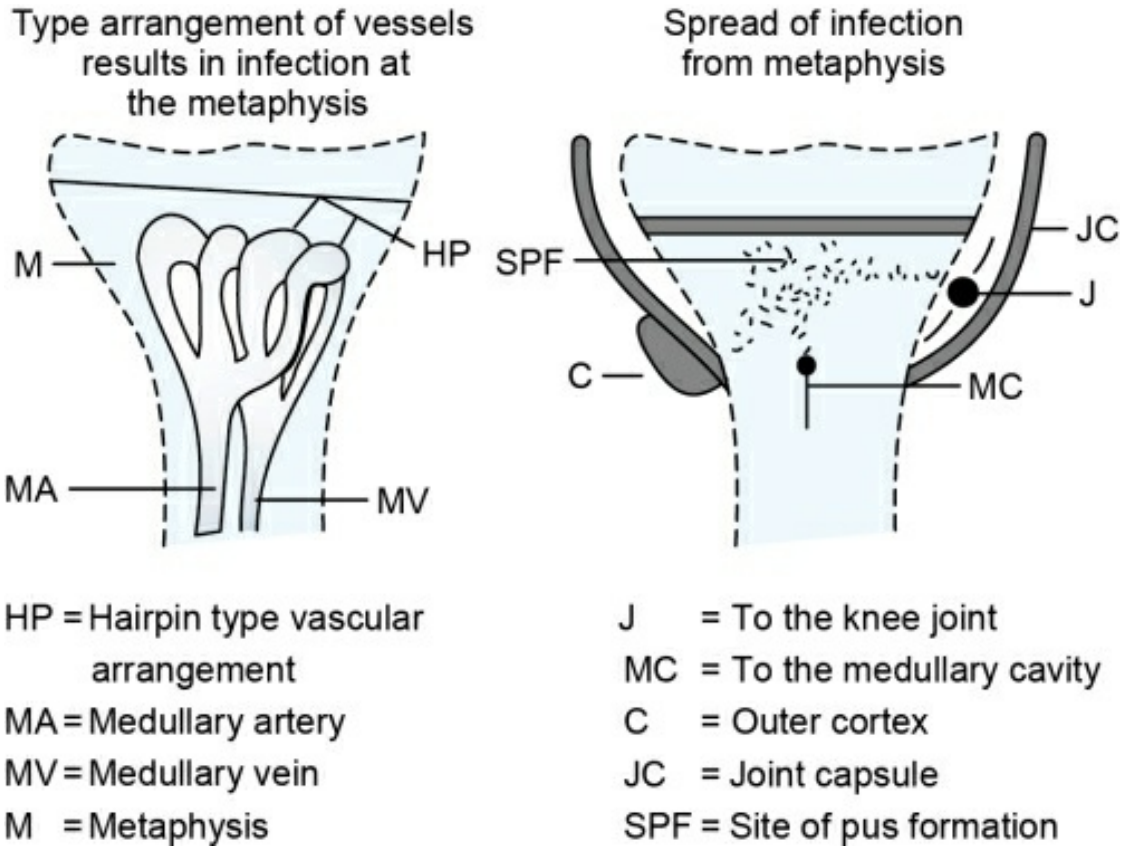

FIG. 21-1 Factors promoting infection and its spread.

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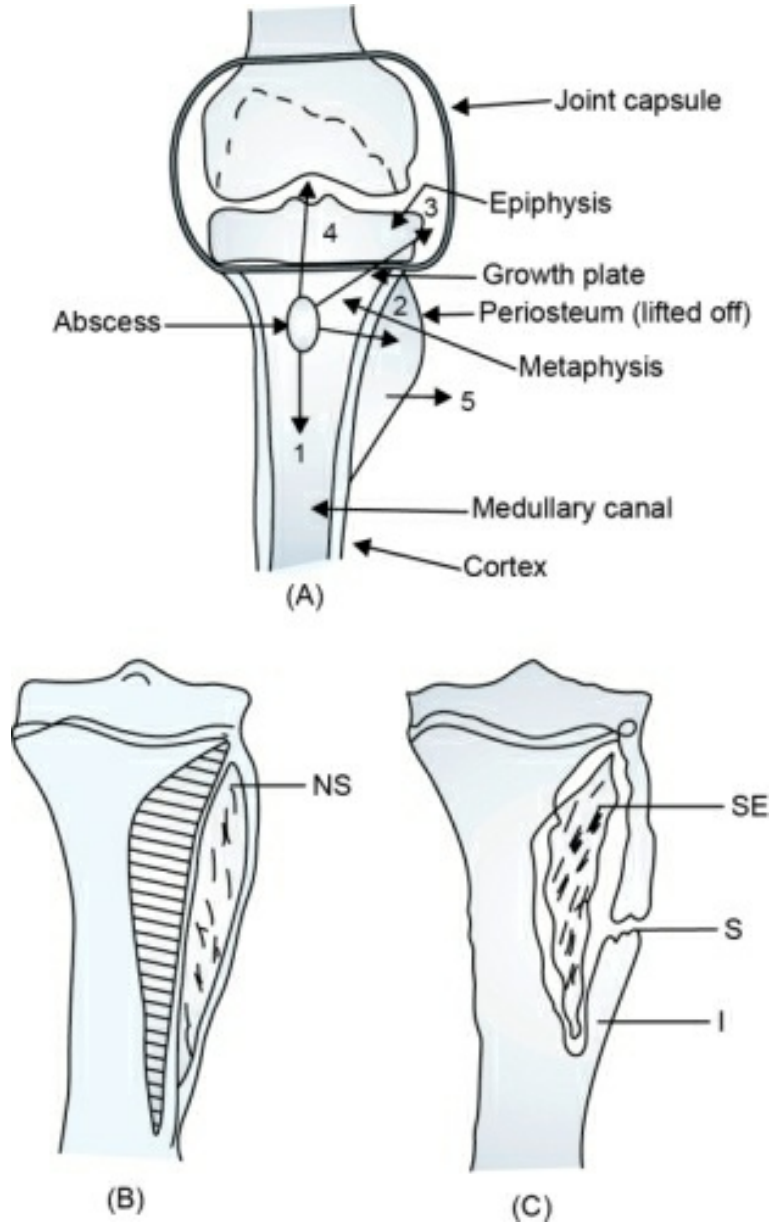

FIG. 21-2 Osteomyelitis stages. **(A)** Acute haematogenous osteomyelitis. Spread of pus from its origin in metaphysis to (1) the medullary canal, (2) under the periosteum, (3) the joint, particularly where the metaphysis is intra-articular, (4) the joint directly, particularly in infants, and (5) outside the bone through a sinus. **(B)** NS: Necrotic segment. **(C)** SE, sequestrum; S, perforating sinus; I, involucrum.

An abscess is formed and the infection spreads to the medullary cavity of the diaphysis or the shaft. It may spread underneath the periosteum. This results in lifting of the periosteum thereby cutting off the blood supply to the underlying bone and resulting in its death

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(necrosis) and formation of sequestrum. Subsequently, the tense (Fig. 21-2B) abscess ruptures the periosteum and pus comes out through a sinus (Fig. 21-2C). In children, the periosteum is loosely attached to the bone and therefore gets lifted off easily by the underlying pus, resulting in a large diaphyseal sequestrum (Fig. 21-3). On the other hand, in adults, the periosteum is closely adherent to the bone and therefore cannot be lifted off easily. If not controlled, it may spread to other parts of body.

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FIG. 21-3 Chronic osteomyelitis of humerus, showing a large diaphyseal sequestrum.

In most of the long bones, the metaphysis is extra-articular and therefore when the abscess bursts open, it does not involve the joint (Fig. 21-4). In certain situations where the metaphysis is intra-articular, the abscess bursts open directly into the joint cavity and causes septic arthritis. The most common example is the hip joint. At the upper end of the femur, the neck of the femur is the metaphysis, which is intra-articular and therefore an abscess in the metaphysis will drain directly into the joint cavity (Fig. 21-5). The other sites where the metaphysis is partially or totally intracapsular are the upper end of the humerus, the lower end of the humerus and the lower end of the femur.

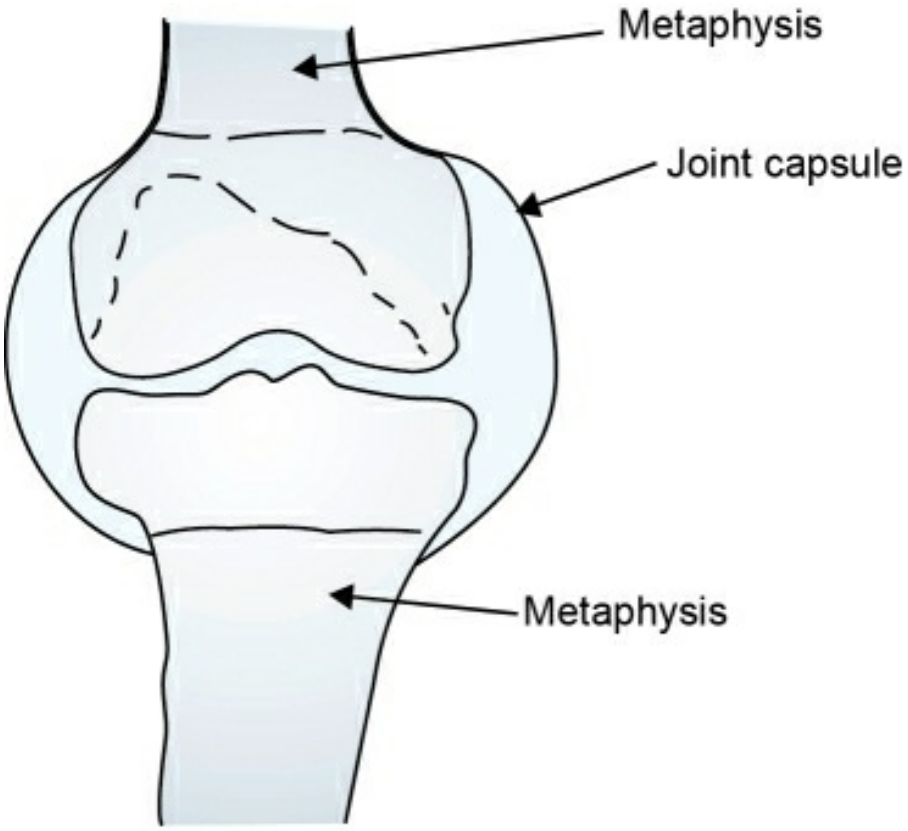

FIG. 21-4 The position of metaphysis is outside the joint capsule.

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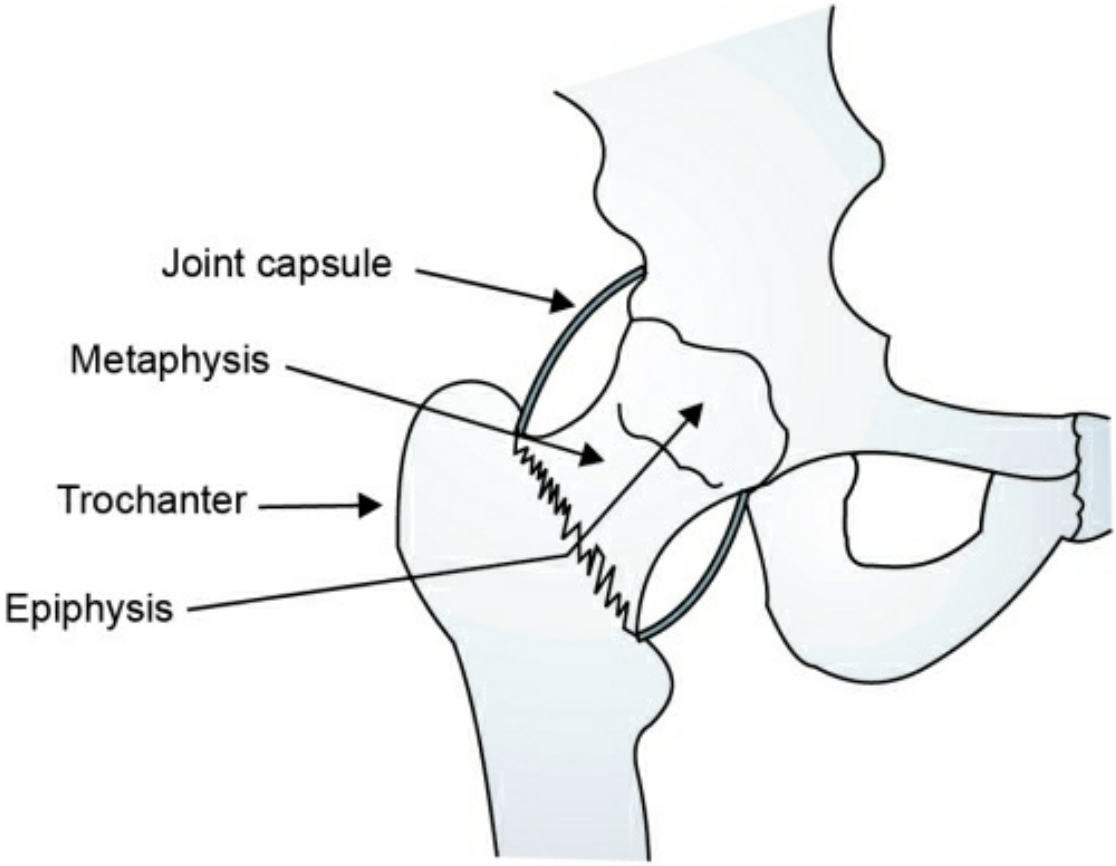

FIG. 21-5 Metaphysis at the proximal femur is within the joint capsule.

In this situation, the pus bursts open outside, through the periosteum, resulting in multiple discharging sinuses.

Acute osteomyelitis, when not treated promptly and adequately, may result in chronic osteomyelitis. Chronic osteomyelitis may also develop in bones following a compound fracture or following surgery.

Another variety of chronic osteomyelitis, i.e., tuberculous osteomyelitis, presents insidiously in the chronic stage only, without presenting in the acute form.

In chronic osteomyelitis, the dead bone (called sequestrum) becomes surrounded by infected granulation tissue; it becomes a chronic source of pus discharge through the already formed sinus.

Reparative new bone is laid down beneath the elevated periosteum. It is called *involucrum*. In neglected cases, the infection may become chronic resulting in repeated bouts of acute exacerbations, with discharging sinuses (Fig. 21-6) and progressive destruction of the

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affected bone and the surrounding soft tissues.

FIG. 21-6 Discharging sinus in the right thigh, due to chronic osteomyelitis of the femur. Note that the affected thigh is short, as seen by the different levels of the knee joint.

Clinical features

The diagnosis of acute osteomyelitis is essentially clinical. The onset of symptoms may be preceded by a history of trauma to the affected part. A primary focus of infection may also be detectable somewhere in the body, e.g., skin and tonsils.

In the acute stage, the child presents with high fever, headache, irritability and mild swelling. On examination, signs of dehydration may be found. The affected limb is kept in a position of slight flexion of the adjacent joint. This position relaxes the joint capsule and increases its capacity to accommodate the effusion, which is usually sympathetic. Tenderness and signs of inflammation are present over the metaphysis. Swelling may become apparent when the pus comes into muscular or subcutaneous plane. The child resists any examination or even change of bed sheets, etc. because of severe pain.

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In rare cases, there may be signs of toxaemia.

Investigations

The following investigations may help in the diagnosis of acute osteomyelitis, though they may not be specific.

1. Blood

   (a) Leucocytosis should be up to 20,000 cells.

   (b) Erythrocyte sedimentation rate (ESR) level is elevated.

   (c) Blood culture may be positive for the organism.

2. Radiograph of the affected part

   (a) The radiograph is usually normal in the first week.

   (b) A periosteal reaction may be seen between 7 and 10 days.

3. Bone scan: It shows an increased uptake by the affected bone.

Treatment

The key to successful treatment of this condition is its early diagnosis. Acute osteomyelitis should be suspected if there is tenderness over the metaphyseal area of the bone, and any attempt to move the joint/limb causes excruciating pain. The following measures are adopted in its treatment.

Conservative treatment

Early stage

- *Antibiotics*: Appropriate antibiotics are administered intravenously

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after determining the sensitivity of the organism from the blood or pus for the first 7–10 days; oral administration is continued further for at least 8–12 weeks. Blood transfusion may be necessary.

- *Rest and proper positioning of the limb (area of infection) with a suitable POP cast with the limb elevated:* The POP cast decreases pain and stops the spread of infection by reducing muscle action and blood flow.

- Adequate balanced diet and fluid intake have to be ensured.

- Regular monitoring of general condition, fever, pulse and the state of hydration, etc., has to be done.

- Observation: The affected area should be observed for soft tissue oedema, redness of skin, warmth, soft tissue abscess and discharge, etc.

- IV fluids are administered in case of marked dehydration, or blood transfusion if the patient is anaemic.

Surgical treatment

Surgery is indicated if there is no favourable response to conservative treatment by 48 h. By this time, an abscess usually forms, which needs drainage. In addition to the incision and drainage of pus from the subcutaneous abscess, multiple holes are drilled into the cortex of the bone for proper drainage of the pus. Sometimes, a small window may be made in the cortex of the bone for better drainage.

Physiotherapy management

Physiotherapy objectives

- To plan graduated exercise in relation to the muscles skeletal destruction by the disease process

- To restore optimal range of motion (ROM) or at least functional

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ROM to the affected joint

- To maximally increase the strength and endurance of the muscle groups in the proximity of the diseased bone
- To plan tailored programme of exercises towards maximizing the functional independence to the patient, heavily depending upon correct guidance to the mother or child's attendant, providing the necessary devices, aids or orthoses

Expected problems

- Acute exacerbations or recurrence
- Joint stiffness and weakening of the muscles close to the site of lesion
- Possibilities of a pathological fracture
- Deformity or a limb length discrepancy
- Prolonged nonhealing sinuses

Salient features of the disease to plan the therapeutic approach

- *S. aureus* is the common organism which precipitates the disease with an affinity to attack the *epiphysis*.
- It commonly affects children.
- It involves the metaphysis.
- Fever is a common presenting symptom.
- Conservative approach with rest, nutritious food and drugs can effectively control the disease.

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Physiotherapy in acute haematogenous osteomyelitis

- Pain and muscular spasm should be controlled by cryotherapy with icepacks or ice water packs.
- Splinting of the affected joint in functional position should be done. Guide mother in changing posture and repetitive toe movements.
- As far as possible, the affected limb should be comfortably placed in an elevated position to reduce oedema.
- As soon as there is an evidence of the disappearance of the acute symptoms like fever, rigors, chills, although persistence of pain remains, superficial thermotherapy may be introduced to reduce pain and spasm.
- Unaffected joints are moved through the active full range by guiding the mother.
- Brief and light isometrics are initiated to the muscles under immobilization by self-efforts within the pain-free range.
- Mother of the child should be warned not to allow or hastily carry out bearing weight of the affected limb to avoid undue stress over the affected joints.
- The vigorousity and self-resistive modes of exercise to the unaffected joints are guided and supervised.
- Isometrics under the splints are progressed to strong and sustained mode, especially focusing on the functional muscle groups.

Late stage

- Initiate light rhythmic relaxed self-active movements within the pain-free ROM.

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- The joint stiffness and muscular weakness, which have occurred during immobilization are major problems that needs concentrated efforts to improve.

- Wherever possible, educate mother to encourage the child on self-performed exercises in a gradual mode.

- Encourage maximally the self-stretching-hold technique to improve the ROM of the postimmobilization joint stiffness.

- As the deformity is minimal, in due course, initiate standing balance, weight transfers in the parallel bars.

- Provide proper orthoses if needed and initiate ambulation in a parallel bar.

- Progress the exercise mode to antigravity or self-resistive one.

- Guide the mother adequately to help the child to properly carry out functional activities as independently as possible and be alert and watchful for the signs and symptoms of recurrence and report immediately.

- The mother should be taught the technique of friction massage in the event of formation of an adherent scar.

- Beside ambulation, focus on achieving strong and maximum ROM at the hip and knee towards functional ambulation, with the limit of the process of recovery of the disease.

NOTE: Every child has high potential to be progressive towards self-sufficiency, which itself many times provides clues to help in achieving the goal early.

Exogenous osteomyelitis

In exogenous osteomyelitis, the microorganism enters through an

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open wound, an open fracture or following surgery. Within 2–3 days, a purulent discharge develops, accompanied by fever.

This type of osteomyelitis can be prevented by early surgical intervention. Otherwise, appropriate antibiotics and regular dressing remain the mode of treatment.

Complications

- Septic arthritis
- *Chronic osteomyelitis:* If the disease is not treated enthusiastically in the acute stage, the condition slips into a chronic stage and is then called chronic osteomyelitis
- *Destruction of a growth plate:* When the infection involves the growth plate, it causes destruction of the growth plate; this in turn causes premature closure of the growth plate resulting in either shortening of the limb or deformity (Fig. 21-7)

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FIG. 21-7 Destruction of the epiphysis of tibia, due to infection, causing deformity at the ankle.

Chronic osteomyelitis

Acute (pyogenic) osteomyelitis, when treated inadequately, passes on to chronic osteomyelitis. The other causes are weak host defence mechanism due to malnutrition, etc., or high virulence of the organisms.

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Pathology

When the periosteum is lifted off due to pus, the underlying bone loses its blood supply, becomes dead and forms a sequestrum. The process of repair continues and new bone is laid down subperiosteally. This is called involucrum. The new bone is laid down in an irregular fashion which gives an irregular surface to the bone.

The sequestrum is defined as a piece of dead bone surrounded by infected granulation tissue. It has a smooth surface which is 'bathed' in pus and an irregular edge which is surrounded by granulation tissue. The size of the sequestrum may vary from a flake of a bone to a large diaphyseal segment of the bone.

Involucrum is the new bone laid down under the raised periosteum, as a part of the repair process. It lies outside the sequestrum and develops holes in the bone through which the pus drains out. The holes are called *cloacae*.

The following are the characteristic features of chronic osteomyelitis:

1. Discharging sinus (Fig. 21-6), which is usually fixed to the underlying bone

2. Irregular thickening of the bone (Fig. 21-8)

3. Irregular surface of the bone

4. Deformity of the limb

5. Shortening of the limb

6. Joint stiffness

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FIG. 21-8 Radiographic features of chronic osteomyelitis: (A) Cavities seen in the bone. (B) Thickening, irregularity and deformity of the bone. Loss of distinction between the cortex and medulla of the bone.

Radiographic features

- Thickening and irregular cortex and deformity of bone (Fig. 21-8)
- Patchy sclerosis giving honeycomb-like appearance
- Bony cavity (area of rarefaction surrounded by sclerosis)
- Formation of granulation tissue surrounding the sequestrum giving the appearance of radiolucent zone around it
- Involucrum with sinus holes (cloacae) visible outside the

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sequestrum

A pathological fracture is shown in Fig. 21-8

Complications

1. **Acute-on-chronic osteomyelitis:** Acute exacerbations of a chronic disease can occur repeatedly and are treated with antibiotics, and drainage of pus, if required.

2. **Stiffness of the adjacent joints:** This can occur due to the following:

(a) Soft tissue contractures

(b) Secondary septic arthritis (Fig. 21-9)

3. **Pathological fracture:** This can occur through the weakened part of the bone. This is generally treated by conservative methods. However, nowadays, it can very well be treated by Ilizarov fixation technique.

4. **Deformity** can occur due to the following:

(a) Malunion of a pathological fracture

(b) Premature arrest of the epiphyseal growth plate due to infection (Fig. 21-10)

5. **Limb length discrepancy**

(a) *Shortening* occurs when the growth plate is damaged due to infection.

(b) *Lengthening* may occur occasionally because of increased vascularity in the region of the growth plate as

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a result of osteomyelitis.

6. **Malignancy:** A long-standing discharging sinus may in rare cases transform into squamous cell carcinoma.

FIG. 21-9 Septic arthritis of the right hip joint.

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FIG. 21-10 Premature closure of the distal epiphysis of tibia, caused by infection, leading to shortcoming of tibia and the resultant deformity at ankle joint.

Treatment

Antibiotics

Antibiotics are given as per the pus culture and sensitivity reports.

Surgical operations

The following surgical operations are performed either singly or in combination.

Sequestrectomy: Removal of the necrotic bone (sequestrum) with curettage of the cavity is carried out. The infected granulation tissue is also excised.

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Curettage: The cavity in the bone allows accumulation of pus and bacteria inside it. The cavity is curetted and after a thorough curettage, it may be filled with cancellous bone grafts or a viable muscle.

Saucerization: Pus gets collected in the deep cavity in the bone (Fig. 21-11A). The cavity is therefore made shallow like a 'saucer', by removing its overhanging edges which prevents accumulation of pus. This procedure is called *saucerization* (Fig. 21-11).

Excision of the sinus tract: The sinus tract is excised and the wound is allowed to heal slowly.

Amputation: It is indicated in very rare situations when a discharging sinus of longstanding duration undergoes a malignant change or when other organs of the body get involved due to the infection.

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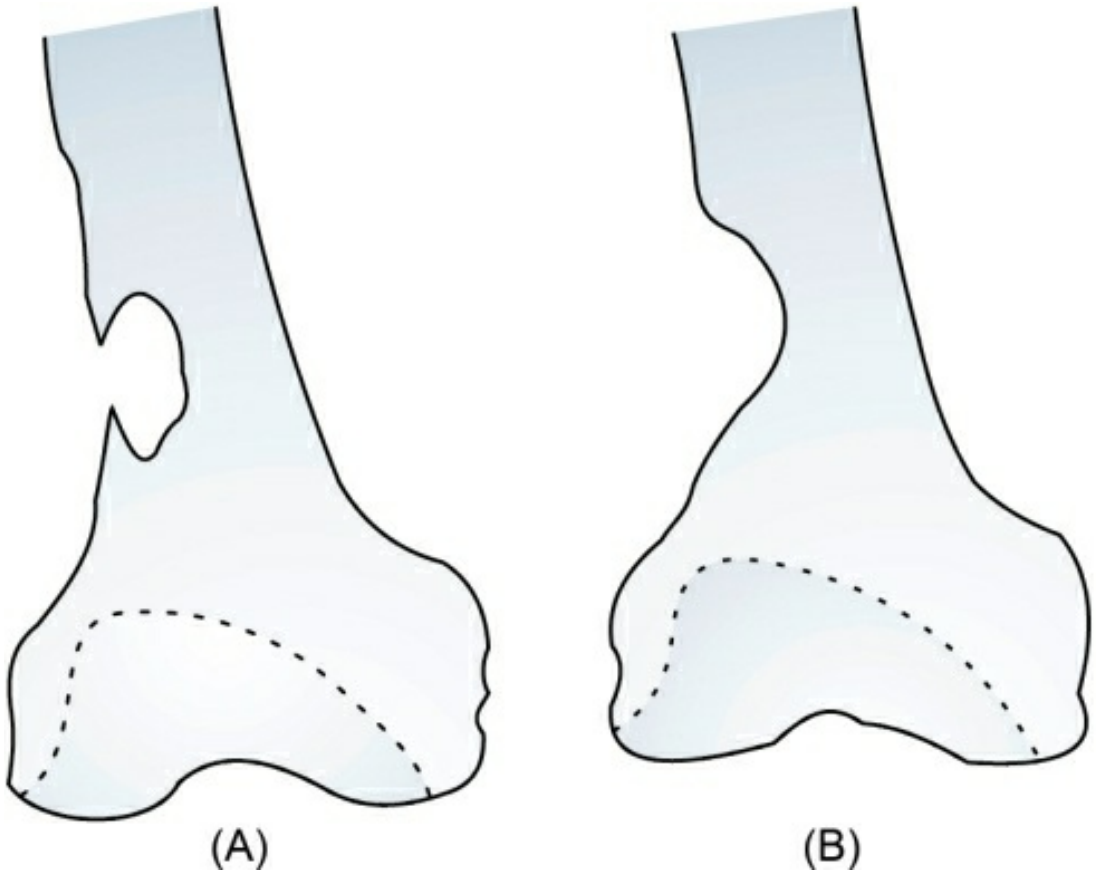

FIG. 21-11 Saucerization: **(A)** A deep cavity in the bone is converted into **(B)** a shallow (saucer-shaped) cavity.

Physiotherapy management of chronic osteomyelitis

When the active disease is controlled, it leaves certain chronic musculoskeletal deficiencies.

Therefore, maximum efforts are introduced to restrict the residual disabilities to the minimum.

Limb length imbalance

There may be a limb shortening due to damage to the growth plate by the disease, whereas limb lengthening may occur as a result of localized increased vascularity at the growth plate. This requires periodical checking of the leg length and providing correct raise in the affected or the contralateral limb.

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Deformity

- Initially by the passive stretching mode
- Adjustable dynamic orthosis
- Wedge serial POP cast

Adherent scar

- Sustained and gradually passive stretching combined with friction massage may be tried.
- Ultrasound exposure has been found to be effective.
- Ambulatory assistive devices like LL braces, crutches, canes with gait training sessions may be required. Increase the vigorousity of exercise modes to depend heavily on self-performed exercise training.
- Resistance exercises and resistive functional movements are maximized to ease the stability as well as the freedom of movements and the ADLs.

Amputations

Long-standing infection may undergo malignant changes, and one has to undertake limb amputations. The standard methods of sequential stages of rehabilitations following limb amputations are used.

Subacute osteomyelitis

When the disease is caused by organisms of low virulence or the host has a high resistance, the disease presents itself primarily as subacute osteomyelitis; with insidious onset.

Subacute osteomyelitis may present as one of the following three categories:

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1. Salmonella osteomyelitis

2. Brodie abscess (Fig. 21-12)

3. Sclerosing osteomyelitis of Garre

FIG. 21-12 Brodie abscess: (**A**) Diagrammatic representation. (**B**) As seen on a radiograph; note the oval-shaped lytic lesion.

Salmonella osteomyelitis

Salmonella osteomyelitis is a subacute type of osteomyelitis which presents during or following enteric fever.

Salient features: Mostly bilaterally symmetrical involving ulna or tibia, and involving the diaphysis

Radiography: Area of rarefaction in the cortex surrounded by the sclerosis

Treatment: Antibiotics, curettage or drainage of the abscess

Remember

The rate of recurrence is high and therefore adequate treatment and regular follow-up are advisable.

Brodie abscess

Brodie abscess occurs from low-grade infection of the bone by staphylococcus.

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Salient features

A single abscess is commonly formed in the metaphysis of the long bones, especially the lower end of the femur or upper end of the tibia.

Clinical features

Brodie abscess is commonly seen in adolescents. Dull and deep pain is felt over the site when the abscess is studded with pus and granulation tissue. Initially, it is asymptomatic due to the body's own defence mechanism.

Radiography

Round or oval-shaped lytic lesion surrounded by the zone of sclerosis is seen distinctly in the metaphysis (Fig. 21-12).

Treatment

- Antibiotics
- Drainage of the abscess or curettage of the cavity
- If the cavity is large, surgical evacuation of the abscess followed by cancellous bone grafting is done under antibiotic cover

Sclerosing osteomyelitis of garre

- It is a diffuse sclerosing inflammatory lesion of unknown aetiology.
- It is commonly seen in children, affecting long bones.

Clinical features

- Chronic dull pain over the site of lesion (usually tibia) which worsens at night.
- Deep bony tenderness
- No discharging sinus

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- Radiography: Increased density and cortical thickening over the affected part of the bone with obliteration of the medullary canal are seen

Treatment

- Antibiotics
- Excision of the thickened bone
- Differentiation from Ewing sarcoma, osteosarcoma, or osteoid osteoma which have a similar radiographic picture

Physiotherapy

- During the initial phase, rest in a proper splint in a relaxed position is provided for augmenting healing of the lesions by antibiotics.
- Perform limb elevation to help drainage of the waste following drainage of the abscess or curettage.
- Following excision and bone grafting, strictly check the close fit position of the immobilization.
- Provide vigorous exercise to the nonaffected limb joints and to the toes of the involved limb.
- Gentle short-duration isometrics are initiated as soon they are not painful.
- Gradually increase the vigorousity of the therapeutic exercises from free rhythmic relaxed movements to self-resistive mode.
- Check the adjacent joint for joint tightness or contractures and begin with self-stretch-hold mode.
- Posterior above-knee (AK) orthosis or cast may be necessary during early ambulatory training sessions.

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- Ambulation is progressed from supported to independent mode correcting the limb by gait training.

Osteomyelitis in HIV disease

The rate of bone destruction greatly exceeds the rate of new bone formation. The areas of lower femur and upper tibia are the common sites and the disease is often bilateral with secondary septic arthritis further complicating the condition.

Skeletal tuberculosis

Tuberculosis of bones and joints accounts for about 3% of all types of tuberculosis; the maximum incidence being that of the spine (>50%) followed by hip, knee, shoulder, elbow and hand.

Tuberculosis is a systemic disease which may affect various organs. Skeletal tuberculosis, i.e., tuberculous infection of the bones and joints, is almost always secondary to an infection elsewhere in the body, usually in the lungs, lymph glands or intestines, etc. Young children and adolescents are commonly affected. Debility, general weakness and unhygienic surroundings could be the predisposing factors. Injury may be a precipitating cause, resulting in small haemorrhages inside the bone. Such haemorrhages cause vascular stasis which favours deposition of the organisms in the injured area.

The causative organism, the tuberculous bacillus (*M. tuberculosis*), enters the body by inhalation, by ingestion or by inoculation. The bacilli multiply after invasion infecting the bone at the epiphyseal cartilage. An inflammatory reaction sets up and eventually a typical tuberculous follicle is formed. There occurs destruction of the bone with pus formation. The infected granulation tissue and pus spread to the nearby soft tissues and subperiosteal planes – as 'cold abscess' and may find its way to the exterior as sinus. Later on, there is an attempt at fibrosis at the periphery. Tuberculous infection of the bone is seen in vertebrae, phalanges and metacarpals and rarely in long bones. Infection of the synovial membrane occurs in tuberculous arthritis.

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Clinical features

Tuberculous arthritis is usually monoarticular but may involve multiple joints occasionally. Hip, knee and elbow joints are commonly involved, whereas wrist and tarsal joints may occasionally be affected.

Tuberculosis can be seen at any age but it is more common before the age of 30 years. Both sexes are equally involved. The onset is insidious and may be associated with constitutional symptoms like low-grade evening rise of temperature, loss of appetite and weight, night sweats and anaemia. Early inexplicable appearance of atrophy in a muscle close to the site of infection may also be found.

In the early stage, the synovial membrane is affected. A soft, tender swelling develops over the affected joint. Attempted movements of the joints are extremely painful, when the bony ends of the joint are involved. Joint movements are restricted due to muscle spasm, and involvement of the cartilage.

If treated early and adequately, there may be good recovery. Delay in treatment may result in the fibrous ankylosis, bony ankylosis, joint destruction and even dislocation.

In fibrous ankylosis, the cartilage and the synovial membrane are replaced by fibrous tissue. The bony ankylosis may be due to the knitting of the bony ends following destruction of the cartilage, or ossification may occur in the fibrous tissue surrounding the joint (Fig. 21-13).

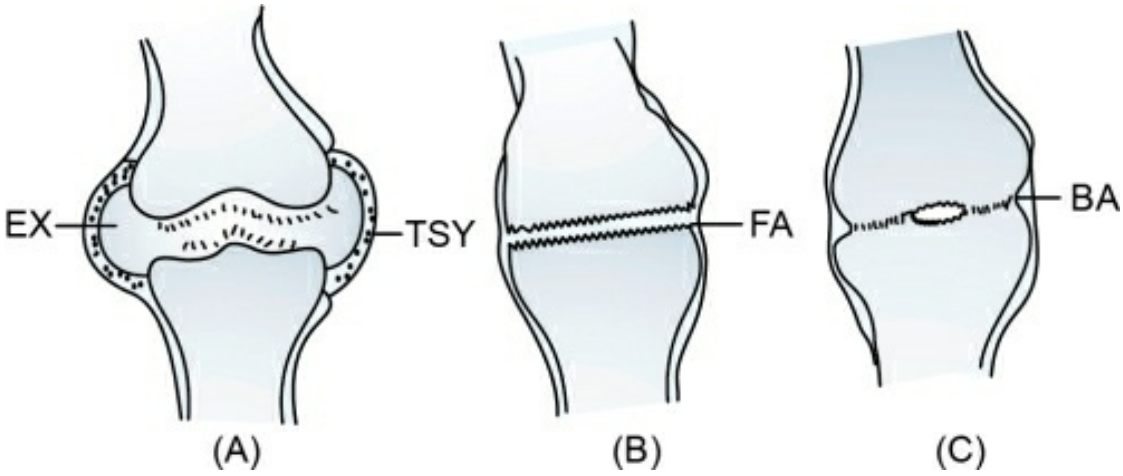

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FIG. 21-13 Tuberculous arthritis involving knee. **(A)** TSY, thickened synovial membrane; EX, exudate-turbid fluid or pus. **(B)** FA: fibrous ankylosis. **(C)** BA: bony ankylosis.

Dislocation of the joint may occur due to destruction of the ligaments supporting the joint.

Investigations

1. Radiographic investigations:

(a) As the radiographic changes are minimal in the early stage, radiograph may be taken of both the sides (bilateral) for comparison.

(b) *Tuberculous osteomyelitis:* A well-defined area of bony destruction without any new bone formation (unlike pyogenic infection) (Fig. 21-14).

(c) *Tuberculous arthritis:* Reduction of joint space, erosion of articular surface with marked periarticular destruction, rarefaction (no subchondral rarefaction like osteoarthritis or septic arthritis) (Fig. 21-15).

(d) Radiograph of chest to detect any primary lung lesion.

2. *Blood investigations:* Investigations show slightly raised ESR, and lymphocytic leucocytosis, normal or low haemoglobin.

3. *Mantoux test:* It is a skin test which gives information whether a person has been infected with Tuberculous bacilli or not.

4. *Serum ELISA:* It is done for detecting antimycobacterium antibodies to mycobacterium antigen.

5. *TB Gold test:* It is a blood test that detects whether a person is

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infected with tuberculous infection or not.

6. *Synovial fluid aspiration:* It is done to confirm inflammation; may show raised protein content at early stage along with leucocytosis and decreased glucose level.

7. Aspiration of cold abscess and pus examination for tuberculous bacilli are done.

8. *Histopathological test:* It is the examination of the granulation tissue of biopsy or curetted tissues.

9. *CT scan:* It is useful in small lytic or destructive lesions especially cervicodorsal junction not visualized by plain radiograph (Fig. 21-16).

10. *MRI:* Early detection is much better not only in bony but also in soft tissue lesions (Fig. 21-17).

11. *Biopsy:* Biopsy from bone cavity or synovium can provide confirmed diagnosis.

12. *Confirmatory tests:* Ziehl–Neelsen stain for acid-fast-bacilli (AFB) and growth from the joint aspirate or biopsied tissue are confirmatory tests.

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FIG. 21-14 Tuberculosis osteomyelitis of the neck of femur. There is destruction of the bone (cavity) without any new bone formation.

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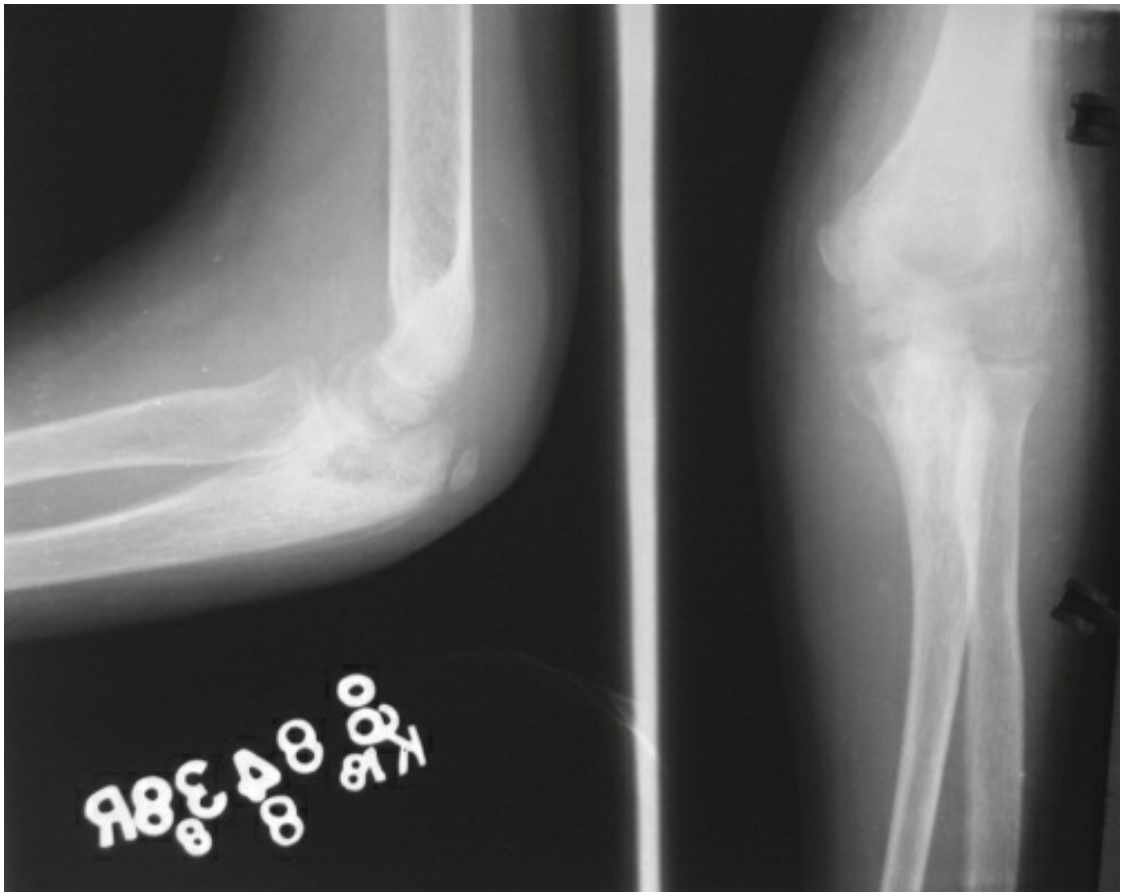

FIG. 21-15 Tuberculous arthritis of the elbow joint. There is considerable soft tissue swelling and destruction of the olecranon of ulna including the articular surface.

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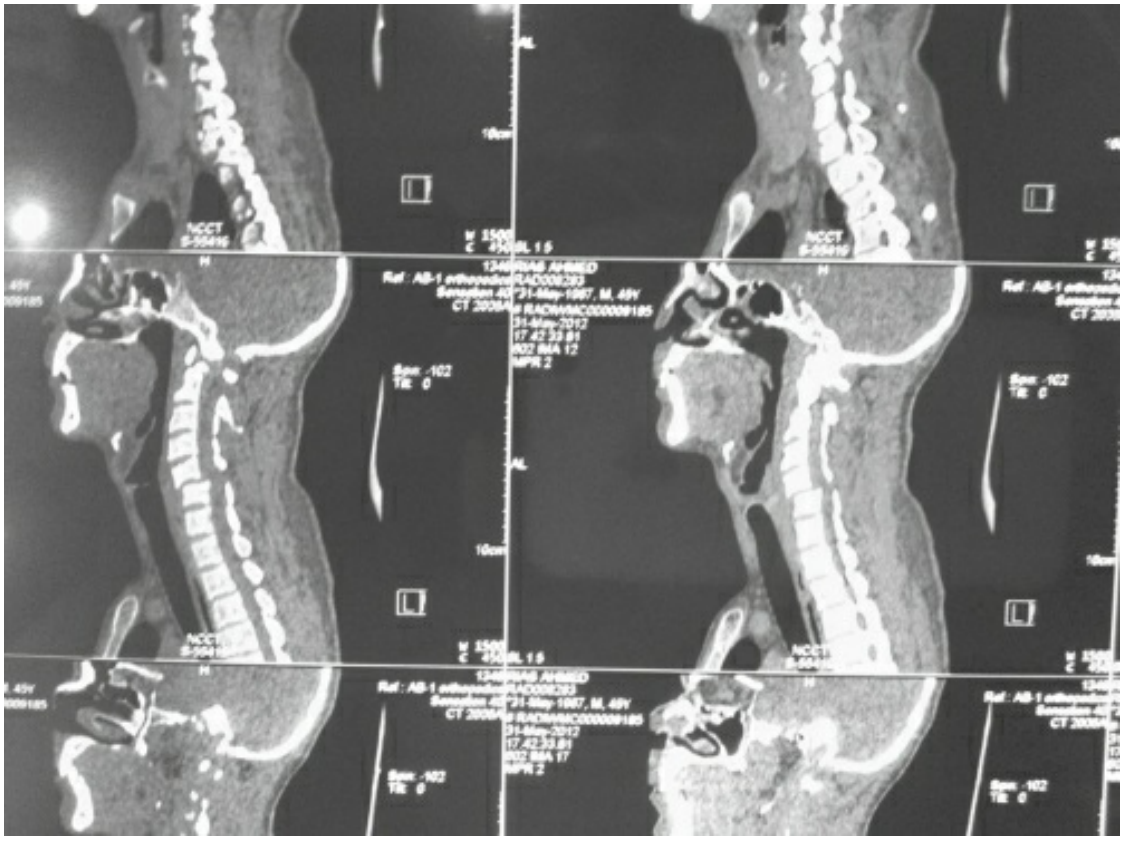

FIG. 21-16 CT scan of cervicodorsal spine shows subluxation of C5-C6 vertebrae.

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FIG. 21-17 MRI of the spine showing tuberculosis of D10-11 vertebrae.

Treatment

Conservative

1. Bed rest and well-balanced nutritious diet are given.

2. *Drug therapy:* Initially, four drugs – rifampicin, INH (isoniazide),

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pyrazinamide and ethambutol – are given for 2–3 months, followed by 2 drugs – rifampicin and INH – for 18 to 24 months.

Second line of antituberculous drugs is given if the patient fails to respond to the aforementioned primary drugs.

3. Rest to the affected part in the acute stage may be achieved by traction or splinting or POP cast in the optimal position of the joint.

Optimal positioning of the affected joint and the limb are of primary importance to avoid deformity and contractures (Table 21-1).

Table 21-1

Optimal Positioning of Joints to Ensure Rest and Possible Prevention of Deformities

Joint	Optimal Positioning
Hip	Neutral extension, 15–30° of abduction and neutral rotation
Knee	As much extension as possible
Ankle and foot	Neutral position of dorsi and plantar flexion (at right angles)
Shoulder	Abduction of 40–45° with internal rotation
Elbow	In flexion close to right angle
Wrist	In 15–20° of extension

Surgical

The surgical treatment depends upon the stage and the extent of the disease and its complications.

1. Drainage of the abscess is done.

2. *Curettage:* A cavity in the bone is curetted thoroughly, with or without bone grafting.

3. *Joint debridement:* The infected focus, including the granulation tissue and necrotic material, is removed from the joint. This helps in early healing of the disease.

4. Decompression of the cord is performed.

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5. *Arthrodesis:* The joint is fused in the functional position when the joint is destroyed beyond repair.

6. *Arthroplasty:* Excisional arthroplasty (also called Girdlestone arthroplasty) is done in cases of tuberculosis of the hip. In this operation, the infected/affected head and neck of the femur are excised. A part of the acetabulum may also be excised (Fig. 21-18). This helps in the healing of the disease. Excisional arthroplasty has the advantage of giving a mobile hip where the patient can even squat but leaves the hip unstable and the limb short.

FIG. 21-18 Girdlestone arhtroplasty of the hip. Please note that the head and neck of the femur have been excised.

Physiotherapeutic management

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Objectives

- To reduce the possibility of fixed bony deformities
- To improve the lung function to the normal or near-normal level
- To optimally restore the ROM of the joints close to the lesion
- To optimize all the muscular functions close to the site of lesion and the whole body
- To provide graduated functional training towards self-sufficiency

Expected problems

- Possibility of developing body ankylosis around the lesion
- Possibility of developing sinuses, cold abscess or secondary infections

Physiotherapy for conservatively treated patients

Early stage

- Active exercise to the unaffected areas
- Chest physiotherapy to improve respiratory function
- Proper limb positioning, comfortable and well supported posture, not promoting the possible kyphosis
- Frequent position change to prevent pressure sores, and expected contractures

Late stage

- As soon as the healing of the lesion is conformed, vigorous but gradually progressive modes of exercise are initiated.

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- Stepwise training of exercise to the spinal extensors is initiated beginning isometric in side lying, and progressed to prone lying.
- Isometric flexion and rotational exercises also incorporated to improve the overall mobility of the spine.
- Initiate supported sitting. If no paralysis, progress to supported standing with spinal brace and maybe with walking aids.
- Teaching ADLs by self-effort is a must.
- Vigorous training sessions are devoted to standing balance, weight transfer to supported ambulation. Progress gradually to independent mode.

Prognosis of recovery

- Most patients respond favourably to chemotherapy.
- Majority of the cases with neurological defect recover by drugs and rest, remaining may need curettage or decompression.
- The patients who undergo surgery usually show good recovery.

Tuberculosis of the spine (pott disease)

Pott disease which is also known as *caries (decay) spine* is the tubercular infection of the vertebrae by *M. tuberculosis*. Vertebra is the most common site of tuberculosis accounting for nearly 50% of the cases; out of which, 60–80% are seen in the lower dorsal and lumbar spine. This is due to the cancellous nature of bones and body weight transmission through these areas. The disease is more common in children between the age group of 5 and 10 years. The bacteria reach the spine via the haematogenous route from lungs or lymph nodes and spread via the paravertebral plexus of veins (Batson plexus) which communicates freely with the visceral plexus of the abdomen. The disease process may involve the metaphyses or the superior and

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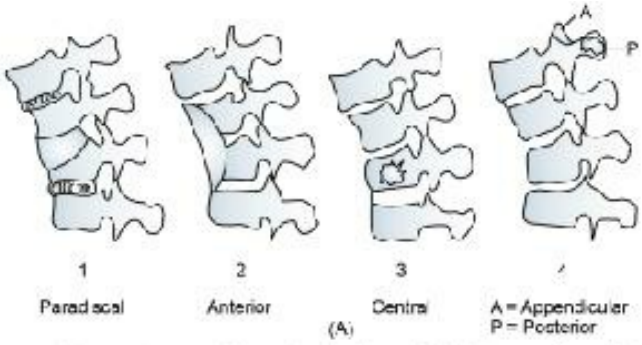
inferior end plates of the vertebra; less commonly the anterior portion of the body is involved. The lesion is common at the contiguous areas of the two adjacent vertebra including the intervening intervertebral disc, and adjacent paradiscal area, anterior central or posterior parts of the vertebral body are rarely involved (Fig. 21-19A and B). The disease may spread from this primary focus to the adjacent vertebra. Rarely, the posterior elements of the vertebra, i.e., lamina, spinous process, etc., may be affected. The disease, as it progresses, destroys the bone substance of the vertebra and may lead to its collapse due to the formation of a cavity (Fig. 21-20). The spinal cord in the affected region may get compressed due to collection of pus or sequestra or angular deformity of the spine, leading to paraplegia/quadriplegia (Fig. 21-21). The anterior collapse of the vertebra may cause an angular (kyphotic) deformity resulting in prominent spinous process which is known as a 'gibbus' (Fig. 21-22).



Paradiscal lesion is the commonest type and may result in vertebral collapse which in turn usually results in excessive compression of the anterior part of the vertebral body resulting in posterior gibbus(kyphosis)

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(B)

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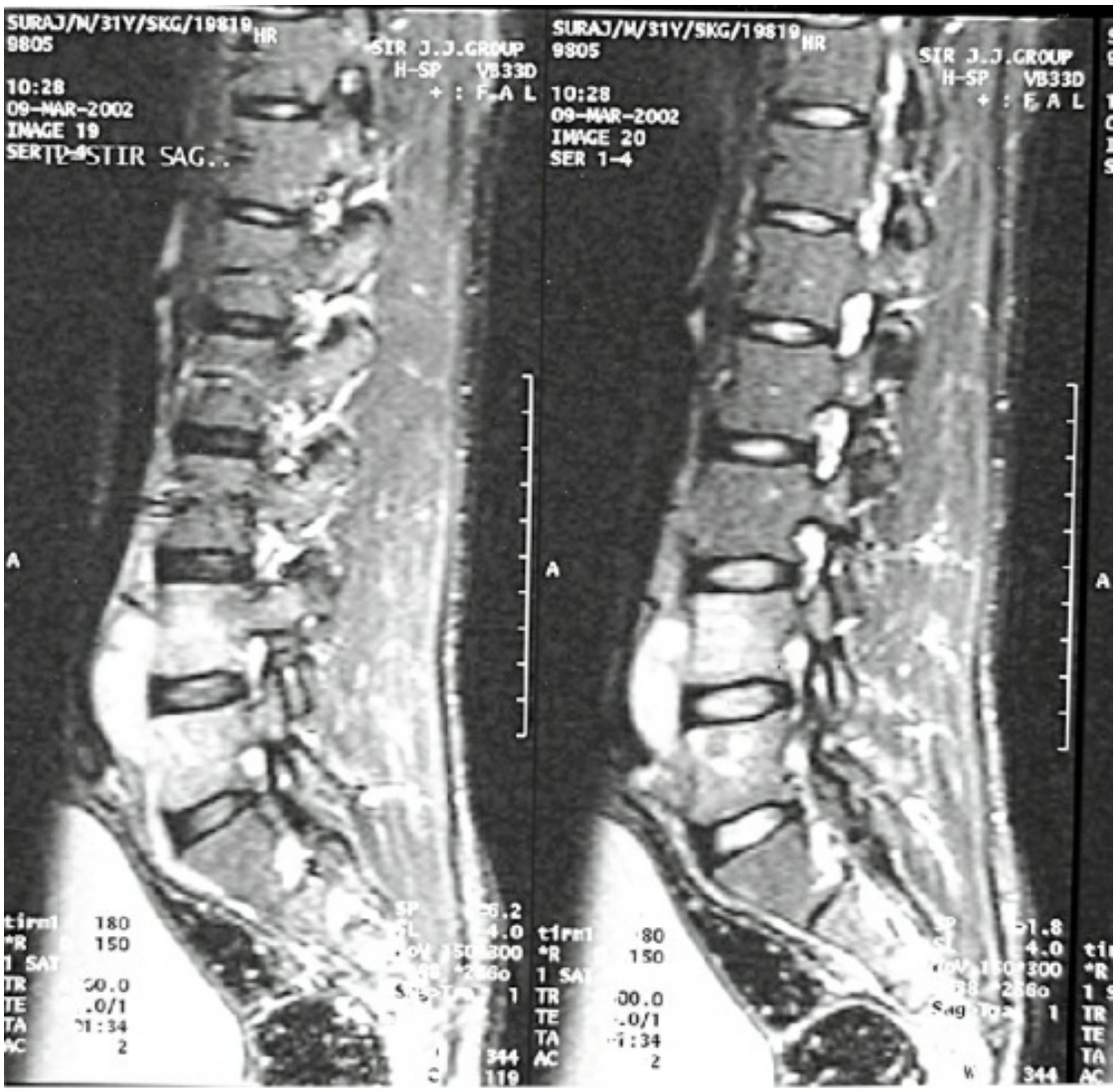

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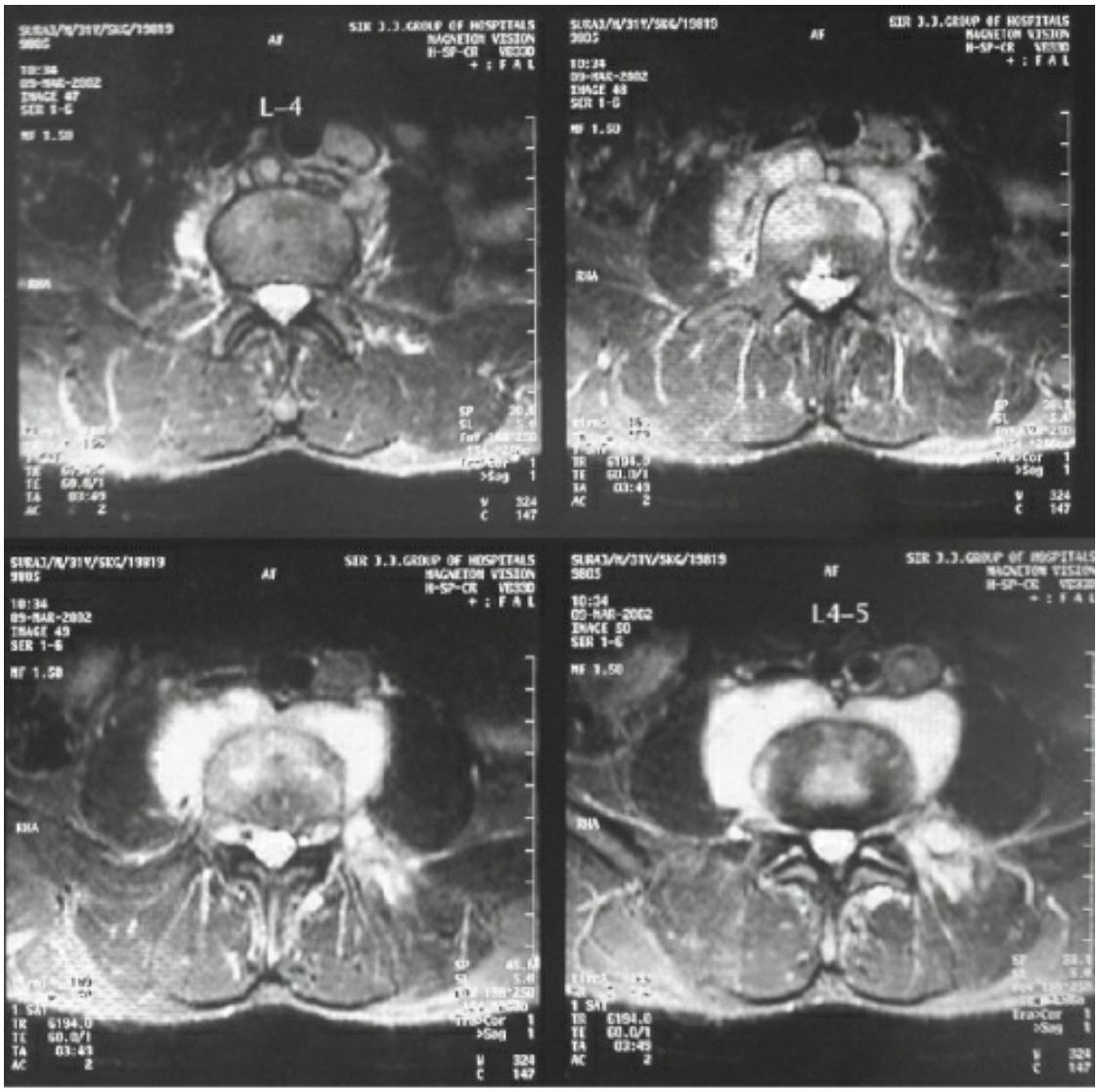

FIG. 21-19 Vertebral tuberculosis (lesion sites). **(A)(B)** MRI of the same case showing destruction of vertebrae and a soft tissue mass encroaching posteriorly into the spinal canal. **(C)** MRI lateral view. **(D)** Cross-sectional view indicating the location of an active disease on the anterior aspect of L4-5, invading and destructing the intervertebral disc.

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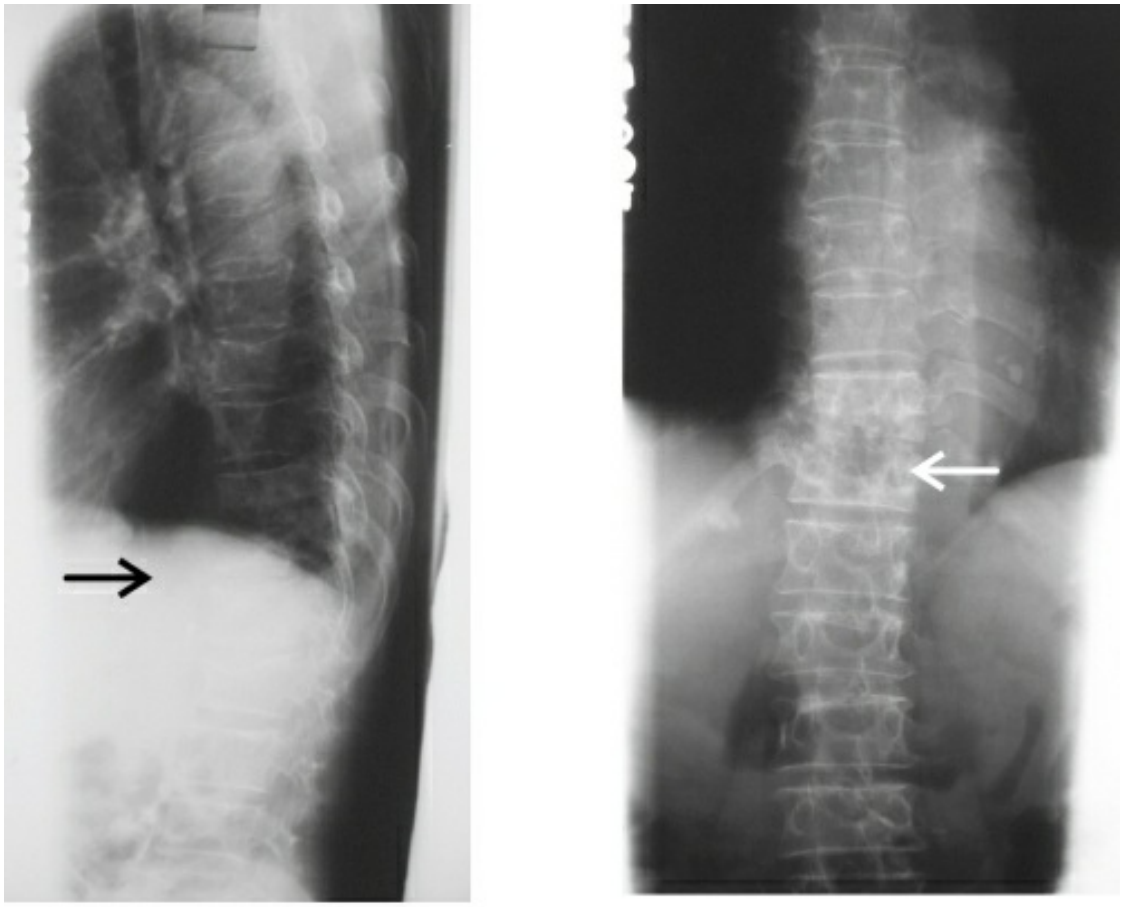

(A) (B)

FIG. 21-20 **(A and B)** Tuberculosis of spine: Note the destruction of vertebra and loss of intervertebral disc space (arrow).

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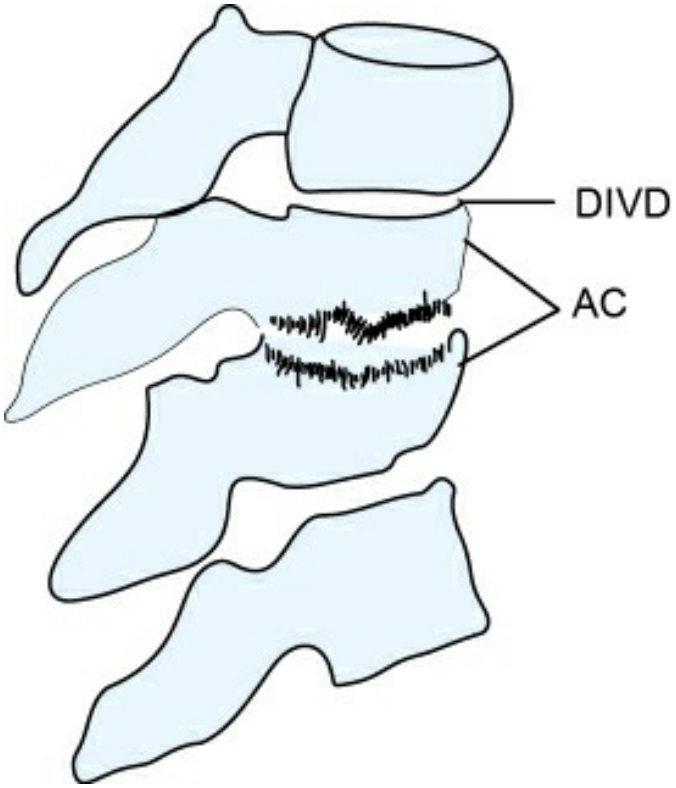

FIG. 21-21 Vertebral collapse due to Pott spine. DIVD, destruction of the intervertebral disc; AC, anterior body collapse due to erosion.

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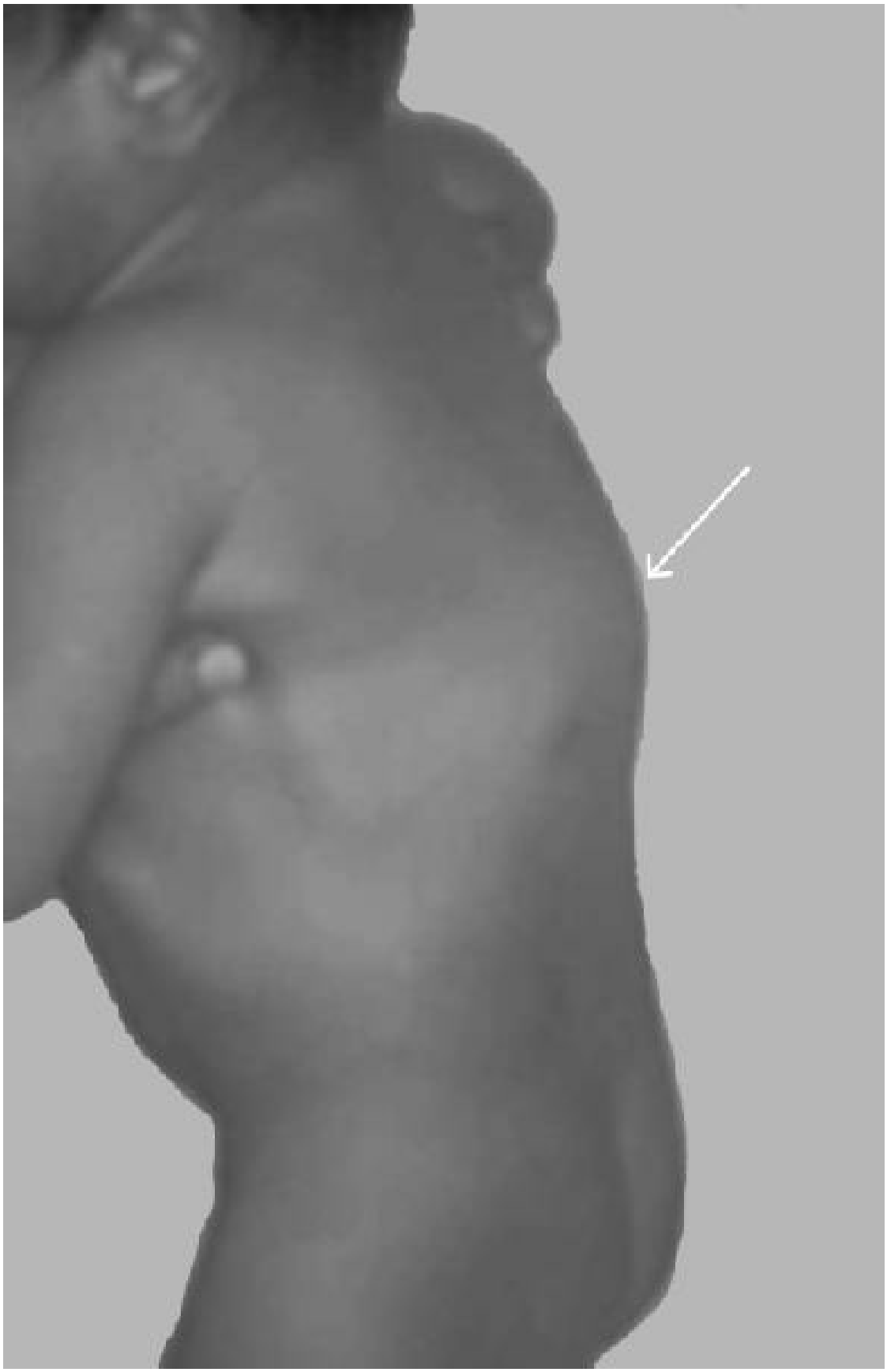

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FIG. 21-22 Gibbus (arrow) in tuberculosis of spine.

The common site of infection in the spine is the junction of the lower thoracic and upper lumbar spine. Caries of the cervical as well as the dorsal vertebrae is also seen.

Clinical features

A patient with tuberculosis of the spine presents with pain and rigidity in the back. The pain is usually localized over the affected vertebra(e). However, it may radiate along the spinal nerves. Pain from a lesion in the dorsal spine may radiate to the front of the chest and is called 'girdle pains'.

The presence of an abscess is another important symptom in tuberculosis of the spine. It may either be associated with pain in the back or be the presenting symptom. The pus may trickle down, from the vertebra, along the course of a nerve or vessel and present over the chest wall or back, or may be seen on radiographs as a 'paravertebral shadow'. Since this abscess is generally away from the site of activity, i.e., the site of the disease, it does not have redness or raised local temperature and is hence called a 'cold abscess'.

The patient may also have other features of tuberculosis such as low-grade fever, loss of appetite, and loss of weight and cough. When the disease is advanced and has produced compression of the cord due to pus and/or sequestra, etc., it may result in complete or incomplete paraplegia.

On examination, marked tenderness is found over the spinous process of the involved vertebra with occasional girdle pains. Protective spasm may be present in the muscle groups close to the site in order to provide natural immobilization. Movement of spinal flexion produces a sudden increase in pain.

The common deformity due to collapse of the vertebra is that of kyphosis. However, there may be scoliotic deformity when the disease affects lateral border of the vertebra.

Pott paraplegia: The onset of paraplegia may occur during the early active stage of the disease due to cold abscess, necrotic debris and

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sequestrae or endarteritis of spinal blood vessels.

Pott paraplegia may also occur at the late stage of the disease due to reactivation of the disease or due to mechanical stretching of the spinal cord over the deformity.

Investigations

- *Radiography*: The affected bones are rarefied and are osteoporotic, with loss of intervertebral space.
- At a later stage, the vertebral body collapse occurs.
- Cold abscess may present as an enlarged soft tissue shadow.
- *CT scan*: Fine calcification of the paravertebral shadow is diagnostic besides showing neural compromise.
- *MRI*: It indicates the amount of canal compromise and the status of soft tissue.
- *Biopsy*: It is the most specific investigation which confirms the diagnosis of tuberculosis.

Complications

- Abscess formation
- Paraplegia

Treatment

Conservative

1. Specific drug therapy, nutritious diet and rest are given.

2. Immobilization of the spine is done by bed rest or by plaster jacket or a brace. Immobilization in prone-lying position is more advantageous as it further diminishes the compressive force on the

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vertebrae, relieves pain and thereby prevents the commonly seen flexion deformities.

3. Care of the back and bladder should be taken if a patient develops paraplegia.

As the disease becomes quiescent, the patient may be allowed to sit up and walk with proper spinal support (e.g., POP jacket or spinal brace) till the process of repair is consolidated.

Surgical

Indications for surgery

- No response to chemotherapy
- Setting in and worsening of paraplegia in spite of chemotherapy

The basic principle of surgery in tuberculosis of spine is drainage of pus and decompression of the cord. This may be achieved by any of the following surgical operations:

1. Aspiration of the cold abscess

2. *Costotransversectomy:* Through a posterior approach, a part of the rib and transverse process of the affected vertebra are removed to drain out the paravertebral abscess (Fig. 21-23A).

3. *Anterolateral decompression:* This operation is a further extension of costotransversectomy. In this operation, in addition to the part of the rib and transverse process, the pedicle and posterior part of the body of vertebra are removed (Fig. 21-23B). The spinal cord is, thus, decompressed from the anterior and lateral aspects. By this operation, the pus is drained and the infected granulation tissue and sequestra, etc. are removed. A maximum of three ribs may be excised to gain access to the lesion.

Postoperatively, the patient is nursed in bed for 3 weeks,

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after which he/she may be made to sit up with the support of a spinal brace.

4. *Anterior decompression* (Fig. 21-23C): This is a major surgical undertaking in which the cord is decompressed through an anterior approach. The diseased vertebra, infective granulation tissue and pus, etc. are removed through a transthoracic or transabdominal approach. The gap thus created is bridged by taking bone grafts from ribs and iliac crests.

After operation, the spine should be supported in a spinal brace for about 3–4 months till the fusion between the bodies of the vertebra consolidates.

5. *Laminectomy* (Fig. 21-23D): It is rarely indicated in the treatment of tuberculosis of spine. The only indication is a disease of the posterior elements of the vertebra, such as lamina and spinous process.

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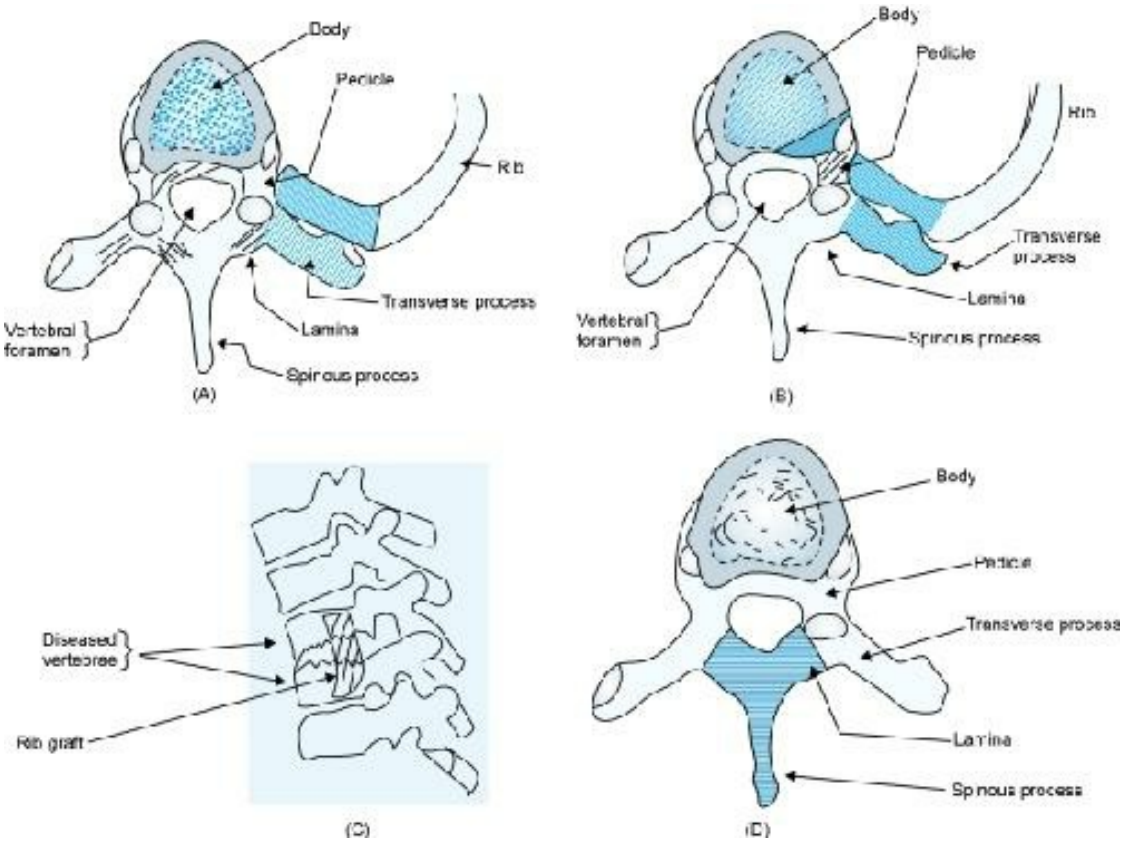

FIG. 21-23 **(A)** Costotransversectomy. The shaded areas are excised. **(B)** Anterolateral decompression: the shaded areas of bones are excised. **(C)** Anterior debridement and decompression with rib graft. **(D)** The shaded areas of bone are excised in laminectomy.

Physiotherapeutic management

For patients treated conservatively: During the initial stage, it is directed to prevent the complications arising out of prolonged immobilization.

1. The patient should be educated on the postural attitudes which may further compress the cord with its subsequent complications.

2. Gentle full-range active movements are given to cervical spine and upper and lower extremities.

3. Spinal immobilization reduces the efficiency of the respiratory system and therefore slow and deep breathing is valuable in

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maintaining the vital capacity.

4. Proper positioning of the body is explained with emphasis on protecting the pressure points to avoid bed sores.

5. Strength of the muscle groups, innervated by the spinal segment of the affected vertebra, should be checked often and exercised.

After healing of the lesions

1. Gradually progressive exercises are begun to mobilize and strengthen the spine. Isometrics to the spinal flexors, rotator and side flexors can be initiated.

2. Costal, diaphragmatic as well as apical breathing should be made vigorous to improve mobility of the thoracic spine.

3. Begin spinal exercise with extension gradually progressing to hyperextension in prone lying. Mobility and strengthening of side flexion, rotation and flexion should be initiated in stages.

4. Mobility should be progressed further as small active free trunk movements.

5. Sitting up, standing and ambulation to be initiated with spinal brace.

6. Preventive measures to avoid recurrence need to be explained and the use of spinal brace to be continued during working.

If the patient develops paraplegia, the treatment proceeds on the same lines as described for traumatic paraplegia.

For patients treated by surgery: *Preoperative assessment* of the neuromusculoskeletal system is done and a special emphasis is put on the respiratory system by thorough physical examination.

Preoperative training: Postoperative regime of physiotherapy during the subsequent weeks is explained. The emphasis of training includes

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the following:

1. Chest physiotherapy

2. Positioning and movements to avoid immediate postsurgical complications like thrombosis

3. Methodology of safe bed activities like turning, transfers with corset or POP jacket

4. Techniques of sitting from lying, getting down from bed, standing balance and ambulation

5. Mobility and strengthening exercises to the spine

6. Correct principles of ergonomics to be strictly observed postoperatively and in future

Immediate postoperative phase

- The surgical procedure involves resection of the ribs, transverse processes and sometimes even the affected vertebra with decompression of the spinal cord. The patient is nursed in bed; therefore, care should be taken to avoid stresses over the operated area.

- Chest physiotherapy in the form of deep breathing exercises and diaphragmatic breathing are initiated to avoid chest complications. Rib resection makes breathing difficult and painful. It needs to be carefully done by the physiotherapist supporting the rib cage with both hands.

- Thrombosis is prevented by early strong movements of the ankle and toes. In the presence of paraplegia, passive movements and positioning of the body and lower extremities are important.

- Susceptible pressure points should be carefully inspected and

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protected.

- Simple resistive movements may be initiated to the arms, avoiding overhead stretching as this will put extra strain on the spine. Similarly, strenuous lower extremity exercises like SLR and pelvic rolling are contraindicated. Paretic but functionally important muscles should be exercised to improve their strength and endurance.

During mobilization

Gradual mobilization is carried out only after thoroughly checking the accurate fitting of the spinal corset.

Log rolling, standing and ambulation are initiated and progressed as described for spinal fusion.

When the fusion between the bodies of the vertebrae consolidates, mobilization of the spine can be started. Vigorous strengthening of the spinal extensors and abdominals can be initiated and progressed.

Ergonomic principles of back care programme are observed strictly and overstraining activities like carrying weights and bending forward are discouraged.

The use of corset is gradually weaned off and daily activities are encouraged.

Patients with paraplegia are managed as described in the section on spinal injuries.

Broad outline for planning specific physiotherapy approach depends mainly on the following factors:

1. The site of infection

2. The extent of infection

3. Specific tissue damages to the involved soft tissues and the bone during the active stage of the disease and residual permanent tissue damages after the healing phase

4. Method of orthopaedic management

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5. Expected prognosis of recovery

- When synovium is involved, maintenance of joint ROM with early mobilization is done.
- When the articular cartilage is destroyed, maintaining functional position of the joint as required for ankylosis or arthrodesis should be the aim.
- When functionally imported joints like elbow, hip and the knee are involved, prevention of contractures is of primary importance.
- When treated conservatively by POP cast for 6–9 months, partial weight bearing (PWB) is allowed only after 6 months, and calipers and crutches are discarded only after about 2 years (in hip joint tuberculosis).
- Knee joint is usually prone to develop a deformity due to the spasm and shortening of hamstrings.
- As such, minimizing the forces responsible for the deformity needs frequent checks and maximal corrective approach is necessary to maintain functional position of the involved joint.

Tuberculosis of the hip joint

It is always secondary to the tuberculosis of lungs, lymph nodes or gastrointestinal tract at the early age of >30 years.

Common sites

- Roof of the acetabulum

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- Femoral capital epiphysis
- Femoral neck
- Greater trochanter

Clinical features

- Localized pain and stiffness – pain is worst at night
- Tenderness at the femoral triangle
- Gradual development of a flexion deformity – which progresses to flexion–adduction–internal rotation deformity
- Limp is typical with a short stance on a good leg and sudden forward jump (at the late stage)
- Painful limitation of all hip joint movements

Pathology

If not arrested, it progresses in three phases (Table 21-2):

Table 21-2
Progressive Stages of the Disease

Phase	Limb Length	Attitude of the Limb
Phase I of synovitis	Apparent limb lengthening due to downward tilting of the pelvis	Abduction–external rotation to accommodate excessive fluid
Phase II of arthritis	Apparent limb shortening due to upward tilt of pelvis	Flexion–adduction–internal rotation
Phase III (late arthritis leading to erosion and bone destruction)	True shortening of the limb; pelvis remains tilted upwards	Flexion–adduction–internal rotation deformity

The bacillus infects the bone adjacent to the joint with the formation of pus and granulation tissue. Multiple cavities may appear in the femoral head or the acetabular roof. The femoral head or the acetabulum gets absorbed – causing dislocation of the head into the ilium – wandering acetabulum (Fig. 21-24).

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FIG. 21-24 Tuberculous lesion in the acetabular roof in the left hip (arrow).

Radiographic features

- Begins with reduction of the joint space with bony haziness
- Destruction of the acetabulum
- Dislocation of the acetabulum (like Perthes hip)

Treatment

Conservative

- Antituberculosis chemotherapy
- Immobilization with below-knee (BK) skin traction to prevent flexion deformity at the affected hip

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Surgery

- The surgical procedure depends upon the pathology.
- In the early stage of the disease, synovectomy or arthrotomy is performed.
- In the late stage when the joint is ankylosed in an unacceptable position, osteotomy is performed to put the hip joint in the position of optimum function.
- When the hip is destroyed/ankylosed with loss of function, total hip replacement may be performed only if the disease is healed completely.

Girdlestone excisional arthroplasty or osteotomy is performed in severely affected cases.

Physiotherapeutic management

During acute stage, follow these points:

- Cryotherapy in the acute stage should be altered to superficial thermotherapy at the later stage if pain persists.
- Give vigorous movements to the joints free of immobilization.
- Carefully watch the positioning to prevent development of a flexion contracture at the hip (repetitive isometric gluteus maximus settings).
- Strong static quadriceps settings with a definite pause in fully extended position should be used.
- When the disease is quiescent, assisted active mobilization of the hip is begun and gradually progressed to achieve maximum ROM of each hip movement.

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- Well-protected non–weight-bearing (NWB) is initiated on crutches gradually progressed to toe-touch weight bearing (TTWB) and PWB – and ultimately to full weight bearing (FWB).

- Gait training to minimize the limp is emphasized.

- Postsurgical physiotherapy – as it depends upon the surgical procedure, follow the relevant discussion for the relevant surgical procedure.

Tuberculosis of the knee joint

Tuberculosis of the knee joint can start as synovial involvement or osseous disease. The synovial involvement is more common; the synovium is inflamed and gets hypertrophied. Subsequently, the articular cartilage/bone may not get affected. The products of inflammation may result in destruction of the joint cartilage and ligaments causing joint subluxation of the joint. Eventually, a triple deformity develops at the knee joint, which consists of flexion at the knee joint and posterolateral subluxation and abduction of the leg as the tibia flexes, slips backwards and rotates externally, respectively (Fig. 21-25).

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(A)

(B)

FIG. 21-25 Triple deformity of the knee. **(A)** Note the flexion deformity along with posterior subluxation of the tibia. **(B)** External rotation deformity of the leg.

Clinical features

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Tuberculosis of the knee joint is commonly seen in the age group of 10–25 years.

- Progressively increasing pain and stiffness with flexion attitude
- Inflammatory exudate causes suprapatellar fullness of the fossae on either side of the patellar tendon
- Inability to bear weight on the affected limb and tendency to prefer using a cane and to hop on the normal leg
- Marked tenderness over the joint line

Radiographic investigations

- Diffuse osteoporosis of the bones is seen around the knee
- Juxta-articular lytic lesions may be seen.
- There is erosion of the joint surfaces.
- Triple deformity could be evident.
- Synovial biopsy and culture LJ medium are confirmatory tests.

Treatment

- Antituberculosis chemotherapy with immobilization of the limb in a BK skin traction
- Followed by above-knee cast

Surgery

Synovectomy and joint debridement are performed either by open surgery or by arthroscopy

In late neglected cases

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Arthrodesis of the knee joint is done with the knee in 5° of flexion using Charnley's compression device (Fig. 21-26) or an Ilizarov fixator.

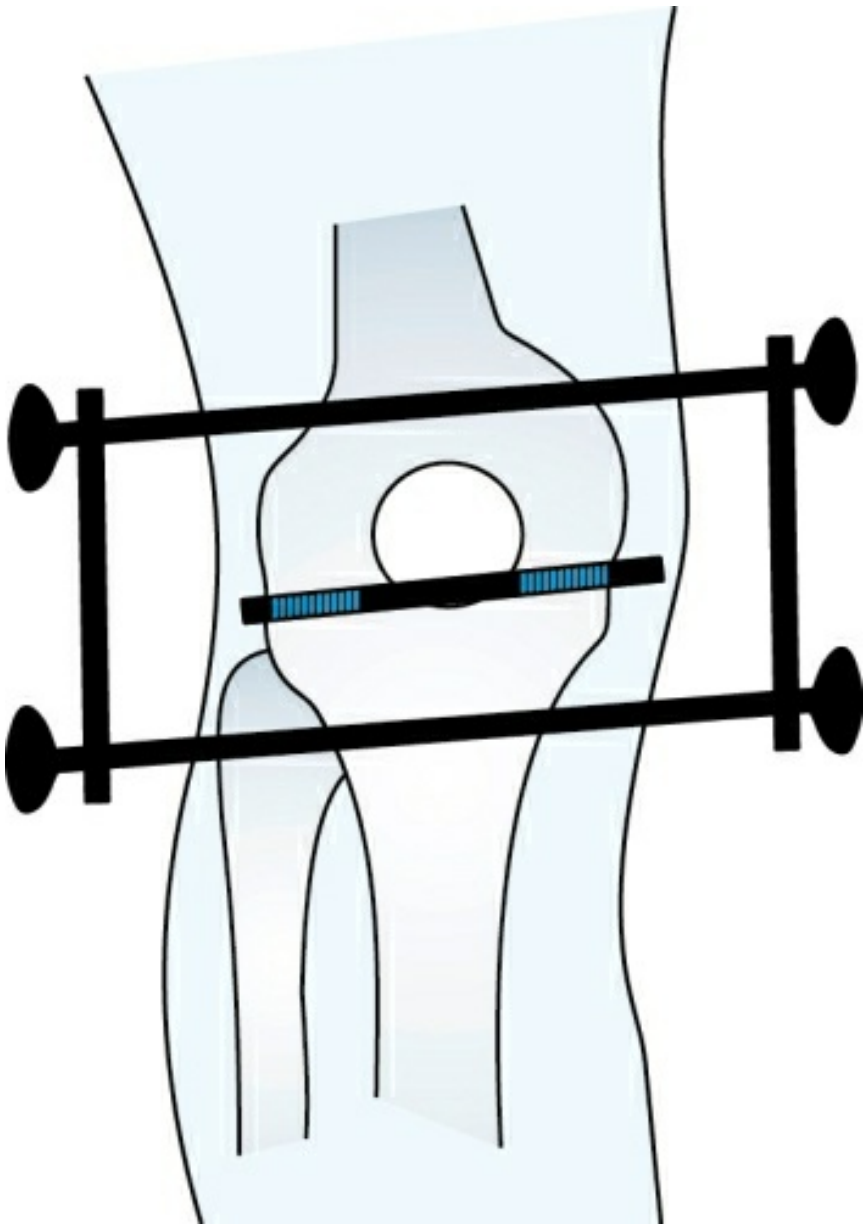

FIG. 21-26 Arthrodesis of knee using Charnley's compression device.

Supracondylar osteotomy is indicated in marked genu varum or valgus knees.

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Physiotherapeutic management

- Initially the major objective is to prevent the occurrence of triple deformity by repetitive observation of the limb positioning and repetitive speedy and sustained isometrics to the quadriceps (of course, pain-free – maximum), with the limb under skin traction.
- Begin early NWB ambulation on crutches.
- Initiate gradually progressing mobilization and strengthening programmes to knee.
- Relaxed free active pendular knee flexion–extension should be initiated in the pain-free range as early as possible.
- Progress to PWB, FWB and gait training to prevent limp.
- Self-assisted and self-stretch-hold technique is guided and continued to achieve functional or a normal knee flexion.

Tuberculosis of the ankle joint

Tuberculosis of the ankle joint is rare. The infective process mainly attacks synovium of the ankle joint initially.

Synovium

- Ankle joint remains positioned in plantar flexion.
- Pain, swelling and antalgic gait manifest early.
- Tuberculosis may proceed to gross destruction of the joint which may result in anterior dislocation of the ankle joint.

Treatment

ATT BK POP cast may require 12 weeks to heal tuberculosis. BK brace may be given after 6 months and continued for another 3 months till the joint becomes pain-free.

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Physiotherapy management

- During early stage, the limb is immobilized in a BK POP cast as such.
- Vigorous repetitive movements for the toes are given with the limb in elevation.
- Unaffected joints are exercised to maintain their normalcy.
- Hip movements of straight leg raise (SLR), straight leg abduction (SLAB), straight leg adduction (SLADD) and straight leg extension (SLEXT) provide self-resistive strengthening besides improving circulation to the lesion.
- Crutch walking is initiated as soon as it becomes pain-free.
- After 6 months, BK brace with 90 degrees foot drop stops to be given and continued for longer periods.
- FWB should be initiated with the brace when it becomes pain-free.
- Proper gait training with emphasis on initial heal strike to facilitate the stance phase of the gait cycle.

In cases treated by synovectomy and debridement, follow these points:

- Reduce pain by superficial thermotherapy and swelling by limb elevation and toe movements.
- Begin joint mobilization with relaxed, rhythmic exercises.
- Educate and guide the patient on efficient self-assisted and self-stretch-hold mode to improve the joint ROM further.
- Begin ambulation with a pair of crutches, progress to a single crutch to a cane and, finally, to independent walking.

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- Ensure that there is no limp by providing long duration gait training guidance.

Note: Standing on the affected leg alone is the key to improve the gait pattern.

Tuberculosis of the shoulder joint

This tuberculosis is very rare, seen in adults, mostly with a history of pulmonary tuberculosis which is its peculiarity; it is 'dry' without any joint effusion and hence known as 'caries sicca'. A common site is glenoid or head of the humerus.

Clinical features

- Pain and stiffness of the shoulder (abduction) are observed.
- Cold abscess may appear over deltoid region, biceps or supraspinous fossa.
- Erosion of the joint occurs with osteoporotic appearance.
- Osteolytic areas may be present over the humeral head.

Treatment

- Chemotherapy
- Immobilization:

The shoulder joint is immobilized in functional position of 'saluting' 90° of abduction, 30° of flexion and internal rotation at the shoulder.

After 3 months, a fabricated abduction frame may be given till healing occurs.

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- Arthrodesis – rarely undertaken in extreme cases of continued pain, disease is uncontrolled or recurs.

Physiotherapeutic management

- Longer immobilization poses problem; however, functional use in immobilized position should be encouraged as early as possible, with the help of unaffected upper limb.

- Strong repetitive isometrics to the deltoid on removal of immobilization.

Efforts are concentrated to teach patient on the compensatory methods of using trunk and shoulder girdle muscles for the functional tasks.

Efforts to mobilize the affected shoulder are continued to ease functional activities, mainly by self-efforts.

Tuberculosis of wrist joint

- Very rare

- Tenderness, pain and swelling localized to the wrist

Treatment

- Chemotherapy is started.

- The wrist joint is immobilized in a POP cast in functional position.

- The infection may involve flexor tendons or may manifest as a carpal tunnel syndrome. Physiotherapy is directed to early functional rehabilitation using immobilized wrist without causing pain.

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Vigorous finger, thumb and elbow movements should be performed repetitively to prevent formation of palmar ganglion or CTS, mainly by guidance to carry out self-exercising progressive modes.

Tuberculous osteomyelitis

The infective focus involves only the short bones (e.g., calcaneum) or short long bones like metacarpals or phalanges. The neighbouring joint structures are unaffected.

The disease progresses by the formation of a cold abscess, sinus, ulcer and irregular bony cavities with sclerotic margins. The infection involving phalanges results in localized spindle-shaped swelling of fingers known as *spina ventosa* (Fig. 21-27).

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FIG. 21-27 Tuberculosis of the proximal phalanx of the little finger. Note the swelling and a discharging sinus.

Treatment

- ATT by chemotherapy
- Immobilization

Physiotherapy

- Prevent stiffness of the fingers free of infection by full ROM active movements to the unaffected digits.
- Regularly check and take care of the immobilized finger till the

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healing of the lesion.

After healing, graduated repetitive self-efforts should be made to achieve full ROM and function of the involved finger.

Concentrate on strengthening hand functions using involved digits.

Pyogenic arthritis (septic arthritis, infective arthritis, suppurative arthritis)

Pyogenic infections of the joints, i.e., pyogenic (septic) arthritis, are caused commonly by *Staphylococcus* and less commonly by streptococci, pneumococci, gonococci, meningococci, etc. The invasion of the organisms into the joint may occur through the following means.

1. *Haematogenous:* Spreads through the bloodstream from a focus of infection elsewhere in the body such as tonsils, teeth, respiratory tract and intestines

2. Secondary to osteomyelitis in the adjacent bone, e.g., septic arthritis of the hip following osteomyelitis of the upper end of the femur

3. Direct implantation of the bacteria into the joint through a punctured wound over the joint, infection from a compound fracture

4. *Iatrogenic:* Following surgical procedures on the joint such as aspiration, arthrotomy, and arthroscopy

Pathogenesis

There is inflammation of the synovial membrane with excessive production of joint fluid/pus. The fluid contains a large number of cells, bacteria and fibrin. There occurs destruction of the articular

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cartilage and the underlying bone. When the joint is distended with pus, pathological dislocation of the joint may occur (Fig. 21-28). The capsule may get perforated and the pus may escape out forming sinuses. If untreated, the joint may get disorganized and end up into fibrous or bony ankylosis.

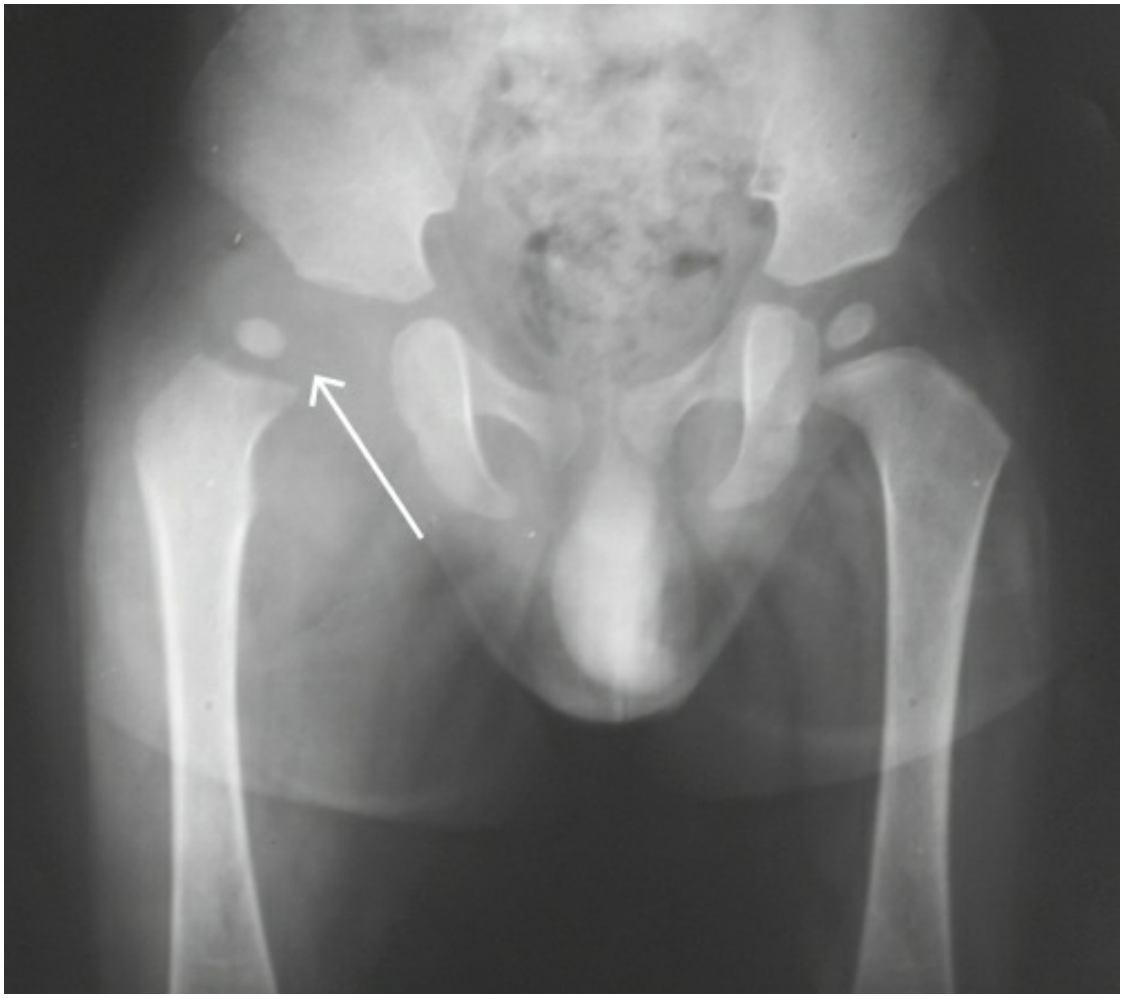

FIG. 21-28 Pyogenic arthritis of the right hip joint. Note the soft tissue swelling and the pathological dislocation of the hip (arrow).

Clinical features

Pyogenic arthritis commonly affects infants and young children. It commences rapidly with high-grade fever, swelling and pain in the

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joint. Movements at the affected joint are not allowed by the child due to pain and muscle spasm.

Investigations

Radiographic investigations

- Early radiographs may be normal or may show increased joint space due to fluid or pus collection.
- Later radiographs show destruction of the cartilage, new bone formation, eventually bony ankylosis or even pathological dislocation.
- Ultrasonography is required especially in children to detect collection of fluid.

Blood test

- Marked elevation of ESR and leucocyte count
- Neutrophillic leucocytosis
- Blood culture shows growth of causative organism
- Aspiration of the joint fluid may show organisms on smear and culture

Treatment

1. Rest should be given to the joint by traction or splinting or by plaster of Paris slab till the symptoms subside.

2. Appropriate broad-spectrum antibiotic drugs are started at the earliest.

3. *Arthrotomy*: Arthrotomy means opening of the joint. Open drainage

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of the pus is carried out as early as possible to prevent permanent damage to the articular cartilage.

4. Gradual mobilization of the joint should be done.

5. If the disease is advanced with destruction of the articular cartilage, the joint is immobilized in the optimal position (described earlier) and allowed to ankylose.

Physiotherapeutic management

During the active stage of the disease

- Check immobilization for comfortable resting position of the affected joint.
- No ROM or strengthening exercises are required.
- No attempt should be made to subject the limb to strenuous activities or weight bearing by assisted ambulation.

During the inactive or quiescent stage

- Relaxed rhythmic active movements should be started to the affected joint by providing the required assistance.
- Educate and guide the patient on how to perform self-movements – beginning with self-assisted mode progressing gradually to active, self-resistive to self-stretching under the guidance and supervision of the physiotherapist.
- Isometrics should be guided to the functional muscle groups.
- Begin special session on assisted functional training tasks and compensatory methods to facilitate ADLs.
- Get necessary orthotic and prosthetic devices early to facilitate

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training towards self-sufficiency.

Acute septic arthritis of infancy (tom smith arthritis)

This arthritis is commonly seen in children younger than 1 year when the head of the femur is cartilaginous and susceptible to complete destruction by the infection.

It occurs due to the spread of infection from the neighbouring bone lesion or from a septic umbilicus.

Clinical features

- Fever occurs with signs of toxaemia.
- Painful hip.
- Swelling and tenderness around the hip joint.
- Occasionally in late presentations, the child may present only with a limp when he/she begins to walk.
- Positive 'telescoping' and limb shortening are indicative of head destruction.
- The condition resembles congenital dislocation of hip (CDH).

Investigations

Radiography

Complete loss of head and neck function with poorly developed acetabulum is seen. There is marked upriding of the trochanter (Fig. 21-29) with absence of femoral head and neck.

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FIG. 21-29 Late sequelae of septic arthritis of infancy of the left hip. Note the complete destruction of the head and neck of femur; with upriding of the trochanter.

Significant feature

The hip joint is hypermobile as against stiff and ankylosed joints in other infective conditions.

Treatment

Drainage of joint in acute stage: In delayed cases, the major problem is the instability of the hip joint. Reconstructive stabilization procedure is carried out.

The end result is ambulatory independence with residual limp.

Physiotherapeutic management

Same as for infective arthritis; but, due to the involvement of the hip joint, the therapeutic procedures are directed mainly to achieve independence in ambulation, whether treated by conservative or

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surgical approach.

Gonococcal arthritis

Although rare, it may be seen due to inadequate treatment of the primary gonococcal infection, and may occur a few weeks after the onset of gonococcal urethritis.

- It affects males between 20 and 30 years of age.
- It usually affects the knee joints.
- Pain, swelling and the usual signs of inflammation are present over the affected knee joint.
- Periarticular oedema of the affected joint develops.
- The infection usually settles to the subsynovial layers.

Treatment

- Rest and chemotherapy
- Aspiration or arthrotomy if required

Physiotherapeutic management

- This management generally follows the same pattern as described for septic arthritis.
- As the knee joint is affected in young adults, the most important objective is to prevent flexion contracture at the knee joint.
- Secondly, maintain or achieve at least functional ROM at the knee, and maximally strengthen the quadriceps and hamstrings.

Early phase

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- The supporting splint should be adjusted with maximal positioning of the knee extensions.
- Cryotherapy may be applied for pain relief.
- Maintain limb elevation as much as possible to reduce oedema.

Late phase

- Removing the splint, the knee is mobilized by relaxed free rhythmic active movements. Self-performed intermittent exercises are guided and supervised to achieve maximum knee extension.
- Initially, dynamic AK splint with an adjustable kneecap to achieve maximum knee stretches is ideal.
- Gradual assisted ambulation is initiated and progressed to unsupported ambulation.
- Putting maximum emphasis on the heel strike phase of the gait cycle promotes stretching of the knee to extension, which is so important in gait training.

Syphilitic infection of bones and joints

This is a rare condition caused by the microorganism *Treponema pallidum*. The syphilitic infection may be congenital or acquired. If mainly affects the elbow or the knee joint. The diagnosis is confirmed by a positive test for syphilis.

The early congenital variety occurs during infancy as osteochondritis in the juxtaepiphyseal region.

It is bilaterally symmetrical with swelling due to serous synovitis. Painless swelling develops with marked effusion (Clutton's joints). In the secondary stage, there is transient fleeting polyarthralgia. In the tertiary stage, there is marked bony changes with disorganization of joint with neuropathic or Charcot joint.

In acquired syphilis, marked bony changes with periosteal reaction

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and a zone of sclerosis like acute osteomyelitis may occur.

Physiotherapeutic management

- Generally, it follows the same pattern of treatment as discussed for infective arthritis.
- As the infection commonly involves the elbow and the knee joints, earliest opportunity to initiate functional training of the involved limb is important.
- If required, any assistive aid or device should be provided as early as possible. It indirectly increases the strength and endurance of the prime movers.
- Special sessions to improve the joint ROM of the affected joint should be concentrated.

Fungal infections of the bone

Patients with immunocompromised status are commonly affected by fungal infection particularly in the rural setup. A common site of fungal infection caused by Maduramyces is the foot – it was first observed in Madurai in South India and therefore is also known as the 'Madura foot'. Infection that begins as a nodular swelling over the dorsum or sole of the foot eventually bursts into discharging sinuses.

Clinically, large diffuse swelling with sinuses develops over the foot. Usually bones are not involved but if secondary function starts, tarsal bones may be extensively destroyed.

The discharging pus contains *black granules* and fungus is found to be present in the microscopic examination.

Treatment

Early stage: Massive doses of penicillin or dapsone are very effective.

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Late stage: When the foot is completely disorganized, amputation may be indicated.

Physiotherapy management

- As the common site of infection centres around the ankle and foot, the foot must be rested in a posterior splint in the midposition of dorsi and plantar flexion – to prevent tightness or contracture of TA.
- Multiple active sinuses may be present, which need to be taken care of with rest, splint and repetitive toe movements.
- Gait training assumes an important role in controlling the tendency of NWB on the affected limb or using whole foot on the ground through the gait cycle instead of a normal heel–toe sequence.
- In patients treated by amputation, training with prosthesis assumes highest importance besides strengthening the muscle groups that primarily stabilize the pelvis and hip during ambulation.

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CHAPTER
22

Metabolic bone diseases

OUTLINE

- Metabolic disorders of the bone
- Osteomalacia
- Hyperparathyroidism
- Osteoporosis

Although the bone appears as a hard, strong, inactive and resilient tissue, physiologically the bone is one of the most active tissues of the body. A process of mineral exchange between the bone reservoir and the extracellular fluid, regulated by hormones and the local factors, goes on continuously to maintain the normal level of bone mineral density (BMD). Any disturbance in this exchange system results in a metabolic bone disease.

Composition of bone

The inorganic elements mainly minerals – calcium and phosphates (accounting for 65% of the bone weight) – play a major role in the process of bone mineralization.

The organic components, which account for about 25% of the bone weight, are contributed by collagenous matrix, polysaccharides, lipids and bone cells, while about 10% of the bone's weight is contributed by water.

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Calcium metabolism

Out of a total amount of 1100 g of calcium in a young adult, 99% of it is stored in the bones. Therefore, the bone plays an important role in calcium homeostasis. On average, 507.5 mmol of calcium is exchanged in and out of the bone daily. Therefore, perfect regulation of calcium metabolism is essential to maintain the normal level of BMP or bone metabolism.

Regulation of calcium metabolism

1. *Calcitrol* or *1,25 dihydroxy cholecalciferol*: A steroid hormone formed from vitamin D by successive hydroxylations in the liver and kidneys increases the absorption of calcium from the intestine in the event of hypocalcaemia and reduces when the level of serum calcium is high (hypercalcaemia).

2. *Parathyroid hormone (PTH)*: The parathormone hormone is secreted by the parathyroid gland and has the following functions:

(a) To mobilize calcium from the bone

(b) To increase urinary phosphate excretion

(c) To increase reabsorption of calcium in the kidney

3. *Calcitonin*: This is a hormone secreted by the cells in the thyroid gland that inhibits bone resorption. When the level of serum calcium is low, the body tries to raise its level by the following:

(a) Increased absorption of calcium from the intestine

(b) Mobilization of calcium from the bone or

(c) Increased reabsorption of calcium in the kidneys

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Thus, regulation of calcium metabolism is most important in the mineralization of bone as well as its constant maintenance of normal mineralization.

Role played by bone cells

There is a balanced interaction between the three types of bone cells contained in the vascular fibrous layer of the periosteum. Each type of cells play a different role as follows:

- **Osteocytes:** These are parent cells of the matured bone which remain constant and are unable to divide.
- **Osteoblasts:** These are osteogenic or bone forming cells.
- **Osteoclasts:** With their phagocytic action, these remove excess of bone cells.

Well-controlled and coordinated intercellular activity of these three types of cells is essential to maintain the normal level of BMP.

Metabolic disorders of the bone

The following are the common metabolic disorders of the bone:

1. Rickets
2. Osteomalacia
3. Hyperparathyroidism
4. Osteoporosis
5. Fluorosis

Classification of metabolic bone disease

1. **Osteopenic** (e.g., osteoporosis): There is generalized reduction in

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the BMD.

2. **Osteosclerotic** (e.g., fluorosis): The proportion of bone mass is increased due to excessive deposition of calcium.

3. **Osteomalacic** (e.g., nutritional rickets, osteomalacia): The available organic matrix remains undermineralized; mineralization terminates at the stage of osteoid formation. The bone remains soft and malleable instead of becoming tough and hard (Table 22.1).

4. **Mixed variety** (e.g., hyperparathyroidism): It is a coexisting combination of osteopenia and osteomalacia.

Table 22-1
Metabolic Bone Disease of Children

Disease	Pathology	Salient Features	Management (Orthopaedic)	Physiotherapy
Infantile rickets (<4 years)	Failure of mineralization of the organic bone matrix (osteoid) due to deficiency of vitamin D and the disrupted calcium metabolism	• General debility, hypotonia, weakness of the proximal muscles with irritability • Tendency to develop typical rachetic deformities and fractures • Radiographic investigations	• Prevention of deformities by correct orthosis (e.g., Mermaid splint) • Heavy oral dose of vitamin D (6 lakh units); maintenance dose of calcium: 0.5–3 g/day, vitamin D: 10,000 IU/day • Treatment of fractures and deformities	• Educate the mother on positioning and carrying the child • Simple limb movements • General body UV exposure • Strengthening exercise to the weak but functionally important muscles. • Guidance on the use of orthosis and ambulation

Nutritional infant rickets

Rickets is a metabolic disorder of children younger than 4 years, which is caused due to the deficiency of calcium and phosphate. In

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rickets, the osteoid formation in the bones is normal but its mineralization is defective. This results in the formation of uncalcified bone matrix. There is an arrest of activity of the growth plate cartilage resulting in retardation of the ossification bone growth. There is softening of bone which causes deformities of long bones.

Nutritional rickets is the most common type of rickets seen in developing countries. It is caused by deficiency of vitamin D. Vitamin D deficiency results from lack of dietary intake and insufficiency of exposure of the body to sunlight.

The absorption of calcium and phosphate from the intestine is reduced due to deficiency of vitamin D. A fall in the level of blood calcium stimulates hypersecretion of PTH. This, in turn, mobilizes calcium from the bone, which leads to deficient calcium in the bone; making them soft and easily malleable to pressure or body weight. This causes typical deformities in the weight-bearing bones.

Clinical Features: The child is inactive/apathetic, has abnormal dentition and muscle weakness due to loss of muscle power. The bones may get fractured or deformed due to weakness of bones.

The common deformities in infantile rickets (Fig. 22-1A and B):

1. **Skull**

   (a) Craniotabes: The fontanelle remains open even after the age of 2 years.

   (b) Frontal bossing: There is prominence (bossing) of the frontal and parietal bones.

2. **Chest**

   (a) Pigeon chest: The thoracic cage is compressed at the sides, and is raised and elongated anteroposteriorly, the sternum being prominent and thrusted forward.

   (b) Rickety rosary: Bony enlargement occurs at the junction

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of the ribs with cartilages. It gives an appearance of a 'rosary', hence the name.

(c) Harrison sulcus: It is a transverse groove in the anterior part of the lower chest, caused by the muscular pull of the diaphragm.

3. **Spine:** Kyphosis involving both the thoracic and lumbar spines may be present which may subsequently lead to lumbar lordosis as the child starts walking.

4. **Abdomen:** The abdomen is protuberant and gives a 'pot-belly' appearance; largely due to muscular hypotonia.

5. **Upper limb:** There is widening at the epiphyseal regions of the wrist (Fig. 22-2).

6. **Lower limb:** Deformities like coxa vara, genu varum, genu valgum (Fig. 22-3), bow-legs or forward bowing of tibia and flat feet occur due to the compressive pressure of the body weight on soft decalcified bones (Fig. 22-4). Occasionally, a peculiar deformity called *wind-swept deformity* of genu valgum on one side and genu varum on the contralateral knee may be seen (Fig. 22-5).

7. **Pelvis:** The size of the pelvis may be reduced; the overall growth of the child is arrested, all resulting in stunted growth or dwarfism.

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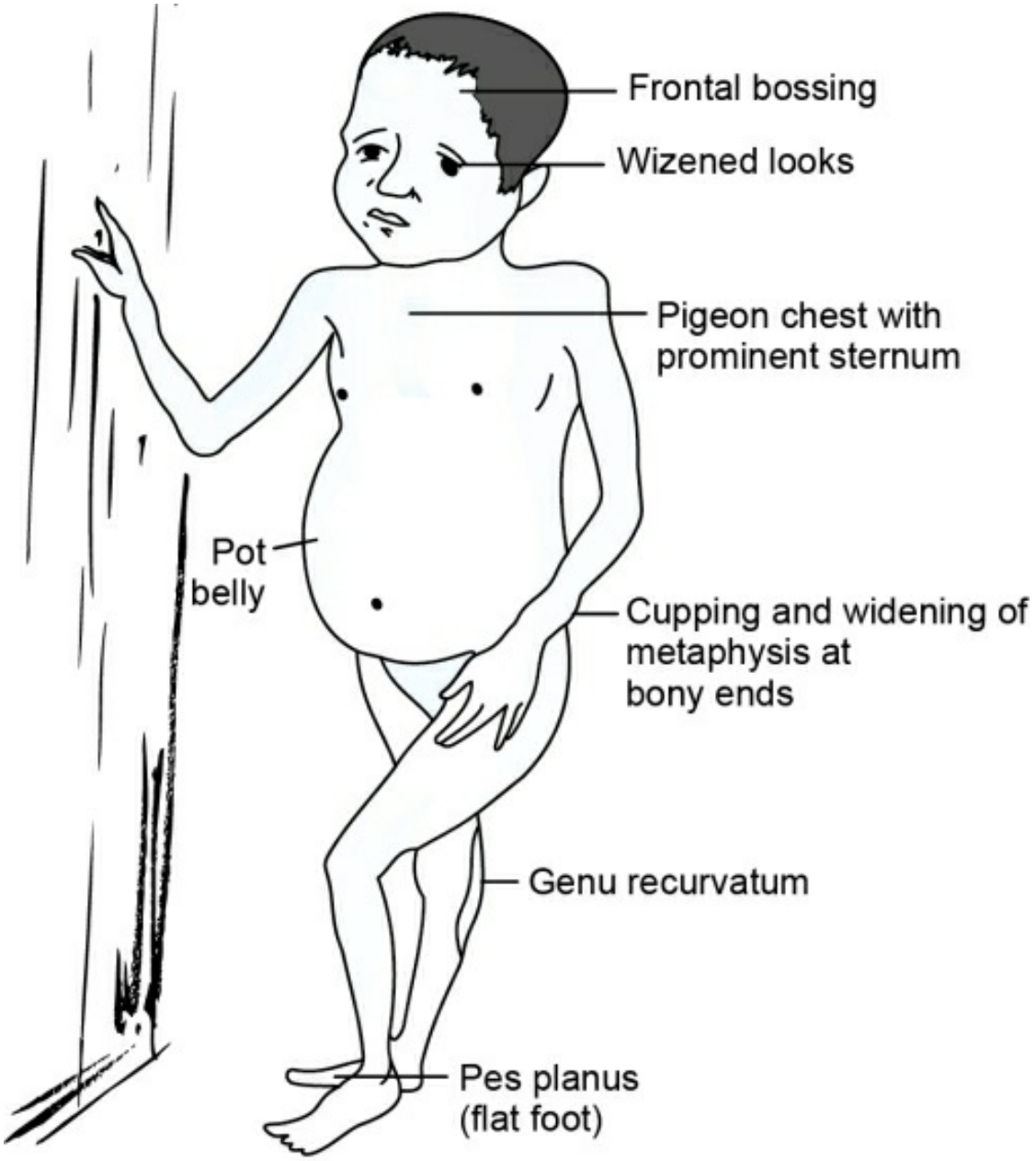

(A)

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(B)

FIG. 22-1 Typical features of a child with nutritional rickets. **(A)** Line diagram. **(B)** Clinical photograph.

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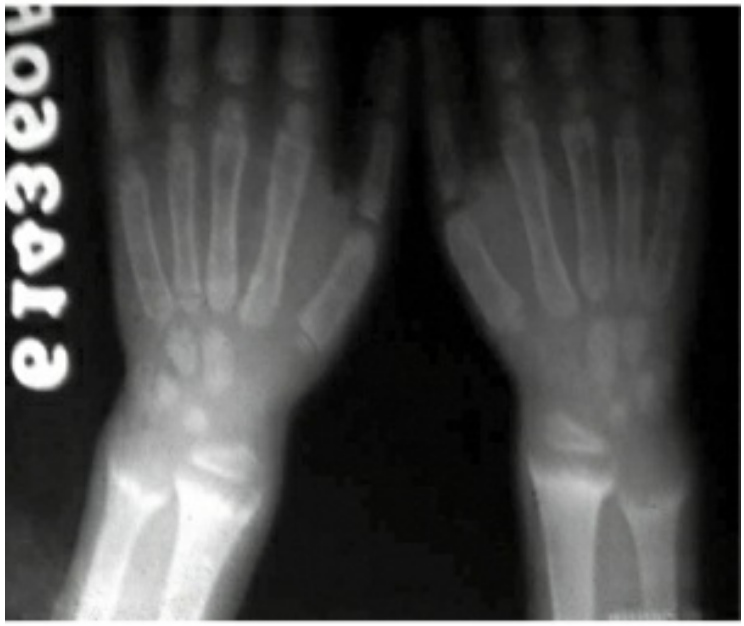
(A)



(B)

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(C)

FIG. 22-2 **(A)** Clinical photograph showing widening of the wrist. **(B)** Radiograph showing cupping and widening of the metaphysis of radius on both sides. **(C)** Normal radiograph of wrist for comparison.

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FIG. 22-3 Genu valgum deformity.

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FIG. 22-4 Deformity (bowing) of the tibia and fibula.

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FIG. 22-5 Windswept deformity.

Overall, the child looks weak, sick, irritable, morose and stunted in growth (Fig. 22-1).

Summary Box

Nutritional rickets: clinical features	
• Skull	• Craniotabes • Frontal bossing
• Chest	• Pigeon chest • Rickety rosary • Harrison sulcus
• Pelvis	• Reduced size
• Spine	• Increased dorsal kyphosis • Lumbar lordosis
• Abdomen	• Pot belly
• Extremities	• Genu valgum/varum • Bowing of bones • Coxa vara • Wind-swept deformity

Investigations

Blood serum chemistry: Serum calcium level may be normal or low but the serum phosphate is low. Serum alkaline phosphatase is markedly raised during the active stage of the disease.

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Radiography: Radiograph of the wrist shows widening of the epiphyseal plate with fluffy and irregular edges. There is 'cupping' of the metaphysis.

Treatment

Medical treatment: Administration of high doses of vitamin D with calcium supplements is the mainstay of treatment.

Orthopaedic treatment: Mild deformities in the limbs should be treated by the use of splints (Mermaid splint). Marked deformities may need surgical correction by corrective osteotomy.

Fractures are treated by adequate immobilization by plaster of Paris (POP).

Physiotherapeutic management

Objectives

- Prevention of deformities (at the trunk and limbs)
- Maintain or improve muscle functions and ROM
- Functional re-education

Early stage: The most important stage when a sick and irritable child is likely to develop multiple problems such as general debility, hypotonia, weakness of the proximal limb muscles and the spinal group of muscles.

1. Therefore, correct education of the mother as regards positioning, handling and carrying the child and not allowing weight bearing is important to prevent limb deformities or even fractures.

2. General body exposure to UV rays at subthermal dose of 3300–2900 A is useful.

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3. Put the child on the floor in different positions and let it perform free movements of the limbs and the trunk.

4. Chest physiotherapy helps in improving general health by increasing oxygen uptake and also in preventing chest infection. As the general condition improves, child will become more active. For chest physiotherapy, if active exercises are not possible, passive (gentle) breathing exercises can be given.

5. Initiate intelligent objective modes of getting purposeful functional exercises done, offering resistance wherever possible (e.g., kicking a ball).

6. Initiate controlled resistive proprioceptive neuromuscular facilitation (PNF) patterns with guided assistance.

7. If a child attempts to stand and walk, provide orthosis or a brace to prevent limb deformities when there is definite evidence of calcification.

Late stage: Increase the vigorousity of exercise concentrating mainly on the functional muscle groups. Continue progression till the child is functionally self-sufficient and free from deformity.

Following surgery: Surgery is mostly undertaken to treat fractures and correct deformities by osteotomy.

Appropriate physiotherapeutic measures of progressive mobilization and strengthening of the related muscle groups facilitates early return of function.

Though these measures appear easy, tremendous long-standing effort is needed to successfully manage a child with rickets. The child may be given supportive orthoses to give ambulatory training, which could be gradually waned and discarded later.

Other types of rickets

1. *Vitamin D resistant rickets:* It is due to the deficiency of blood phosphate (hypophosphataemia). Because of the resistance to vitamin

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D, normal bone formation needs high doses of vitamin D.

2. *Hypophosphatasia:* The calcium deposition in the bone is deficient although its supply is normal. This occurs due to the inherited lack of the enzyme alkaline phosphatase.

3. *Renal rickets:* Inadequate secretion of phosphorus by the kidney results in fall of phosphate in the blood. This follows malfunctioning of the kidneys. There is an increased secretion of PTH which mobilizes calcium from the bones, rendering them soft and liable to deformities.

Osteomalacia

Vitamin D deficiency in adults causes osteomalacia. The patient presents with generalized bone pains. In fact, it is the adult counterpart of rickets in children.

Clinical features

The patient presents with bone pain in the legs, low backache and occasionally with pathological fracture. The patient may have muscle pains and difficulty in going up the stairs.

Radiographs: In osteomalacia, decalcification radiographically appears as bands of radiolucency called *Looser zone* or *Milkman fracture* (Fig. 22-6). Milkman fracture is a pseudofracture commonly observed at the femoral neck, pubis, upper humerus, scapula and ribs. However, the incidence of pathological fractures is common in this condition.

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FIG. 22-6 'Looser zone' (pseudofracture) in the calcar femoral of the femoral neck on the left side (arrow).

Investigations

Serum calcium and phosphate may be decreased while the alkaline phosphatase is elevated.

Biopsy of the bone reveals unmineralized osteoid seams.

Treatment

- The deficiency of vitamin D is corrected by diet and by supplementing vitamin D in high doses.
- A fracture in the bone may require open reduction and internal fixation.

Hyperparathyroidism

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Hyperthyroidism is also called by other names such as von Recklinghausen disease and osteotitis fibrosa cystica. It occurs as a result of excessive secretion of the PTH, usually as a result of hyperplasia or adenoma of the parathyroid gland. This hyperactivity of the parathyroid gland inhibits resorption of phosphates from the kidney which results in phosphaturia and hypophosphataemia. The fall in the blood phosphate level results in the corresponding increase in the level of blood calcium by way of mobilization of calcium from the bones. The decalcified bones become susceptible to deformities or pathological fractures. Bone cysts filled with brownish tissue, also called *brown tumours*, *renal stones* or *soft tissue calcification* may also occur.

Hyperthyroidism can be of the following types:

1. *Primary hyperthyroidism:* A hormone secreting adenoma of the parathyroid gland causes excessive secretion of the PTH resulting in *primary hyperthyroidism*.

2. *Secondary hyperthyroidism:* A kidney disorder or malabsorption syndrome lowers the serum calcium level, which in turn causes excessive secretion of the PTH to mobilize calcium from the bones. This is called *secondary hyperthyroidism*.

3. *Tertiary hyperthyroidism:* During the course of secondary hyperthyroidism, an autonomous nodule develops in the parathyroid which continues to secrete excessive PTH even after the underlying cause of excess secretion is cured. It is termed as *tertiary hyperthyroidism.*

Clinical features

The onset is insidious with abdominal cramps, nausea, vomiting, generalized muscular weakness and anorexia due to excessive levels of calcium in the blood.

The presence of generalized bone pain may be due to osteoporosis; pathological fractures may also occur through the localized cystic lesion or due to osteopororsis.

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Investigations

There is high serum calcium, low serum phosphorus and high alkaline phosphatase.

Radiography

- There is generalized demineralization of the bones.
- There is widening of the medullary canals of long bones, with thinning of the cortex.
- Bone cysts and pathological fractures may be seen.
- Subperiosteal resorption of the phalanges (hand) is a classical sign of hyperparathyroidism.
- There is absence of lamina dura of the teeth sockets in the mandible.

Treatment

- Surgical removal of the parathyroid tumour stops excessive production of parathormone and thereby returns the bones to normalcy.
- The main objective is prevention of deformities and fractures by providing adequate splints, and orthoses. Deformities may need corrective osteotomy.

Physiotherapy

- Physiotherapy is directed towards checking the orthoses, and educating the patient on safe functional movements, with or without orthoses. Cane is a must to carry.
- Plan exercises to weakened muscles and maintain full ROM of the joints. Follow therapeutic regime as described for osteotomy when undertaken.

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Osteoporosis

Osteoporosis is acquiring epidemic proportions and is becoming a major incapacitating metabolic disease all over the globe, because of its asymptomatic nature in the early stage. According to the World Health Organization definition, osteoporosis is 'a systematic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue leading to enhanced bone fragility and a consequent increase in fracture risk' (Dandy & Edwards, 2014).

Normally, there exists a balance between bone formation and bone resorption. In osteoporosis, the rate of bone resorption exceeds the rate of bone formation rendering the bone weak and brittle with loss of bone mass resulting in the reduction of BMD due to the deficiency of vitamin D and calcium (deficient calcium absorption from the intestine→ stimulates parathyroid gland→ PTH resorbs calcium from the bone→ OSTEOPOROSIS).

Risk factors

Osteoporosis slowly sets in when certain risk factors are present (Table 22-2). They are of two types.

1. **Modifiable –** can be reduced with proper early investigations and care

2. **Nonmodifiable –** cannot be avoided

Table 22-2
Risk Factors for the Development of Osteoporosis

Modifiable Risk Factors	Nonmodifiable Risk Factors
1. Hormonal deficiency of gonadal hormones or oestrogen Hypersecretion of adrenocortical hormone 2. Nutritional deficiency (e.g., calcium, phosphorus, proteins) 3. Diseases of liver, kidney, GI, neoplasia, hyperthyroidism 4. Long-duration immobilization due to the loss of stress and strain required to maintain BMD 5. Highly sedentary lifestyle 6. Postmenopausal state	1. Family history of osteoporosis 2. History of repetitive fractures with negligible trauma 3. Age above 55 4. Small body frame

Abbreviation: BMD, bone mineral density; GI, gastrointestinal system.

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Classification of osteoporosis (table 22-3)

Osteoporosis is classified as follows:

1. Primary osteoporosis, which is further divided into the following:

   (a) Type 1 – Postosteoporosis

   (b) Type 2 – Senile osteoporosis

2. Secondary osteoporosis

Table 22-3
Osteoporosis at a Glance

Characteristics	Senile Osteoporosis	Postmenopausal Osteoporosis
• Pathogenesis • Type of bone loss • Rate of bone loss • BMD • Clinical signs	• ↑ Osteoblastic activity • Both cortical and trabecular short duration • Normal or low • Deep spinal pain and tenderness with development of dorsal hump • Vertebral compression fracture • Fracture of distal radius, hip or proximal tibia	• ↑ Osteoclastic activity • Largely trabecular • Long duration • 2 SD below normal level • Deep pain • Stress fractures at vertebrae, distal radius, hip (intracapsular) • Loss of teeth
Laboratory investigations Urine calcium PTH function Renal conversion of 35 $(OH)_2$ 0–1.25 (OH) D	• Normal • Increased • Primarily reduced due to decreased response	• Increased • Decreased • Secondarily reduced due to reduced PTH

Abbreviation: BMD, bone mineral density; PTH, parathyroid hormone.

Primary osteoporosis

Postmenopausal osteoporosis occurs due to the deficiency in the secretion of oestrogen hormone after menopause.

Senile osteoporosis occurs in the elderly with a female preponderance (female: male ratio 2:1).

Primary osteoporosis may be idiopathic.

Secondary osteoporosis

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Secondary osteoporosis develops at any age, with equal distribution among males and females. It is usually secondary to some underlying disease such as endocrine disorders, malignancy or due to the prolonged intake of certain medicines, e.g., steroids and antiepileptic drugs.

Clinical features

In the early stage, the low and asymptomatic progress of the disease goes unnoticed.

- However, in the late stage, the patient develops pain in the dorsolumbar spine.
- There is development of a kyphotic hump deformity due to osteoporosis collapse of multiple vertebrae and loss of vertebral height.
- There is generalized rarefaction of bone, making them susceptible to fractures after a trivial injury/fall.
- There is early fatigue.

Diagnosis

Several methods are available:

- Radiography – loss of bone density, presence of a ballooning of the IV disc (Fig. 22-7) or compression fracture of the body of vertebra
- Dual energy X-ray absorptiometry (Dexa-scan) – for progressive investigation of risk
- MRI scan – details patterns of bone trabeculae
- Neutron activation analysis – to measure the activity of calcium in bone

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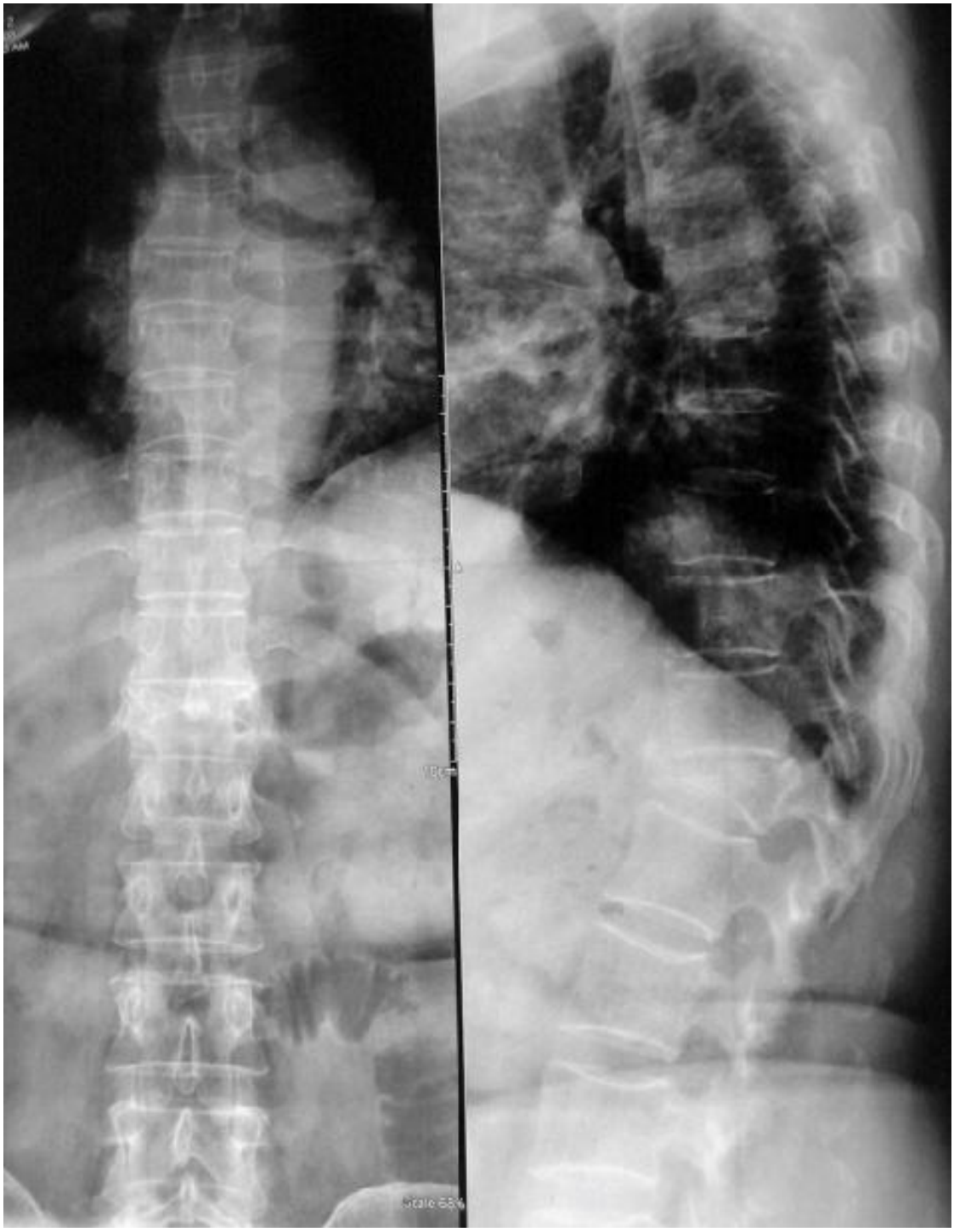

FIG. 22-7 Senile osteoporosis. Radiograph (lateral view) of the spine indicating loss of bone density in the bodies of vertebrae with ballooning (saucerization) of the intervertebral spaces.

BMD evaluation

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An important test to evaluate the mineral density of a bone or overall skeleton:

1. Peripheral ultrasonography graphically analyses the BMD level.

2. WHO (1994) standardized a procedure to assess the BMD level based on comparison of the BMD level with standard BMD value in normal young adults.

WHO Classification of BMD by T-Score (i.e., a Threshold for Fracture Risk and Treatment)

- Normal bone – T-score not less than 1.00 (1 SD) below the level of normal value of BMD of young healthy adult
- Osteopenia (early osteoporosis): T-score between 1.0 and 2.5 (SD)
- Osteoporosis: T-score of >2.5 (SD)
- Severe osteoporosis: T-score lower than 2.5 with a history of prevalent repetitive fractures

Treatment

- Regular check-up of the level of BMD after 50–55 years or menopause in women
- Good nutritious diet to control malnutrition
- Additional calcium intake to curb bone loss (1000–1500 mg/daily)
- Vitamin D to facilitate calcium absorption from the gut
- Hormone replacement therapy (HRT) in postmenopausal women
- Selective oestrogen receptor modulation (SERM) – raloxifene is a drug of choice

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- Calcitonin secreted by thyroid gland – improves bone mass, preventing fracture

- Osteophos (containing sodium alendronate)

Associated symptoms

1. Backache (kyphosis) is treated by Taylor brace or anterosuperior hypertension brace (ASHE brace)

2. Fractures of the femoral neck or distal radius may require surgical intervention with intramedullary nails or plates. Osteoporotic (thin) bones usually do not offer a good bone stock for rigid fixation by plates and screws. The implants usually cut through easily requiring re-surgery. However, newer implants such as locking compression plates (LCPs) offer a better stability to the fixation (Fig. 22-8).

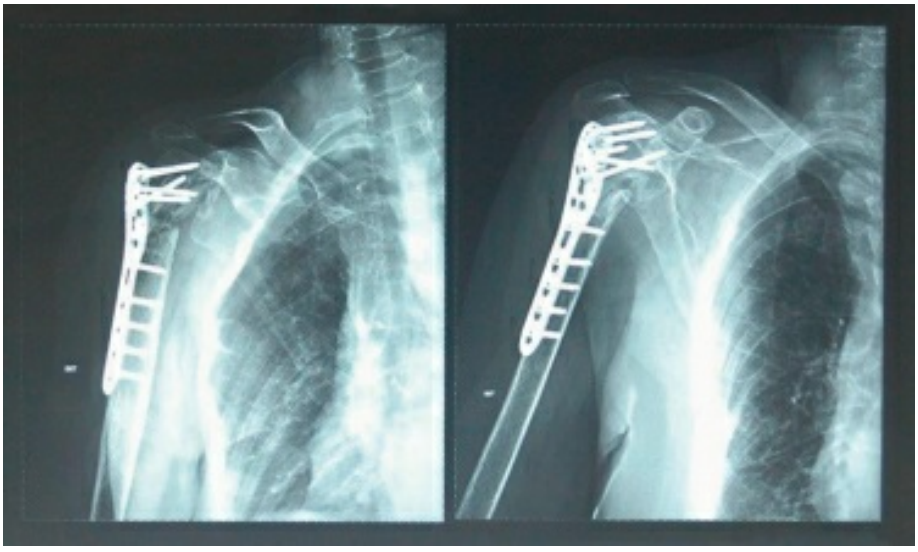

FIG. 22-8 Locking compression plates offer a better stability to the fixation.

Vertebrae

- Usually have compression fracture of the body, leading to collapse of the vertebra.

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- Effectively treated by a new technique called **vertebroplasty** where bone cement is injected into the body of the vertebra to restore the vertebral height (Fig. 22-9).

- Kyphoplasty: In this procedure, the height of a collapsed osteoporotic vertebra is restored by inserting a balloon, percutaneously, in the affected vertebra. The balloon is then inflated by injecting cement into it (Fig. 22-10). Kyphoplasty is a relatively safe/better procedure than vertebroplasty. Since in kyphoplasty, the cement is injected into a balloon, the chances of cement leaking out/spilling into the vertebral canal are much less, making it a relatively safe procedure.

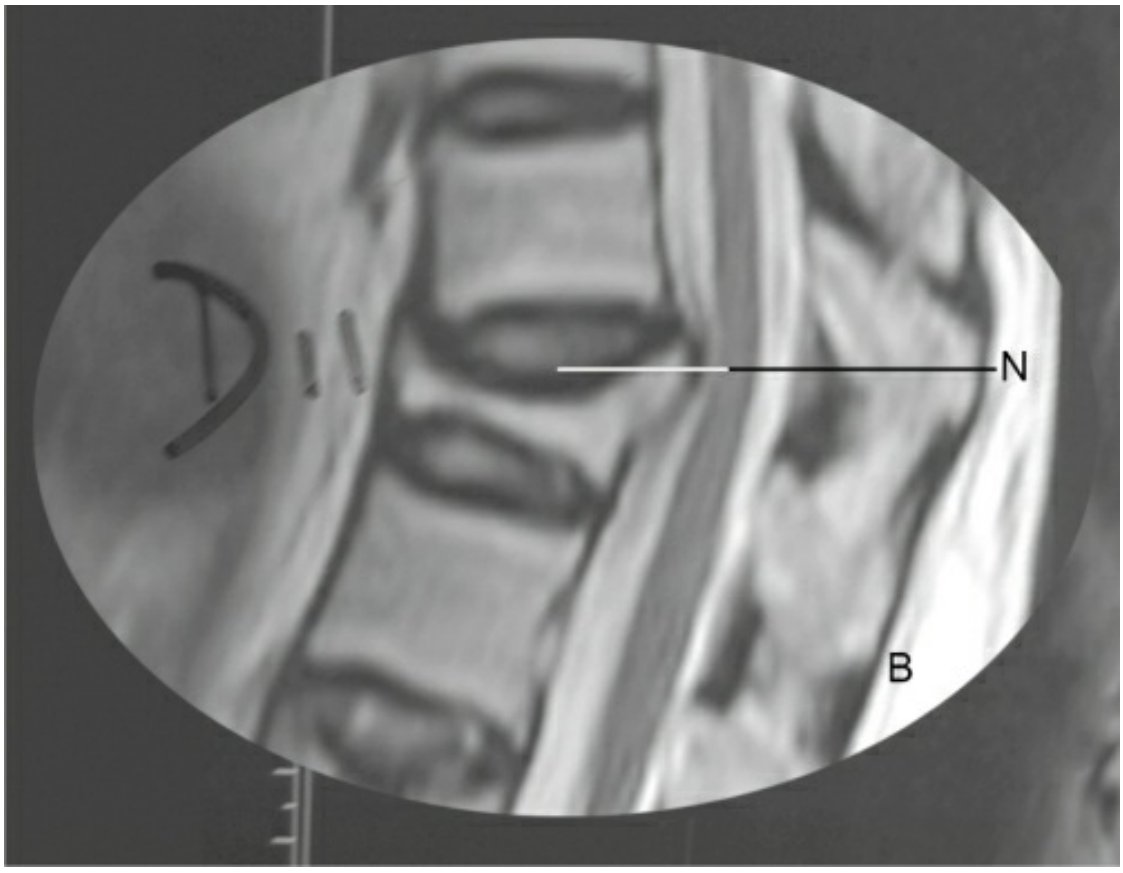

FIG. 22-9 Vertebroplasty. (N) Needle to inject bone cement, to fill the spaces in the bone, due to the compression fracture of the body of D-11 vertebra.

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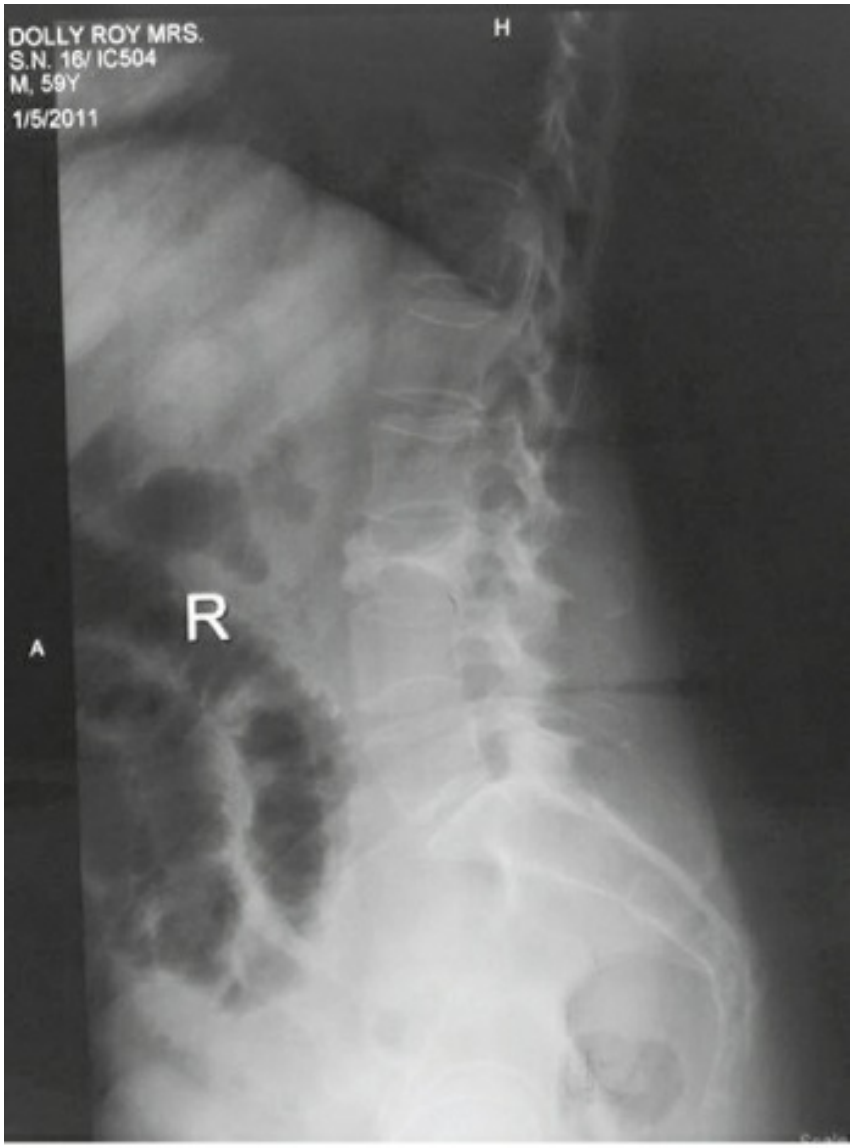

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(C)

FIG. 22-10 Kyphoplasty. **(A)** X-ray shows collapse of L3 vertebra, the vertical height of the vertebra is much reduced. **(B)** MRI of the same patient. **(C)** Bone cement in a balloon injected into the vertebra restoring its vertical height considerably.

Physiotherapeutic management

Physiotherapy plays a significant role, in both primary and secondary prevention.

For primary prevention: There are two different systems of exercise to be incorporated depending upon patient's age and

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physical fitness. This is done only after testing exercise tolerance and cardiac clearance.

1. A system of structured exercise is ideal for young adults and middle age group individuals and physically and medically fit elderly people (Table 22-4).

2. Lifestyle exercise (get habituated to active lifestyle)

(a) It simply means not to avoid a single opportunity to perform some physical activity by increasing the speed, frequency and vigorousity of each physical activity one performs in a daily routine. It should be directed specially to overload the susceptible musculoskeletal complexes (e.g., frequent standing up and sitting, spot marching or double ups during short breaks while watching TV, purposely parking vehicle at a distance from the place of working, not using a lift, instead do faster stair climbing)

(b) Those who are unable to perform vigorous exercise should try and increase the duration of specific exercise at a slower speed.

Table 22-4
Exercise Prescription of Structured Exercise Programme

Exercise	Specificity
Type and mode	Aerobics (dynamic) exercise with emphasis on trunk and lower limbs involving impact loading of the body weight with the floor
Intensity	To begin with 40–60% of the HR_{max} (heart rate maximum) gradually progressing to 70–75% of HR_{max} In elderly people, to 60–65% or more if feasible
Duration	Begin with 10–15 min of stimulus phase of exercise working up to 30 min or more
Frequency	At least thrice a week
Rate	In each exercise, the rate of repetition per minute varies from 40 to 100

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Secondary Prevention: Once the diagnosis is confirmed, physiotherapy is directed to prevent or control the expected complications:

1. Tendency to develop postural deformity of kyphosis leading to vertebral compression fracture – use of Taylor brace or ASHE brace anterosuperior, postural guidance in lying in bed or sitting and trying to perform only hyperextension exercises, or longer periods of lying prone.

2. Incidences of hip fractures are controlled by applying the methods of safe ambulation (e.g., using cane, gait training, nonslippery floors) and exercises to improve strength and endurance of functionally important muscle group around the hip (e.g., hip extensors and abductors).

3. Incidences of Colles fracture: Incidences happen during repetitive performance of resistive or strong isometrics to the wrist flexors and the extensors, forearm pronators and the supinators.

4. Avoid hurry, be watchful always.

5. Get BMD level checked at regular intervals.

6. Be regular on calcium and vitamin D supplements and HRT in postmenopausal women.

Characteristics of some common metabolic diseases are depicted in Table 22-5.

Table 22-5

Metabolic Bone Diseases of Adults

Disease	Pathology	Salient Features	Management (Orthopaedic)	Physiotherapy
Adult rickets, osteomalacia	Failure of mineralization with excessive	• Bony tenderness and pain	• Calcium and vitamin D supplements	• General body exercise to maintain strength and mobility

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	accumulation of osteoid due to abnormal vitamin D and phosphorus metabolism	• Hip joint and back spinal deformities or pathological fractures • Radiographic investigations	• Preventive measures for spinal deformities • Treatment of hip and spinal fractures	• Careful watch on possible deformities • Provide orthosis or aid to prevent fractures at the spine and hip, e.g., NWB ambulation
Osteoporosis	• Progressive diffuse reduction in the mineral density of bones (BMD) • Loss of bone mass and bone proteins results in fractures with a mild trauma	• Gradual development of a dorsal hump (kyphosis) • The common sites of pathological fractures: Vertebral compression fractures • Fractures at the neck femur • Fractures at the wrist • Radiographic investigations • BMD investigation	• BMD evaluation • High vitamin D, protein and calcium supplements – in senile variety • Oestrogen supplementation (HRT), calcitonin or bisphosphonates in postmenopausal osteoporosis • Treatment of fractures when they occur • Use of bone cement to compensate for the bone loss (vertebroplasty)	• Exercise training by • Structured exercise or lifestyle exercise conditioning of the muscle groups guarding the areas susceptible for fractures (e.g., wrist, spine and hip) • Impact weight-bearing exercises are ideal to improve BMD (e.g., jogging, running spot marching, jumping besides spinal loading exercises and isometrics to the wrist)

Abbreviation: NWB, nonweight-bearing.

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CHAPTER 23

Bone tumours

OUTLINE

- Tumours
- Classification of bone tumours
- Benign bone tumours
- Malignant bone tumours
- Primary bone tumours
- Secondary bone tumours (bone metastases)

Tumours

A tumour is a swelling due to excessive neoplasia or new growth of a tissue. It may affect any tissue cell in the body.

Bone tumours are of two types:

1. Benign (Fig. 23-1)

2. Malignant (Fig. 23-2)

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FIG. 23-1 Benign tumours. **(A)** ECH; ecchondroma, ENC; enchondroma. **(B)** OC; osteochondroma. **(C)** GCT; giant cell tumour (osteoclastoma).

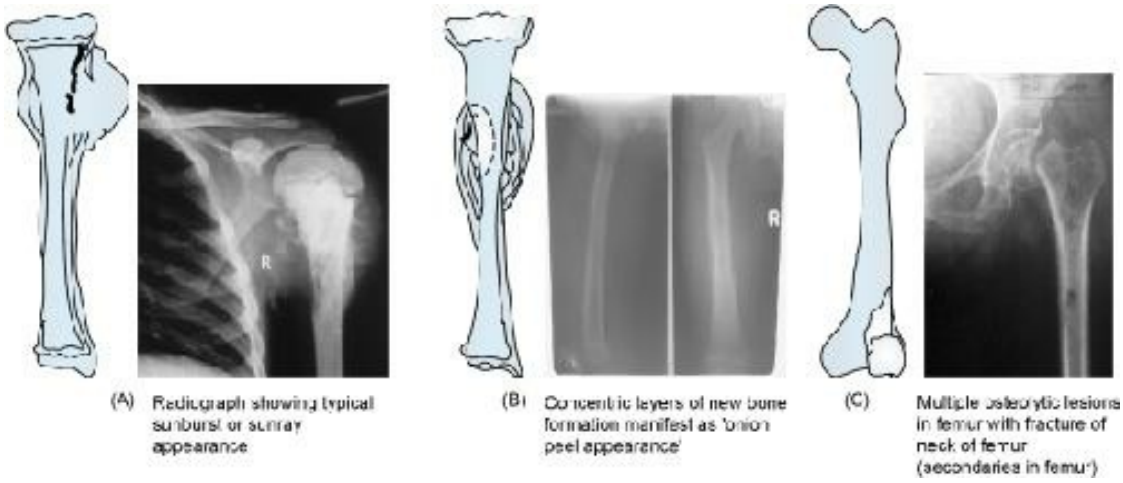

FIG. 23-2 Malignant tumours of bone. **(A)** Osteosarcoma. **(B)** Ewing tumour. **(C)** Metastatic tumours.

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The distinguishing characteristics of both these types of tumours are classified in Table 23-1.

Table 23-1
Distinguishing Characteristics of Benign and Malignant Bone Tumours

Characteristics	Benign	Malignant
Onset	Insidious with slow growth rate	Acute with rapid growth rate
Fever, weight loss, anorexia	Nil or few	Associated with severe unremitting pain and disability
Lesion	Well circumscribed and noninvading	Not well circumscribed and invading
Spread of tumour	Do not metastasize	Metastasize
Radiographic lesion	Confined to the involved bone only	Has ill-defined borders, mottled appearance, the bony cortex may be broken with loss of continuity of the involved bone (pathological fracture)
Prognosis	Generally good; can be cured with timely and correct therapy	Generally poor and depends upon the nature and extent of the tumour; could be fatal

In this chapter, the classification of bone tumours and the basic principles of management are discussed. It is outside the scope of this book to discuss these tumours in detail.

Bone tumours

Bone tumours could be primary, when they arise from the bone itself, and occur mainly in young adults. They are highly malignant and may be fatal.

Secondary bone tumours occur as a result of metastases usually from the carcinoma of breast, kidney, lung, prostate or thyroid.

The classification of bone tumours is depicted in Table 23-2.

Table 23-2
Classification of Bone Tumours

1. **Bone-forming tumours**
Benign
- Osteoma
- Osteoid osteoma

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• Osteoblastoma *Malignant* • Osteosarcoma
2. **Cartilage-forming tumours** *Benign* • Chondroma • Osteochondroma • Chondroblastoma • Chondromyxoid fibroma *Malignant* • Chondrosarcoma • Osteosarcoma
3. **Giant cell tumours** • Osteoclastoma
4. **Marrow tumours** • Ewing tumour • Myeloma • Malignant lymphoma of bone
5. **Vascular tumours** *Benign* • Haemangioma • Lymphangioma • Glomous tumour *Malignant* • Angiosarcoma • Malignant haemangiopericytoma
6. **Connective tissue tumours** *Benign* • Lipoma • Fibroma *Malignant* • Liposarcoma • Fibrosarcoma
7. **Tumour-like lesions** • Bone cysts • Fibrous dysplasia • Eosinophilic granuloma
8. **Secondaries in bone**

Diagnosis

Diagnosis of bone tumours is based on the following steps:

- History of medical and subjective characters.
- Physical examination – size, shape and skin.
- When close to a joint, active and passive ROM of adjacent joints.

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- When close to a peripheral nerve or vertebrae, presence of any neural or vascular compressions must be examined.

Laboratory investigations

- Very high levels of WBC count, serum alkaline phosphatase, serum acid phosphatase and ESR with reduced level of haemoglobin.

- Radiograph: AP and lateral views indicate abnormality, e.g., sclerosis or increased bone density, destruction of bone, lytic lesions and pathological fractures. Chest radiograph is essential to rule out secondaries.

- CT scan: To detect metastasis at any other skeletal site.

- MRI scan (Fig. 23-3): To know the boundaries of the tumour spread to the bones as well as the soft tissues.

- Open biopsy or close needle biopsy confirms the diagnosis.

- According to the location of the tumour, the following investigations may be necessary:

Intravenous pyelography (IVP), barium studies, thyroid scan or arteriography.

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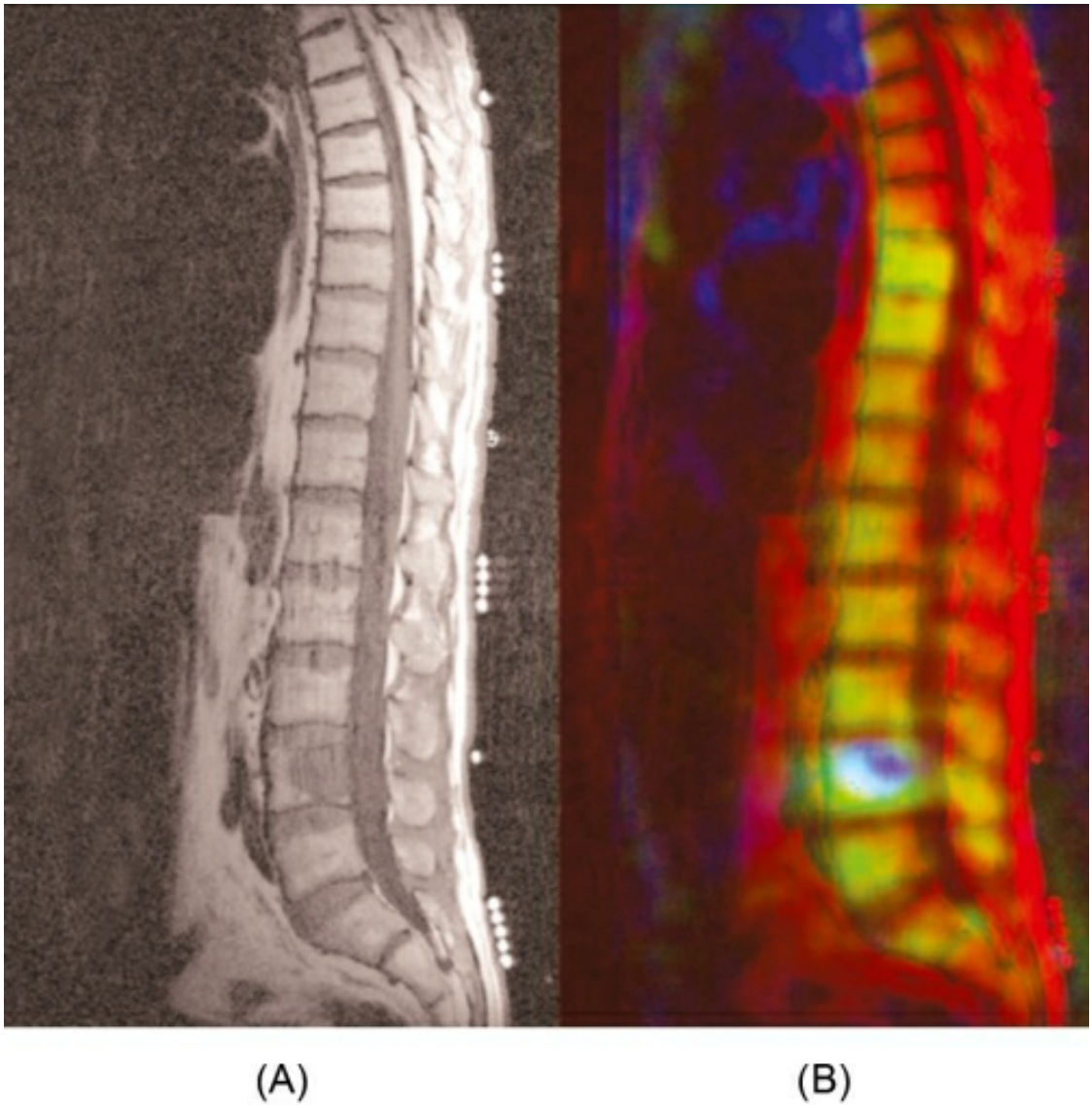

FIG. 23-3 **(A)** MRI scan of spine showing a metastatic lesion in the lower lumbar vertebra, and **(B)** PET scan of the same patient showing metastatic cancer. It shows involvement of multiple vertebrae, in addition to the one seen in MRI.

Benign bone tumours

Benign tumours may overgrow and cause pressure syndromes, e.g., pain and weakness due to interference in muscle action. It may weaken and fracture the affected bone (pathological fracture) or may even progress to malignancy (Tables 23-3 and 23-4).

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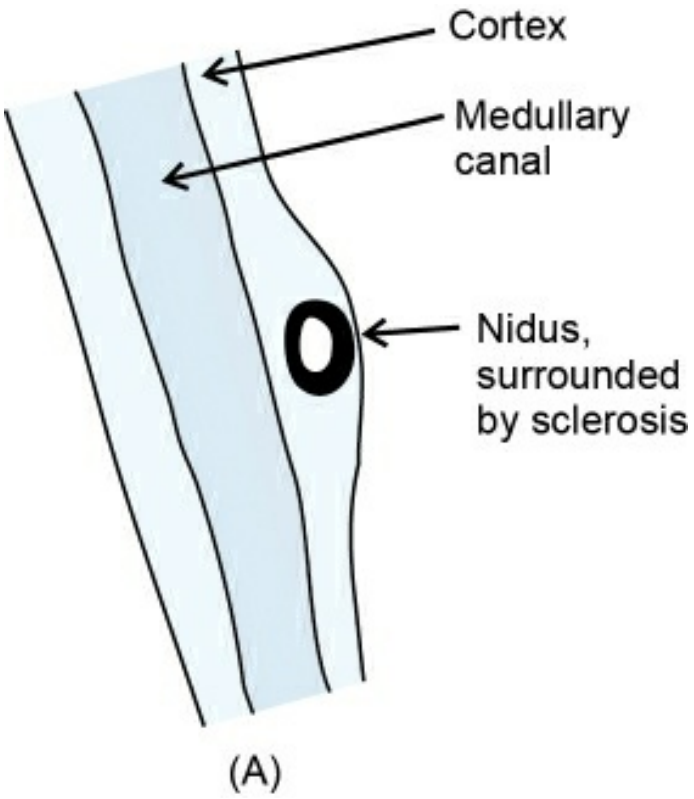

(A)

(B)

FIG. 23-4 **(A)** Diagrammatic representation of osteoid osteoma. **(B)**

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Osteoid osteoma as seen on radiograph.

Table 23-3

Essential Features and Management of Benign Bone Tumours

Tumour (Age in Years)	Origin	Common Sites	Location	Clinical Features	Radiographic Investigations	Treatment
Osteoid osteoma (10–25 years) (Fig. 23-4)	Enchondral bone	Diaphysis of long bones	Tibia, and posterior elements of vertebrae	• Localized tenderness, vague intermittent pain worst at night but relieved completely with salicylates • Back pain when vertebrae are involved	A zone of sclerosis which is surrounding a radiolucent nucleus – nidus	• Usually rest and salicylates • Excision of the tumour along with nidus
Osteoma(30–40 years)	Bones	Flat bones	Face or skull	• Pain-free bony lump near the end of long bones • Bony deformity may occur (diaphyseal aclasis)	Medulla and the cortex of outgrown tumour are in continuity with the parent bone	• Excision of osteoma if the size is bigger and causes hindrance or for cosmetic reasons
Haemangioma (young-adults) (Fig. 23-5)	Vascular (haemangiomatous origin)	• Skull • Vertebrae		• May be asymptomatic or develop persistent pain • Vertebral involvement may result in cord compression	There is loss of horizontal striations with appearance of vertical striations	Radiotherapy

Table 23-4

Essential Features and Management of Benign Tumours which Tend to Develop into Malignancy

Tumour (Common Age)	Origin	Site	Clinical Features	Radiographic and Laboratory Investigations	Treatment
Enchondroma	Cartilaginous	•	• Small-sized	• Cystic lobulated	• Single

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(15–50 years) (Fig. 23-1A)		Metaphysis of short long bones, e.g., • Phalanges • Metacarpals • Rarely humerus, pelvis	slow progressing swelling with or without pain • Lobulated enlargement at the tumour site • Thin and expanded cortex	tumour could be contained in bone (enchondroma), or perforating the bony outline (eccondroma) • Stippling or calcification may be seen	small tumour – curettage • Large tumour – excision with removal of capsule • When the long bones are involved – radical resection with bone grafting
Osteoclastoma (giant cell tumour) (15–35 years) (Fig. 23-1C)	Bone	• Epiphysis of long bones • lower end femur • upper end tibia • lower end radius	• Pain, tenderness, brownish swelling containing blood-filled cavities. • May have 'egg shell crackling' due to fragile cortex • pathological fractures	• Cystic lesion with trabeculae which appear like 'soap bubbles' • Erosion of epiphyseal line appears with the development of malignancy • Histopathology– multinucleated giant cells in fibrous stroma • Spindle cells	• Curettage and bone grafting • Excision with reconstructio • Arthrodesis with turn-o-plasty • Amputation preceded by radiotherapy
Osteochondroma (adolescents) M>F (Fig. 23-1B)	Cartilage	• Metaphysis of long bones • Shoulder • Elbow • Hip, knee, ankle	• Early stage asymptomatic appearance of pain, swelling and other complications • May compress on bursae neurovascular structures, or result in stiff joints	• Pedunculated outgrowth of bone in continuation with cortex and medullary portions, with cartilaginous cap • Tumour grows in an opposite direction to the growing end of the bone	• Surgical excision of the tumour
Chodroblastoma (10–20 years) (Fig. 23-6)	Cartilaginous highly cellular and vascular	• Long bones • Epiphysis close to the growth plate • Femur around	• Pain, swelling and joint effusion • Tumour is positioned eccentrically to bone	• Thinning of cortex • Lytic lesion surrounded by sclerosis • Multiple areas of calcification within the tumour with mottled appearance	• Small tumour – curettage + bone grafting • Large tumour – excision + bone grafting

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		knee is commonly involved			

Such benign tumours need surgical treatment like (a) intralesional excision or (b) curettage.

1. Intralesional excision could be a 'wide excision' where a tumour mass is excised with a rim of normal tissue around it.

2. The procedure of curettage is always followed either by cryotherapy or the use of bone cement to kill the leftover tumour cells following curettage.

Prognosis: Generally good, however, some benign tumours may turn malignant.

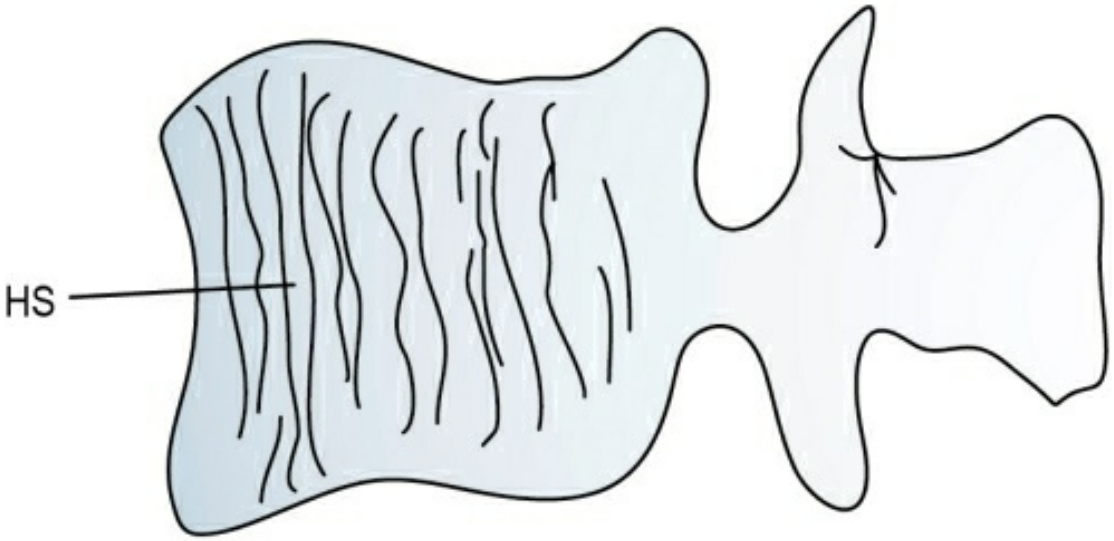

FIG. 23-5 Haemangioma: vertical striations.

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FIG. 23-6 Chondrosarcoma of the lower end of the femur.

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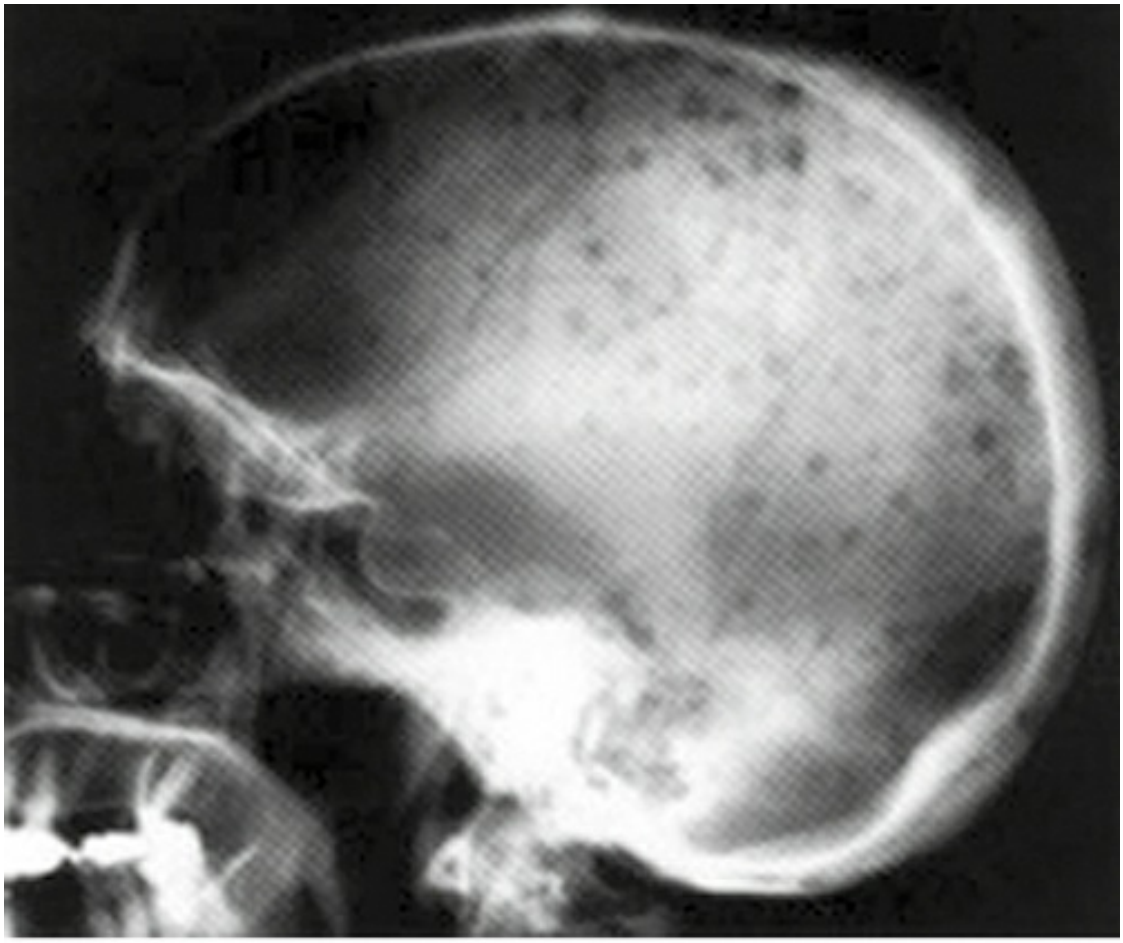

(A)

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(B)

FIG. 23-7 Multiple myeloma. **(A)** Multiple punched-out lesions in the skull are typically seen, and **(B)** multiple lytic lesions are also seen in the pelvis and femur.

Malignant bone tumours

These tumours present as pain and swelling of the affected area (Table 23-5).

Table 23-5

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Essential Features and Management of Malignant Bone Tumours

Tumour (Age of Onset)	Origin	Common Sites	Clinical Features	Radiographic, Laboratory Investigations	Treatment
Multiple myeloma (40–60 years) (Fig. 23-7)	• Plasma cells in bone marrow • Solitary lesion (plasma cytoma) • Multiple myeloma	**Flat bones** • Skull • Ribs • Lumbar spine • Sacrum • Pelvis	• Early phase– asymptomatic • Later – bouts of sharp pain, swelling at the tumour site • Bone marrow is replaced by plasma cells – causing anaemia, haemorrhages • Late signs of renal failure due to blockade by protein casts (myeloma – kidney)	• Skull – punctuated out lytic lesions • Vertebrae – wedge collapse • Pathological fractures • Ectopic bone formation – kidneys, lungs; Histopathology: ↓Hb, ↑ESR, total proteins, serum calcium; bone biopsy – gamma globulin, features of multiple myeloma; urine – Bence Jones proteins	• Preventive measures for pathological fractures • Chemothera • Surgery (suitable) • Decompressi laminectomy • IM fixation for pathological fracture • Palliative – radiotherapy when the tumour is widely spread and is nonoperative
Ewing sarcoma affecting mainly children (4–25 years) (Fig. 23-2B)	• Bone • Reticulum cells lining the marrow spaces	**Diaphysis of long bones** • Femur • Tibia • Fibula • Numerous • Rarely flat bones	• Intermittent vague pain worst at night • Redness of skin, dilated veins • Tumour spreads to medullary cavity • Metastasis to skull, vertebrae through the blood, lymphatics • Periods of exacerbations and remissions	• Rarefaction, lytic lesions in medullary region • Bone destruction and subperiosteal new bone formation • Expansion of tumour raises periosteum which appears like 'onion peel'. Histopathology: sheets of round cells	• Tumour is highly radiosensitiv • Chemo + radiotherapy • Surgery • Debulking of tumour by surgery • Limb preservation surgery • Irradiation followed by resection or amputation
Primary –	• Bone	•	•	• Tumour site –	•

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osteosarcoma (10–25 years)(Fig. 23-2A)	tissue from multipotent mesenchymal cells • Tumour could be fibroblastic osteoblastic or chondroblastic	Initiates at epiphysis but, after fusion of epiphysis occupies metaphysis • Long bones • Lower ends of femur • Upper end of tibia or humerus or lower end of radius	Intermittent night pain, tenderness and swelling • Egg shell cracking may be present • Dilated veins • Fatigue, anaemic metastasis to lungs or lymphatics through the blood or lymphatics	sclerotic lesion • Laying down of bone along the blood vessels gives an appearance of 'sun rays' • Codman's triangle is present • Pathological fractures may occur	Chemotherap • Radiotherap – preoperative mega-voltage therapy (4000–6000 rad) • Immunother – allogenic sarcoma tumour cell vaccine • BCG vaccine can be used • Early radical ablation

Local tenderness, warmth over the skin, with visible dilated veins, severe pain and joint stiffness may be present. There is sudden appearance and increase of swelling as the growth of the tumour is rapid. Malignant tumours very often metastasize to lungs.

Primary bone tumours

The diagnosis is confirmed by biopsy. Once the malignancy is confirmed, the treatment is started immediately.

Treatment

The treatment could be either single or a combination of the following:

1. Surgical excision or amputation

2. Radiotherapy

3. Chemotherapy (Table 23-6)

Table 23-6

Surgical and Nonsurgical Methods of Treating Malignant Bone Tumours

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Surgical Methods	Nonsurgical Methods
• Curettage	• Adjunctive therapy
• Excision	• Radiotherapy
• Excision with reconstruction	• Chemotherapy
• Limb salvage procedures • Resection arthrodesis • Turn-o-plasty • Joint arthroplasty – either by allograft or metallic prosthesis • Amputation	• Hormone therapy • Immunotherapy

Surgical excision or amputation

The treatment specifically depends upon the nature of involvement. Complete surgical excision of the tumour is the treatment of choice if there are no metastases.

Limb salvage procedures: The current trend is to employ limb salvage procedures (any of the following) after complete excision of the tumour.

1. *Resection arthrodesis:* The tumour is excised and the gap, thus created, is bridged with the help of fibular and cancellous bone grafting (Fig. 23-8). If this procedure is done for a tumour at the lower end of the femur or upper end of the tibia, then the knee joint loses its movements.

2. *Turn-o-plasty:* This procedure is usually done for a tumour at the lower end of the femur or upper end of the tibia. After excision of the tumour, other intact bone is split into two halves and the bone required to bridge the gap is turned upside down and fixed to the remaining stump of the bone (Fig. 23-9).

3. *Arthroplasty:* After excision of the tumour, the affected joint is reconstructed using either an allograft or a metallic prosthesis (artificial joint), custom-made for individual patients (Fig. 23-10). If limb salvage is not feasible, amputation of the affected limb is undertaken, in highly invasive tumours.

4. *Amputation:* The amputation can be *palliative* or *definitive. Palliative*

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amputation is performed, when inoperable metastases are present, to relieve pain or to prevent bleeding from a fungating tumour.

(A)

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(B)

FIG. 23-8 Resection arthrodesis by fibular grafting. **(A)** Osteosarcoma proximal tibia in a 14-year-old boy, and **(B)** postoperative X-ray of the same patient treated by resection arthrodesis.

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(A)

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(B)

FIG. 23-9 Turn-o-plasty. **(A)** Preoperative radiograph of the knee and leg in a 16-year-old boy with osteosarcoma of the upper tibia, and **(B)** postoperative radiograph of the same patient treated by turn-o-plasty, showing good union.

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FIG. 23-10 Pre- and postoperative X-rays of osteosarcoma of the distal end of the femur in an 18-year-old boy treated by resection of tumour and endoprosthetic replacement.

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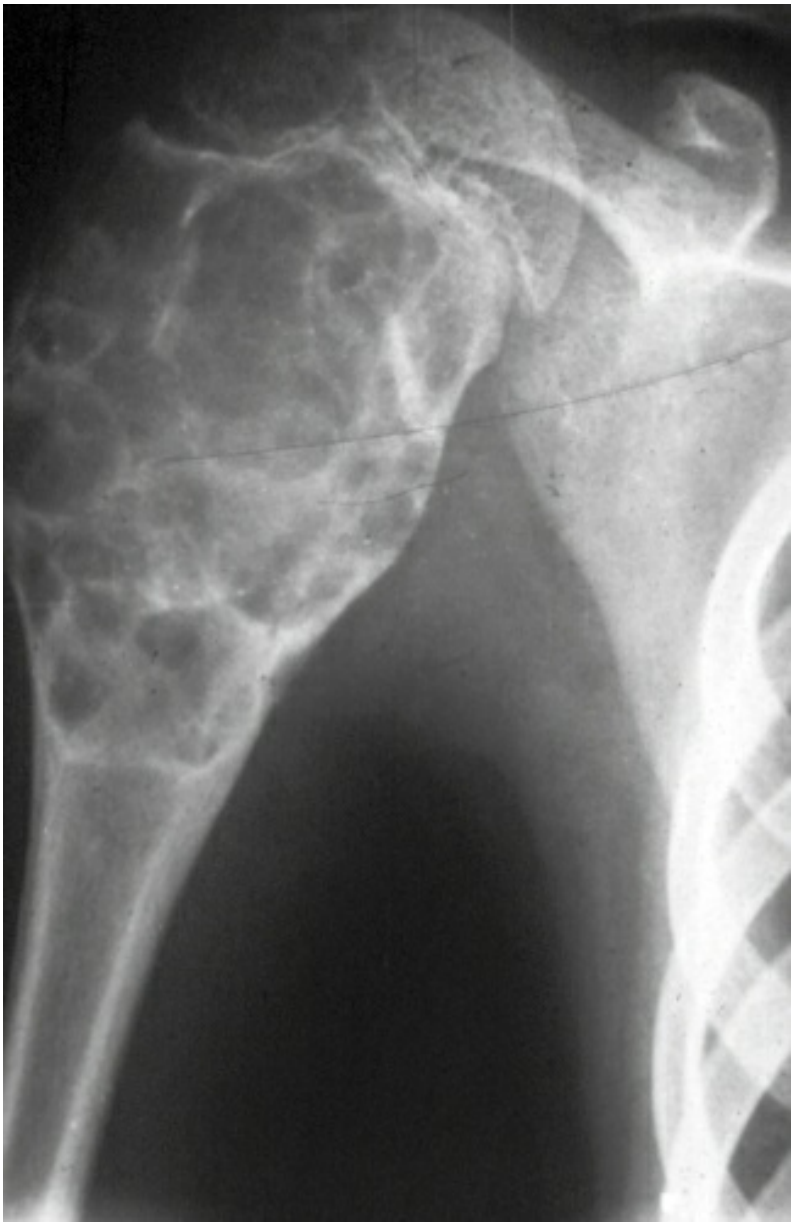

FIG. 23-11 Aneurysmal bone cyst in humerus.

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FIG. 23-12 Simple unicameral bone cyst in a child.

Single metastases, e.g., in lungs may be excised. As a protective measure, radiotherapy may follow amputation even if there are no metastases. In the presence of metastases, usually radiotherapy is the treatment of choice.

Definitive amputation is done when complete removal of the tumour is possible and there are no metastases. The tumour is excised along with a safe margin of normal tissues/adjacent compartment to prevent recurrence (Table 23-6).

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The level of amputation is divided by the site or the location of the tumour (Table 23-7).

Table 23-7
Site of Tumour and the Level of Amputation

Site of Tumour	Level of Amputation
• Upper end of humerus	• Four-quarter amputation
• Upper end of femur	• At an early stage • Hip disarticulation • At late stage • Hindquarter amputation
• Lower end of femur	• At an early stage • Mid-thigh amputation • At late stage • Hip disarticulation
• Upper end of tibia	• Mid-thigh amputation

Radiotherapy

Radiotherapy helps in the shrinkage of the tumour mass. It, many a times, offers relief in pain. It is one of the effective palliative measures in reducing the residual mass of tumour either before surgery or in cases where surgery cannot be performed.

Chemotherapy

Chemotherapy is helpful when used in combination with radiotherapy and/or surgery. The drugs (cytotoxic drugs) used in chemotherapy are of various types and are used in a combination of 2–4 drugs. The drugs commonly used in the treatment of malignant bone tumours are cyclophosphamide, adriamycin, vincristine, nitrogen mustard, methotrexate and actinomycin-D.

However, the cytotoxic drugs are extremely toxic and produce marked side effects in patients.

Prognosis

The prognosis of malignant bone tumours is generally poor; however,

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a combination of surgery and chemotherapy has improved the prognosis remarkably, over the years. The 5-year survival rate after the combination treatment has been reported as 70%.

Secondary bone tumours (bone metastases)

Secondary bone tumours are metastatic deposits from primary tumours in some other tissues. The carcinoma of breast, kidney, lung, thyroid and prostate usually metastasize in the bone during or after middle age. The common sites of metastatic deposits are vertebrae, pelvis, ribs, proximal humerus or proximal femur.

Routes of metastasis

Through

- Blood
- Direct spread
- Lymphatic spread

Treatment

The treatment modalities will vary by the severity of the stages and the methodology of the management of the disease (Table 23-8).

Table 23-8
Essential Features and Management of Pseudo-Tumours or Resorptive Bone Tumours

Pseudo-Tumour	Origin	Common Site	Clinical Features	Radiographic Features	Treatment
Aneurysmal bone cyst (10–40 years) M>F (Fig. 23-11)	Bone	Ends of long bones (metaphysis)	Localized pain and swelling	Centrally placed radiolucent areas in the metaphyseal ends of long bones	• Curettage and bone grafting • Excision of the lesion
Simple	Localized	Metaphyseal region	Asymptomatic	Well-defined centrally	• May

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unicameral bone cyst (children and adolescents) M>F (Fig. 23-12)	cystic bone lesion	of the long bones (e.g., proximal humerus) (Fig. 23-5) close to a growth plate	till pathological fracture occurs	placed lytic area. Break may occur in the cortex resulting in a pathological fracture (Fig. 23-5)	heal spontaneou • Aspiration of a cyst, inject methyl prednisolo • Curettage and bone grafting in a large cyst

Drugs

- Analgesic drugs to control pain. Hormonal drugs in carcinoma of breast and prostate.
- Chemotherapy: To control primary focus and the spread.
- Radiotherapy: To obtain shrinkage of tumour.

Surgery

It involves decompression when the tumour mass compresses upon the spinal cord. Division of the sensory nerves, nerve roots or nerve tracts may be necessary to control severe pain. If the tumour fungates, its excision or amputation may be necessary. Pathological fractures due to secondary metastases of the long bones may need internal fixation.

Physiotherapeutic management (table 23-9)

Objective: The main objective is to use all the necessary physiotherapeutic measures to maintain and promote the optimal function of the affected part in particular and the whole body in general.

Table 23-9
General Principles of Physiotherapy

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Early stage	
• Keep up the morale of patients who are highly depressed	• Counselling • Emphasizing moving unaffected body parts (ability) and maximizing functional activities • Diversion procedures as per aptitude (e.g., reading and playing cards)
• Reduction of pain	• Pain-free relaxed rhythmic movements • Cryotherapy if accepted well • Medications
• Reduction of oedema	• Lymphoedema which persists longer and is difficult to control; it is treated by • Relaxed full ROM free active movements to distal most joints • Limb elevation
• Improvement in muscle function and joint flexibility	• Intermittent compression • Gentle effleurage • Simple full ROM or maximum ROM exercise, progressing (PRE) in a graduated manner
Late stage	
• Improving restoring function in complicated cases involving limbs or major surgical procedures	• Early initiation of assistive functional activities, to provide optimal functional independence • Guidance and training in the use of orthosis or prosthesis for functional self-sufficiency

Definitive physiotherapy measures cannot be specified due to the complexities of the disease and remarkable individual variations in the disease process and the medical management.

Some broad outlines

- *Psychological upgrading*: The patient usually suffers from a great psychological trauma resulting in depression, anxiety and loss of self-confidence. Along with appropriate comforting physiotherapeutic measures, the physiotherapist has to provide all possible encouragement through counselling along with emphasis on the patient's abilities rather than inabilities.

- Worrying over the disease and remaining sedentary happens to be a natural human tendency in any sickness. Longer periods of personal attention during the treatment right from the initial stage, use of touch and support provide adequate assistance in winning the confidence of a patient to perform difficult physical activities.

Assessment: Routine procedures of assessment should be carefully employed to assess the specific problems; they should be recorded as

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initial evaluation, along with other investigations and planned medical treatment.

The whole process of physiotherapy should be drawn in gradually progressive steps.

Contraindications

- Not to use any physiotherapeutic modality which results in increase in circulation (especially early stage).
- No thermotherapy should form part of therapy.
- Deep heating modalities close to the site of lesion are totally contraindicated.

Early stage

Measures to control oedema: When lymphoedema is present, it is difficult to control and takes long time to reduce.

Measures to control pain

- Joint movements: Encourage and promote ROM by slow-relaxed-brief active movements.
- Muscular weakness: Repetitive movements are done with slow speed for a brief period. Controlled isometrics are ideal to improve muscular strength.
- Functional activities: Nonexerting performance of the functional activities of daily routine. They may vary from sitting up and transfers to ambulation.

Late stage

- If surgery is performed, depending upon the type and the extent of surgery, all postsurgical physiotherapeutic techniques described, under each heading should be employed.

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- The procedures to improve strength and endurance should be started.

- In selected cases, low intensity, brief sessions of cardiorespiratory conditioning to provide multiple benefits should be attempted ensuring safety, e.g., especially in young adults.

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CHAPTER
24

Arthrodesis, arthroplasty and osteotomy

OUTLINE

- Arthrodesis
- Intra-articular arthrodesis
- Extra-articular arthrodesis
- Arthroplasty
- Arthroplasty of the hip joint
- Arthroplasty of the knee joint
- Arthroplasty of the ankle joint
- Arthroplasty in the upper limbs
- Arthroplasty of the elbow joint
- Arthroplasty of the wrist joint
- Arthroplasty of the hand
- Arthroplasty of the PIP joints
- Osteotomy

Arthrodesis

With the advent of replacement arthroplasty and other reconstructive surgical procedures, arthrodesis is undertaken selectively only as a salvage procedure.

This procedure involves fusion of a joint which has been

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damaged/destroyed due to disease/trauma beyond repair or reconstruction with marked instability, severe pain and functional handicap.

The procedure provides remarkable relief of pain and offers maximum stability to the joint, but at the cost of mobility. It is generally performed only at one joint in a limb provided the other joints of the same limb as well as those of the contralateral limb are good. It is always performed to fuse the affected joint in a functional position, to promote the use of the limb for ease of activities of daily living (ADLs); which are not possible otherwise.

Indications of arthrodesis

1. *Infection*, e.g., tuberculosis

2. *Paralytic conditions*: Arthrodesis is done for a flail joint, e.g., shoulder in brachial plexus injuries, arthrodesis of foot joints in poliomyelitis.

3. *Malignancy*: The involved joint is fused after excision of a malignant joint.

4. *Degenerative conditions*: Arthrodesis is done to relieve severe pain, e.g., arthrodesis of the subtalar joint in secondary osteoarthritis of the subtalar joint following an intra-articular comminuted fracture of the calcaneum.

5. *Miscellaneous*: Arthrodesis is also indicated after failure of a total joint replacement.

The operation of arthrodesis is performed in two ways:

1. Intra-articular arthrodesis

2. Extra-articular arthrodesis

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Intra-articular arthrodesis

In this procedure, the articular cartilage is removed from both the opposing bony ends of the joint and the bone ends are cut and shaped to fit in an optimum functional position (Fig. 24-1). The fusion is secured by internal fixation, an external fixation device, by a plaster cast, or by a combination of these methods. This type of arthrodesis is commonly performed in the hip and knee joints for tuberculosis.

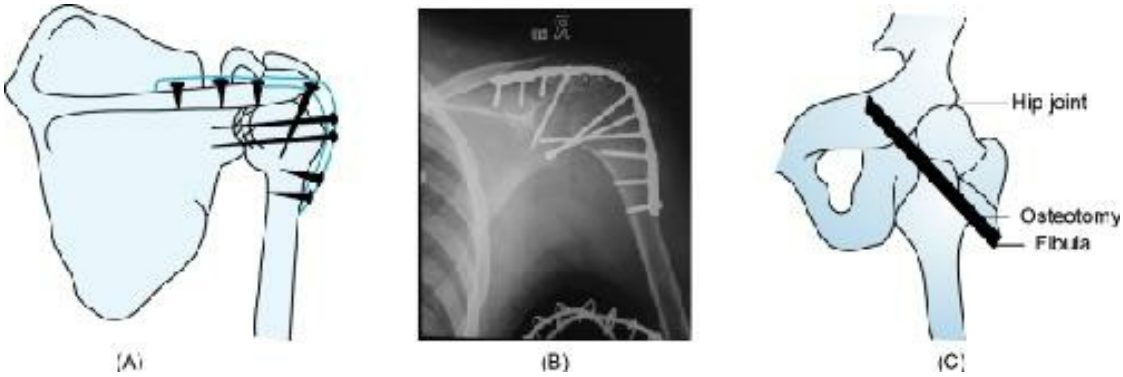

FIG. 24-1 **(A)** Intra-articular arthrodesis of the shoulder joint. **(B)** As seen on a radiograph. **(C)** Extra-articular arthrodesis of the hip joint.

Extra-articular arthrodesis

In extra-articular arthrodesis, the joint surfaces are not denuded of its articular cartilage but the fusion is achieved in the position of optimum function, by a bone graft placed outside but adjacent to the joint (Fig. 24-1), e.g., hip and shoulder joints.

Position of arthrodesis

The position of arthrodesis for a joint depends upon the functional requirements of the individual. The standardized functional positions of arthrodesis for various joints are as follows (Table 24-1):

1. **Shoulder:** The shoulder joint is arthrodesed, in 40–50 degrees of true abduction, 15–20 degrees of flexion and 25 degrees of medial

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rotation. This position facilitates the hand to reach the mouth.

2. **Elbow:** Arthrodesis of the elbow joint is rarely performed. The indication includes destruction of the joint by infection or trauma. When only one joint is affected, it is arthrodesed in a position of 75–90 degrees of flexion, for sedentary jobs whereas for bilateral arthrodesis, one elbow is fused in 110 degrees of flexion to enable the patient to reach the mouth, the other elbow in 65 degree to facilitate toileting, etc.

3. **Wrist:** Wrist joint fusion is commonly performed for the following conditions: tuberculosis, rheumatoid arthritis, secondary osteoarthritis following fractures of scaphoid and lower end of the radius, as a reconstructive procedure for nerve and tendon injuries, Volkmann ischaemic contracture, poliomyelitis and cerebral palsy.

In unilateral wrist arthrodesis, it is fused in 10–20 degrees extension (Fig. 24-2) whereas for bilateral disease, one wrist is fused in 20 degrees of extension and the other in slight flexion.

4. **Hand:** Arthrodesis of the smaller joints of the hand is indicated when the joint is damaged by injury or disease resulting in pain, deformity or instability.

Fingers: The metacarpophalageal joint is fused 20–30 degrees of flexion. The proximal interphalangeal joint is arthrodesed in 40–50 degrees of flexion (slightly less in the index and middle fingers), while the distal interphalangeal joints are fused in 15–20 degrees of flexion.

Thumb: Instability, pain or deformity due to trauma burns, contracture, nerve palsy, injury to the collateral ligament or osteoarthritis of the carpometacarpal joint may require

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arthrodesis. The interphalangeal joint of the thumb is arthrodesed in 15 degrees of flexion (Fig. 24-3) and the metacarpophalangeal joint in 10–20 degrees of flexion. The carpometacarpal joint is fixed in 40 degrees of palmar abduction and 20 degrees of radial abduction.

5. **Hip:** The arthrodesis of hip is generally indicated when the articular cartilage is eroded, the joint is destroyed to an extent where a mobile joint cannot be expected. The commonest indication for fusion of the hip is tuberculosis. Arthrodesis should, however, be performed in an adult patient only. The optimum position for arthrodesis of the hip joint is as follows:

Flexion: The flexion actually varies with age; degree of flexion for each year of age is up to a maximum of 20 degrees. To facilitate standing, walking and sitting, the usual choice of arthrodesis is 15–20 degrees of flexion.

(a) *Abduction*: The extent of hip abduction depends upon the degree of the limb length disparity as abduction leads to apparent lengthening of the limb. The usual position of arthrodesis is the neutral position of abduction and adduction.

(b) *Rotation*: The hip joint is usually arthrodesed in the neutral position of external and internal rotation or in slight external rotation.

6. **Knee:** The knee joint is arthrodesed, mostly for tuberculosis, either in full extension or in 20 degrees of flexion.

7. **Ankle:** In men, the ankle joint is arthrodesed in the neutral position while in women, who wear high heels, in 15–20 degrees of plantar flexion. It is commonly indicated in secondary osteoarthritis following

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trauma or tuberculosis.

8. **Subtalar (talocalcaneal) joint:** It is arthrodesed in the neutral position. The talocalcaneal joint arthrodesis is most commonly performed following comminuted fracture of the calcaneum with severe pain and inability to bear weight. This joint is fused along with the talonavicular and calcaneocuboid joints (triple arthrodesis) in deformed/flail foot in poliomyelitis (Fig. 24-4).

9. **Great toe:** The metatarsophalangeal joint (MP) is arthrodesed in a few degrees of extension and slight valgus (Fig. 24-4) (a little more extension for women wearing heels). It is performed for painful conditions such hallux rigidus and hallux valgus. The interphalangeal joints are arthrodesed in the neutral position in addition to tendon transfers in poliomyelitis.

10. **Rest of the toes:** The rest of the toes are arthrodesed in the neutral position.

11. **Spine:** Arthrodesis of the spine is routinely performed for a large number of conditions. The types of spinal fusion are as follows:

(a) *Posterior spinal fusion:* This is commonly performed in scoliosis, old healed tuberculosis, in association with disc excision surgery, in fracture dislocations of the cervical spine, etc.

(b) Posterolateral fusion is performed in spondylolisthesis.

(c) Transalar fusion is performed between the transverse processes of the lower lumbar vertebrae and the ala of the sacrum. It is commonly performed in spondylolisthesis at L4–5 or L5–S_1 levels.

(d) Anterior spinal fusion is done in tuberculosis of the

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spine, spondylolisthesis and in patients who have had laminectomy.

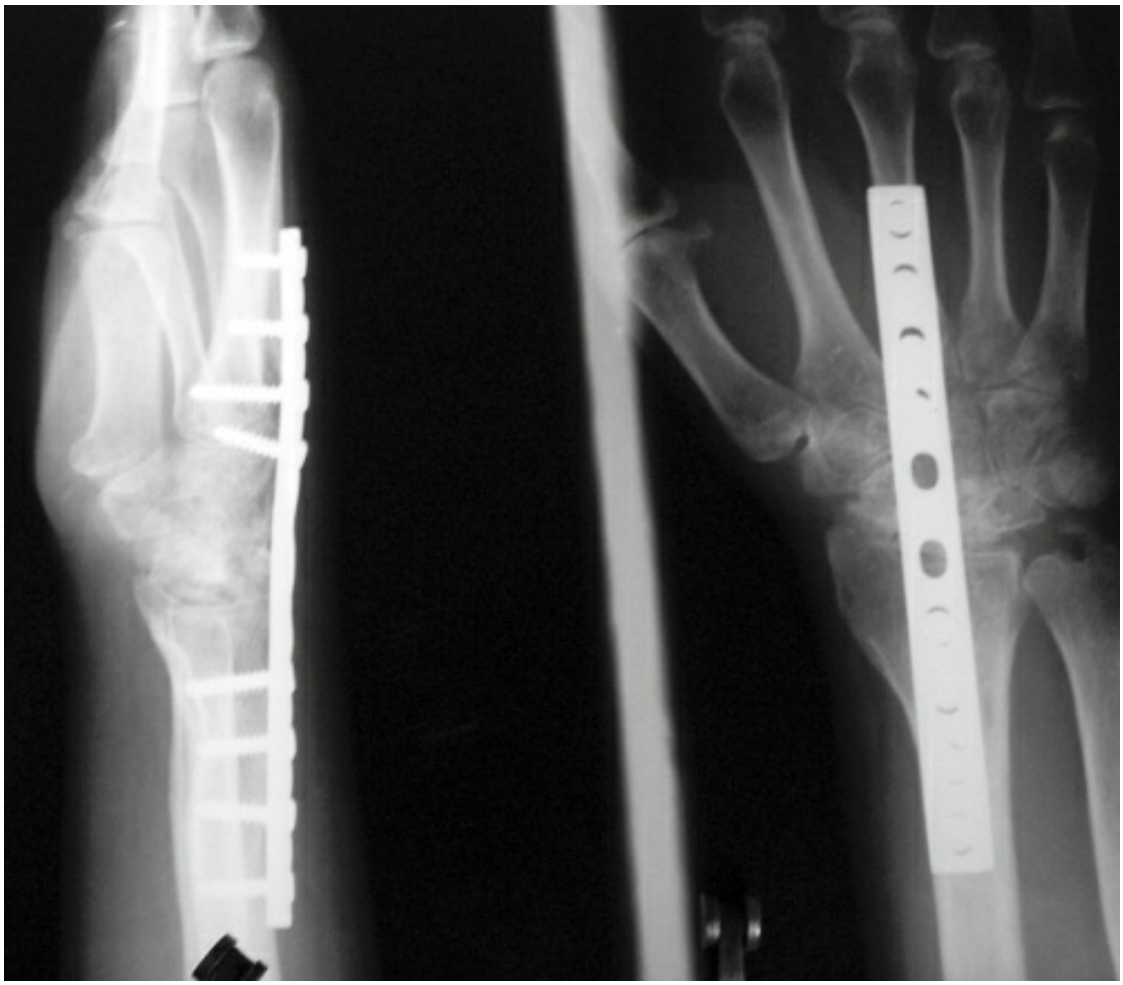

FIG. 24-2 Wrist arthrodesis.

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FIG. 24-3 Thumb arthrodesis.

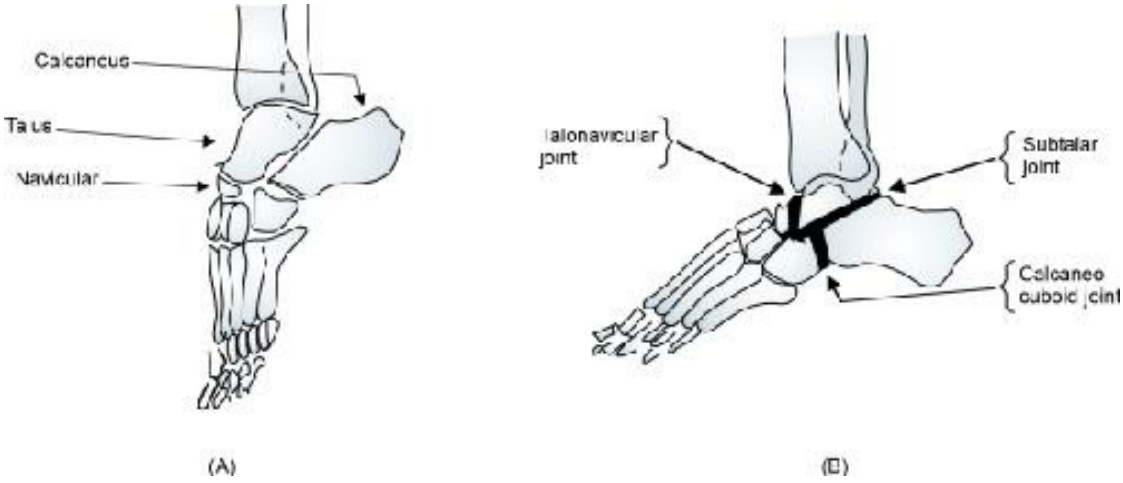

FIG. 24-4 Triple arthrodesis: **(A)** equinus deformity, and **(B)** correction of

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deformity and fusion of talonavicular, subtalar and calcaneocuboid joints.

Table 24-1

Position of Arthrodesis of Various Joints

Joint	Position of Arthrodesis
• Hip	• In 15–20° of flexion with neutral position of abduction, adduction and rotation • Sometimes in a few 5–10° of external rotation to facilitate ambulation
• Knee	• In full extension or 20° of flexion
• Ankle	• In men: neutral position • In women who wear high heels, 15–20° of plantar flexion is preferred
• Subtalar joint (talocacaneal joint)	• In neutral position
• Big toe (metatarsophalangeal joint)	• In a few degrees of extension and valgus
• Rest of the toes	• In neutral position
• Shoulder	• In 40–50° of abduction, 15–20° of flexion with 25° of internal rotation
• Elbow (single joint involvement)	• In 75–90° of flexion (for sedentary jobs)
• Elbow (bilateral involvement): on the side of eating hand	• In 90–110° of flexion
• On the side of the hand used for toileting	• In 65–70° of flexion
• Wrist (unilateral) • Wrist (bilateral) • Forearm	• In 20° of extension • One fused in 20° of extension and the other in 10° of flexion • In 10° of pronation
• Metatarsophalangeal joints (MP)	• In 30–35° of flexion
• Proximal interphalangeal joints	• In 40–50° of flexion (slightly less in index and ring fingers)
• Distal IP joints, thumb	• In 15–20° of flexion • Carpometacarpal joint is fixed in 40° of palmar abduction and in 20° of radial abduction • Metacarpophalangeal joint in 10–20° of flexion • Interphalangeal joint in 15° of flexion
• Spine	
•Anterior, spinal fusion	• Anteriorly, the vertebrae are fused, e.g., • Tuberculosis of spine • Spondylolisthesis • Postlaminectomy
• Posterior spinal fusion	• Posteriorly, the spine is fused, e.g., scoliosis, disc excision, fracture dislocation of cervical spine
• Posterolateral fusion	• In spondylolisthesis
• Transalar fusion	• Fusion between the transverse processes of the lower lumbar vertebrae and the ala of sacrum • In spondylolisthesis, at L4–L5 or L5–S1 levels

The postoperative regime after all these types of spinal fusion is

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almost similar. Initially, the patient is nursed in bed for a period of 2–3 weeks. After this period, the patient is given a spinal support which may be a corset, plaster jacket or a brace (depending upon the disease and the level of fusion) till the fusion consolidates which may take 3–6 months.

Physiotherapeutic management

The basic objective is to train the patient to functionally use the arthrodesed joint and the limb.

Preoperative education

Depending upon the joint to be arthrodesed, the related musculoskeletal structures needed to facilitate functional tasks after arthrodesis should be identified and given special exercise training to improve:

- The strength, endurance and flexibility of the muscle groups required to perform the functional activities, ideally using proprioceptive neuromuscular facilitation (PNF) techniques.
- To improve the range of motion (ROM) of the related joints by repetitive short duration sustained stretches (manual therapy). For example, in a planned shoulder arthrodesis, sessions are given to improve muscle function of the following:
- Shoulder girdle muscles
- Elbow flexors and extensors
- Forearm pronators and supinators
- Wrist and hand muscles and all the associated joints
- Strong resistive isometrics to the muscle groups – passing over the joint to be arthrodesed, this programme should be

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made vigorous during postoperative mobilization by performing activities of daily routine (ADRs) against graded resistance) as soon as it is pain free.

Postoperative education

During immobilization

1. To prevent and/or manage the possible postoperative complications.

2. Maintenance of proper position of the operated joint. The limb should be protected against postures putting strain on the joint.

3. Strengthening and ROM exercises for the joints free from immobilization.

4. Initiating early nonweight–bearing ambulation in case of hip, knee and ankle arthrodeses. The functional use is encouraged and initiated early in upper extremity arthrodesis. These approaches of early functional mobilization need to be emphasized as immobilization following arthrodesis is often prolonged.

The major objective of physiotherapy is the education of the patient to perform the functional activities of daily routine. It is achieved by using compensatory mechanisms altering the biomechanics of the associated joints and the various postural adaptations. Encouraging persuasion of the patient to untiring efforts is an important aspect of the success.

During mobilization

The whole limb is to be exercised in the functional patterns of movements. Ideally, it should be incorporated with some objective and competitive tasks. Several repetitions of such sessions are necessary to improve function in the upper extremity. In the lower extremity, gradual and correct weight bearing, weight transfers and

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balancing should be initiated with adequate aid.

Functionally important muscle groups and compensatory techniques, e.g., trick movements, are to be strengthened to facilitate ADLs.

Guidance and assistance with several sessions a day are needed to achieve functional proficiency. A patient should be left alone to work out and surprisingly he/she may report back with self-developed compensatory methods to perform functional tasks many a times unknown to the physiotherapist.

Optimal function should be regained by 4 weeks following mobilization.

Physiotherapy following spinal arthrodesis: This is covered in Chapter 15, the section on Scoliosis.

Note: Arthrodesis provides required stability in performing major activities like standing balance and ambulation, and the functional activities of the upper limbs at the cost of mobility as such is the last resort.

Arthroplasty

Arthroplasty is performed to restore pain-free functional range of motion (ROM) in a stiff and or painful joint by replacing the joint partially or totally with an artificial joint.

Arthroplasty of the lower limbs

Arthroplasty of the hip joint

This may be of two types:

1. Replacement arthroplasty

2. Excisional arthroplasty

Replacement arthroplasty

Replacement arthroplasty is reconstruction of the joint by replacing the joint partially or totally. It can be:

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1. Hemireplacement

2. Total joint replacement

Hemireplacement arthroplasty

Hemireplacement arthroplasty is indicated in fractures of the femoral neck in elderly patients. In this operation, the femoral components of the head and the neck are replaced with a metal prosthesis. Two types of prostheses – Austin Moore and Thompson prostheses are being commonly used (Fig. 24-5). It can be used with or without bone cement (methyl methacrylate). However, nowadays, a bipolar prosthesis is more common. The stem of the prosthesis is implanted into the upper shaft of the femur with the help of bone cement while the head of the prosthesis is put in the acetabulum inside a metal cup which moves freely into the acetabulum (Fig. 24-5). The advantage of this prosthesis is that the wear of the acetabulum is relatively less and the subsequent conversion into a total hip replacement (THR) is also easy.

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(B)

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(C)

FIG. 24-5 **(A)** Austin Moore prosthesis. **(B)** Thompson prosthesis. **(C)** Fracture of the neck of the femur treated by Austin Moore prosthesis (replacement arthroplasty).

Postoperatively the patient is nursed in bed in supine position with the limb in abduction to prevent dislocation of the prosthesis. A pillow or a wedge-shaped foam block can be kept between the legs to keep them in abduction. In an elderly, disoriented or uncooperative patient, a below-knee skin traction is applied to the operated limb to avoid unwanted movements of the limb. The movements of flexion

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and adduction are particularly avoided for a period of 4–6 weeks as these movements may precipitate dislocation of the prosthesis. The traction is maintained for about a week after which mobilization is initiated. While in bed, the patient should be turned frequently to prevent bed sores, etc.

Partial weight-bearing crutch walking is started after 3 weeks, and full weight bearing (FWB) is allowed after 4–6 weeks.

Total hip replacement (THR)

In this operation, the acetabular as well as the femoral head components are replaced. There are two types of total hip joint implants:

1. Cemented implants

2. Noncemented implants

(i) In the cemented hip, the acetabular as well as the femoral components are fixed into place with the help of bone cement (methyl methacrylate; Fig. 24-6). This technique is generally used in elderly patients where the bone stock is poor, i.e., the bones are osteoporotic (Fig. 24-6A–C).

(ii) **Noncemented hip arthroplasty**, the acetabular component is fixed into place with the help of screws and the femoral component is fitted snugly into the medullary canal of femur (Fig. 24-7A and B). Bone growth around the stem of the prosthesis secures its placement in about 2–3 months. This technique is therefore used in young patients where the bone stock is good.

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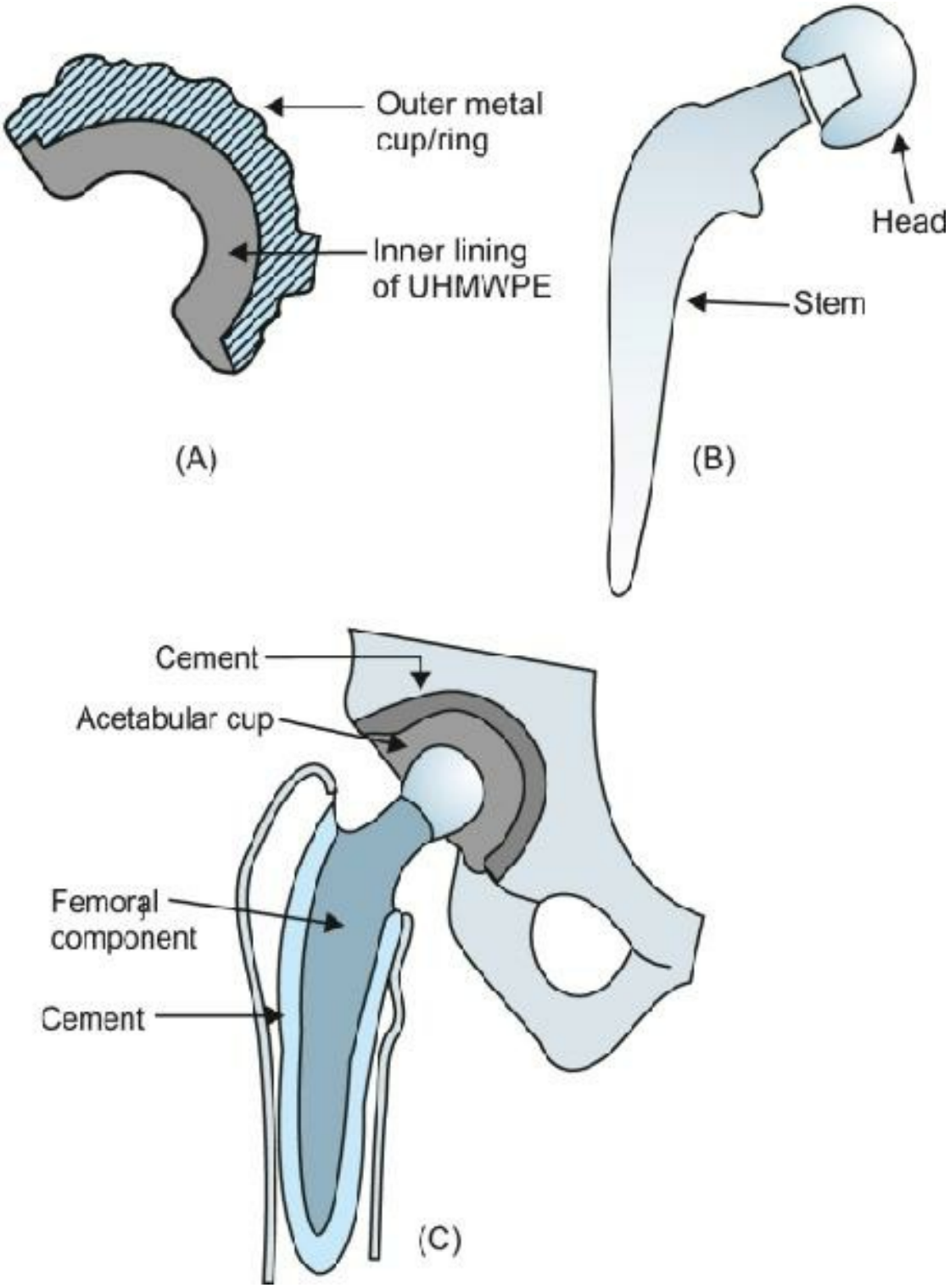

FIG. 24-6 **(A)** Acetabular cup, **(B)** femoral component and **(C)** cemented THR.

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(A)

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(B)

FIG. 24-7 **(A)** Preoperative radiograph showing osteoarthritis of both hip joints, **(B)** postoperative radiograph after noncemented total hip arthroplasty has been done on both sides.

Total surface replacement arthroplasty of the hip

This is a newer development in the field of arthroplasty of the hip. In this procedure, only the articular surfaces of the femoral head and the acetabulum are replaced by thin prostheses, leaving behind the healthy host bone largely intact (Fig. 24-8A and B). It is indicated in younger patients and is reported to give better and long-lasting results.

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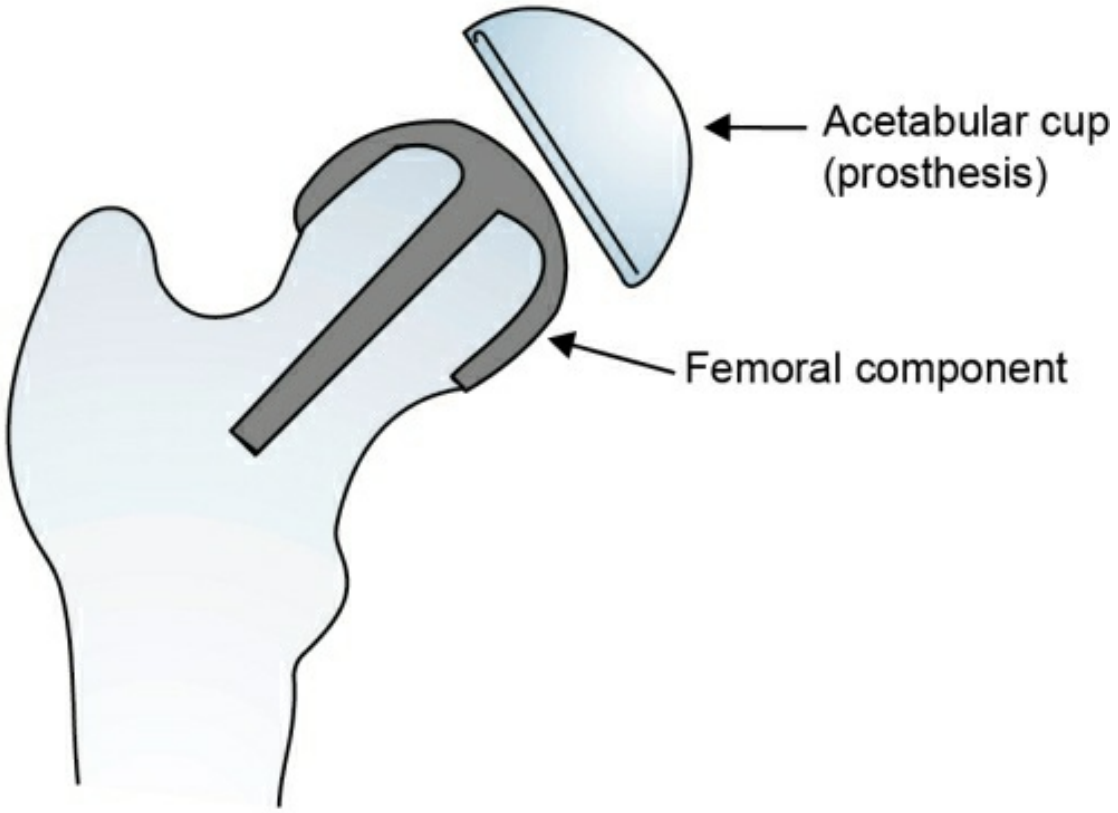

(A)

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(B)

FIG. 24-8 **(A** and **B)** Total surface replacement arthroplasty of the hip.

Postoperative regime: The patient is nursed in bed in supine position. The movement of flexion and adduction is avoided to prevent dislocation of the hip. In these patients, however, mobilization is started early in the postoperative period. The patient can be made to stand up as early as on the third postoperative day. Initially, crutches and later on a walking stick may be used for support.

Physiotherapeutic management

Objectives:

- To restore near normal or at least functional ROM to the hip joint.
- To prevent redislocation of the prosthesis in the early postoperative period.

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- To restore adequate strength, power and endurance to the functionally important muscle groups like hip extensors, abductors, knee extensors, flexors and dorsi and plantar flexors.

- To facilitate stability in the ambulatory activity.

Hemireplacement arthroplasty: Hemireplacement is a common procedure done for fresh and ununited fractures of the femoral neck in the elderly and in avascular necrosis of the femoral head.

The objective of pre- and postoperative evaluation and education as well as postoperative physiotherapeutic regime follows the same routine as described for THR.

The basic differences, however, are as follows:

As the surgical procedure involves the replacement of only the head and neck of the femur, the whole programme can be initiated earlier than THR.

Other precautions during the early postoperative phase:

- Avoid active flexion and adduction but continue self-resistive isometrics to these muscles by blocking these movements with the help of the contralateral limb after adequate guidance.

- Encourage isometrics to the hip extensors by pushing the whole limb down on the bed within a pain-free range. Increase its duration and intensity as the pain reduces.

- Prevent the development of pressure sores by alert nursing care.

- Avoid undue stiff knee by early check and guidance.

Guidance in ambulation:

- Initiate ambulation on a walking aid (walker) to gain confidence.

- Start partial weight bearing (PWB) by 3 weeks, first with a walker, gradually weaning to a single crutch to a cane – not to compromise the gait pattern.

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■ By 6–8 weeks, FWB is safe with restoration of near-normal ROM at the hip joint.

The range of flexion of the hip in THR is contraindicated beyond 90 degrees; no such limitation is to be observed with hemireplacement patients. It can be taken to the near-normal range at the earliest to facilitate floor squatting at a later stage. However, excessive adduction with rotation should be avoided, to prevent subluxation or dislocation of the hip.

The programme of exercises to facilitate floor squatting and cross-leg sitting can be started early.

The exercises include the following:

1. Self-assisted hip flexion in supine lying or in sitting with back supported

2. Prone kneeling (Fig. 24-9A)

3. Knee support squatting against stall bars (Fig. 24-9B)

4. Back supported, assisted cross-leg sitting (Fig. 24-9C)

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(A)

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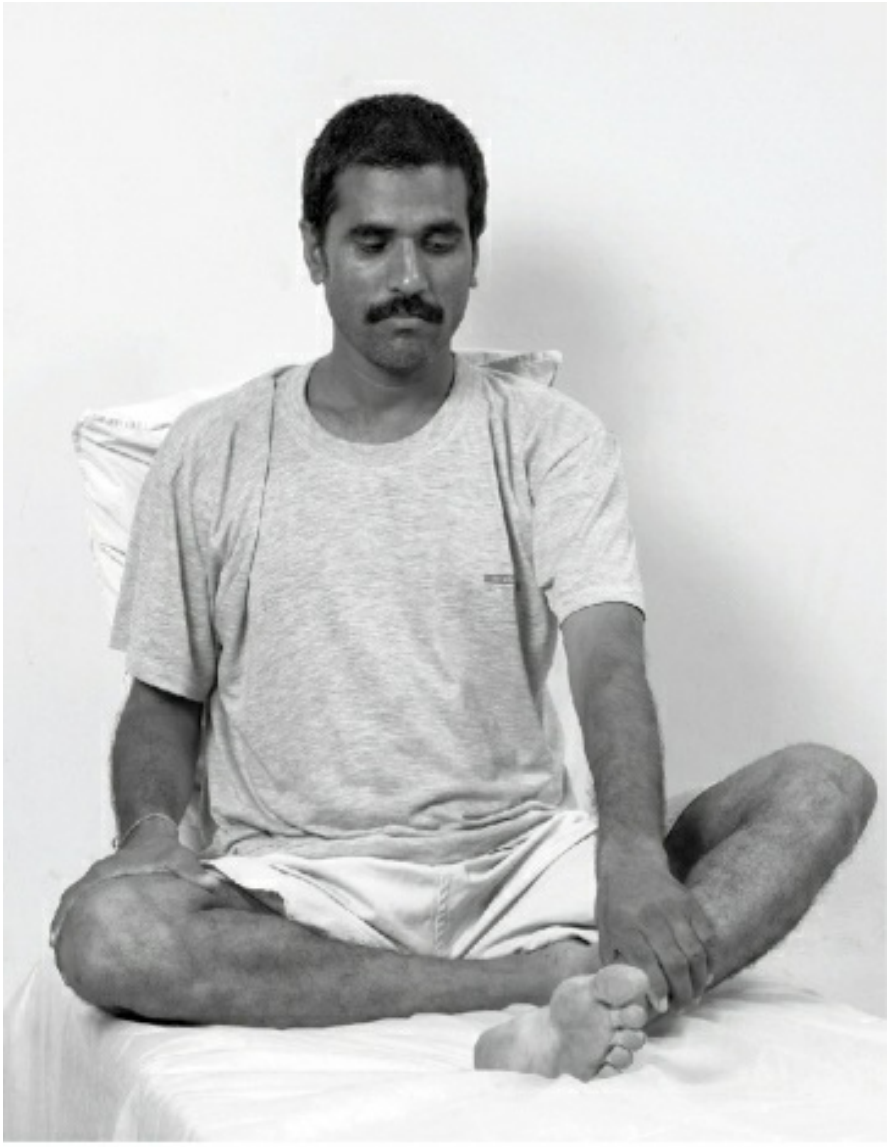

(C)

FIG. 24-9 Self-assisted early initiation of hip and knee flexion which also promotes weight bearing on the operated leg. **(A)** Prone kneeling. **(B)** Knee support squatting. **(C)** Back supported cross-leg sitting.

The exercise must give a feeling of soft tissue stretching but not pain.

FWB is quite safe by 8 weeks following surgery provided it is well accepted, and there are no complications.

The patient should be fully independent functionally by the end of 12 weeks.

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THR: The basic objective is to offer a painless, mobile, stable and functionally acceptable reconstructed hip joint.

The physiotherapeutic programme is broadly divided into:

A Preoperative regime

B Postoperative regime

Preoperative regime: The objective of the preoperative programme includes: (1) evaluation and (2) education of the patient.

1. *Evaluation*: The following parameters are used to evaluate the patient:

(a) Pain

(b) Deformity including limb length

(c) Range of motion at the hip and related joints

(d) Muscle power and muscle atrophy

(e) Ambulation and gait

We have used the functional assessment criteria as formulated by Lansky (1967) with slight modifications. We suggest that rating with numerical scores should be incorporated in all the centres (Table 24-2).

2. *Preoperative education*: It is extremely important to educate the patient on the exact regime of physiotherapy to be followed in the early postoperative period.

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Table 24-2

Functional Assessment Criteria

Ambulatory Aids		Ability to do Floor Sitting (Cross-Leg Sitting)	
Total assistance (bed ridden)	1	Unable to do	1
Chair life	2	Able to do *partially* on plinth with back supported	2
Two crutches	3	Able to do on high plinth without support	3
Two sticks	4	Able to do on the floor with considerable support	4
One cane (always)	5	Able to do with some assistance	5
One cane (outdoor only)	6	Able to do independently but with pain	6
No aid	7	Able to do without discomfort	7
Walking ability		*Ability to do floor squatting*	
Bed ridden or a few yards	1	Able to do *partially* with considerable support	2
Limited time and distance	2	Able to do *partially* without assistance	3
Limited with one cane	3	Able to do *completely* but with considerable support	4
Long distance with one cane	4	Able to do, needs some assistance	5
No aid but limp	5	Able to do independently but with pain	6
Normal for age and condition	6	Able to do without any discomfort	7
Gait without aids			
Cannot walk	1	Functional ambulation requires an ability to walk over 100 ft (30.5 m)	
Shuffles with small steps	2		
Walks with gross limp	3		
Walks with marked limp	4		
Walks with slight limp	5		
No limp	6		
Stair management			
Unable to do	1		
Does with assistance	2		
Does independently	3		
Toilet activity			
Needs assistance	1		
Manages independently	2		

It should be taught first on the sound limb or by self-demonstration for easy grasp. It is also necessary to make sure that the patient has followed these techniques.

Preoperative physiotherapy

1. Deep breathing and coughing to improve vital capacity of the lungs and to be able to get rid of the postanaesthetic secretions.

2. Strong and sustained isometric contractions to glutei, quadriceps

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and the hamstrings to improve strength and endurance of both the limbs.

3. Guidance on ROM and strengthening exercises for both the limbs to avoid stiffness and incoordination.

4. Resistive exercises for the ankle and foot on the affected side and for the weight-bearing muscle groups of both the arms, to facilitate early ambulation with walking aids.

5. Teach proper limb positioning of the operated leg in consultation with the surgeon to avoid hip dislocation in the postoperative period. Limb positioning depends upon the surgical approach to be used.

6. Teach appropriate techniques of transfers, avoiding undue strain on the operated hip.

7. Mentally prepare the patient for the painful active stage ahead.

Postoperative physiotherapy

Broad outlines of the physiotherapeutic schedule are given in Table 24-3.

Table 24-3

General Outline of Physical Therapy Schedule for Total Hip Replacement (THR)

Day 1:	1. Chest PT 2. Vigorous toe and ankle movements 3. Isometrics to quadriceps
Day 2:	1. Sitting up by gradually raising the back rest 2. Bed transfers 3. Standing, walking with partial weight bearing (PWB) or toe down weight bearing (TDWB) with a walker
Day 3–7:	1. Isometrics to gluteus maximus, medius and minimus 2. Assisted hip flexion (heel drag) and hip abduction 3. Initiate prone lying 4. Thomas stretch 5. Relaxed passive hip movements
Week 2:	Active hip flexion, knee extension (bedside sitting or chair sitting with back rest)
Week 3:	PWB walking on crutches with free swinging of the operated leg
Week 4:	1. Pedo cycle or static bicycle (possible free ROM)

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	2. Stair climbing going up with the GOOD LEG first. Coming down with the OPERATED LEG first 3. Initiate leg rotation in supine and progress to against gravity and against resistance
Week 5–6:	Gradually increase hip abduction and rotation in supine and bedside sitting
Week 6–8	Achieving near normal strength, ROM, balance standing on the operated leg alone
Ambulation and Weight Bearing Schedule	
Cemented prosthesis	
As the stability of prosthesis is achieved within 15 min of surgery, weight bearing to tolerate (WBTT) can be started on a walker immediately or on the second day • Progress to crutch walking and continue crutch walking up to 6 weeks • Use a cane for 4–6 months	
Noncemented prosthesis	
PWB or TDWB on walker for 6 weeks Progress to crutch walking and continue up to 8–12 weeks Use cane for 4–6 months Provided there is no limp or pain on weight bearing. If pain persists, go slow on FWB, give repetitive sessions of standing on the operated leg alone. Eight week onwards: FWB – minimally assisted walking; by 12 weeks: independent (unsupported) free walking	
Precautions	
Prevention of hip dislocation	
1. Avoid early initiation of hip adduction and rotation 2. Always use pillow between the legs in resting, sitting, while turning in bed or during transfers 3. Hip flexion ROM to be restricted to 80 degrees	
Prevention of Trendelenburg limp	
1. Initiate isometrics to gluteus medius, minimus and maximus at the earliest 2. Avoid straight leg raise (SLR) or hip abduction against gravity as it puts tremendous load on the hip joint 3. Proper gait training on crutches and cane 4. Continue cane support till the limp persists 5. Initiate early supported standing on the fractured leg alone without Trendelenburg sign; and progress to independent standing to eliminate limp	
Prevention of hip flexion deformity	
1. Initiate Thomas stretch within 2–3 days of surgery 2. Frequent periods of prone lying 3. True hip joint extension in prone lying	

First week

1. Chest physiotherapy to avoid postoperative chest complications.

2. To prevent pulmonary embolism: Pulmonary embolism following THR is quite common. Evarts and Feil (1971) reported an incidence of venous thrombosis in as much as 53.6% of the patients. Massive embolus usually comes from the leg veins and not from the pelvic veins. Physiotherapy plays an important role in its prevention. Charnley (1968) states, 'The physiotherapist should forget the

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operated hip for the first 3–4 days and should be on duty throughout the 24 hours just to avoid this hazard'.

(a) Careful watch to detect any local swelling, tenderness, warmth or oedema in the leg and foot.

(b) Vigorous resistive/active exercises are given to the ankle and foot with concentration on the gastrosoleus and the toe flexor groups (elastic crepe bandage may be used to resist active contractions).

(c) The knee should be supported in slight flexion by a knee roll. Hyperextension at the knee should be avoided.

3. Strong and sustained isometric contractions to the gluteus maximus–medius–minimus, quadriceps, dorsiflexors and the toe extensors should be done simultaneously on both sides. This exercise improves joint stability (Yoslow et al., 1976).

4. Relaxed passive movements – small-range relaxed passive movements for flexion of the operated hip could be initiated. Continuous passive motion (CPM) equipment provides an excellent means of initiating these movements. Isometric programme can be intensified by adding resistance at the terminal range of the available movement.

Second week

1. Relaxed passive and assisted/active movements to be progressed so that, by this time assisted hip flexion should be possible up to 90 degrees.

2. To attain further mobility, the range of CPM should be progressed. Methods like suspension therapy or using roller skates with a special board are excellent.

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3. Special attention needs to be given in exercising tensor fascia lata. The iliotibial band forms a unit with tensor fascia lata and the superficial fibres of gluteus maximus muscle, giving stability to the hip joint and preventing dislocation.

4. *Turning in bed:* Turning in bed to be initiated on the sound side with a pillow in between the legs (knees) to avoid adduction, keeping the knees bent. Bedside independent sitting should be initiated with knees hanging and transferring the weight on both the hip joints.

5. *Standing:* Transfers from bed to wheelchair and to the parallel bars. Brief periods of PWB can be initiated if it is not painful.

Third week

Weight bearing: Ambulation with PWB in parallel bars is safe. Watch for gait deviations.

Progress to ambulation with crutches the next day. The progression in ambulation from walker to elbow crutches, a cane or independent walking should not be hurried up at the cost of the normal pattern of gait. Therefore, in our patients, we avoid the development of wrong pattern of weight bearing. Instead, we concentrate on vigorous strengthening exercises to stabilize hip, knee and the ankle muscles. The single leg standing sessions on the operated side alone, knee standing as well as knee walking are excellent methods of training progression in weight bearing. This methodology reduces the degree of apprehension while bearing weight in standing independently and contributes significantly to the stable and good pattern of gait. Beber and Covery (1987) advocated the use of two crutches up to the end of 6 weeks. One crutch up to 8 weeks and progress to ambulating with a cane and continue for 4–6 months. Overemphasis on unsupported ambulation has to be avoided till the patient is stable and acquires acceptable gait. Patients with gluteal lurch or Trendelenburg limp must continue to use cane. The quality of gait can be improved further by the techniques of rhythmic stabilization and resistive gait as advocated by Knott and Voss (1968).

Caution

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The overenthusiastic patient should be warned against any attempt to overstretch the hip joint to attain floor squatting or cross-leg sitting.

Fourth week

1. Further progression of all the exercises.

2. Stair climbing to be added. While climbing up the steps, the patient should step up with the sound limb. For coming down the steps, step down with the operated leg first.

3. Initiate exercises on pedo cycle or static bicycle.

4. Initiate external and internal rotation in supine position.

5. The patient should be discouraged from adopting positions like long sitting and reaching forward to touch the toes, crossing the knees in sitting, floor squatting and cross-leg sitting. These positions may cause hip dislocation due to movements like flexion beyond 90 degrees with adduction and internal rotation.

Fifth week onwards

Progress all exercises, especially hip external and internal rotation, to achieve strong and functionally stable hip joint. By 12 weeks, the patient should be back to the prefracture status. This regime of physiotherapy may need modifications to suit individual requirements. In our experience, the results of THR have been good except in cases of ankylosing spondylitis. In ankylosing spondylitis, there is a tendency for reankylosis.

Broad Guidelines for Graduated Weight-bearing Following THR

1. Initial ambulation on a walker – adequate support to prevent development of a limp – first 4–6 weeks

- Practising standing balanced with equal weight bearing

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on both the legs.

- Efficient in weight transfer to the affected limb.
- Brief independent standing on the operated leg alone.

2. Using both crutches – may be continued for another 2 weeks.

3. Using a single crutch up to 8 weeks.

4. Walking stick – up to 6 months or could be permanent in weak/elderly patients.

5. Any walking aid which is needed for an adequately confident ambulation may have to be continued in patients with associated neurological disease.

(Programme of vigorous strong isometrics to the glutei, quadriceps and hamstrings is to be continued during ambulatory training)

Precautions: Activities contraindicated for patients treated with THR.

1. Squatting on the floor.

2. Cross-leg sitting

3. Hip flexion beyond 90 degrees

4. Position of flexion–adduction and internal or external rotation, e.g., knee crossing in sitting in the chair.

5. Long sitting and excessive trunk flexion stressing the hip joint, e.g., attempted toe touching.

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Excisional (girdlestone) arthroplasty

Excisional arthroplasty of the hip is indicated in the following conditions:

1. An advanced case of tuberculosis of the hip where extensive destruction of the femoral head and/or acetabulum has taken place and the joint cannot be salvaged.

2. Severe osteoarthritis in the elderly where any other reconstructive procedure is contraindicated.

3. Painful ankylosis of the hip in ankylosing spondylitis.

4. Rarely, septic arthritis of the hip.

5. Pyogenic infection of the hip following surgical procedures or fracture of the neck of femur or THRs.

6. Unsuccessful cases of THR or failed open reduction internal fixation (ORIF) in severe fractures of the hip.

In this procedure, the femoral head and neck are resected down to the base of the trochanter; the superior margin of the acetabulum is also resected to curette out the diseased portion. A gap is thus created between the acetabulum and the trochanter (Fig. 24-10).

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FIG. 24-10 Excision arthroplasty at the hip.

Postoperative regime

The patient is given skeletal traction through the upper tibia for a period of 5–6 weeks. However, intermittent mobilization to the knee and hip is started after 4 weeks while in traction. Nonweight–bearing crutch walking is started after 6 weeks. FWB is started after 3–4 months.

After this operation, the patient regains a painless, mobile hip but loses stability at the hip and the length of the limb.

Physiotherapeutic management

This procedure, also known as *excisional arthroplasty*, is a salvage procedure. It is indicated in selected cases of tuberculosis and septic arthritis of the hip. The aftermath of surgery poses three main problems:

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1. Fairly mobile but unstable hip joint

2. Marked shortening of the limb

3. Weakness of the muscles around the hip

The objective of physiotherapy is to provide maximum functional stability to the operated hip. The physiotherapeutic programme is divided into two parts:

1. Preoperative evaluation and education

2. Postoperative therapeutic regime

1. **Preoperative evaluation and education**

(a) Considering the longer period of postoperative immobilization, isometric exercises for the glutei, knee extensors and flexors should be started at the earliest and, ideally, they need to be repeated for 5 min every hour.

(b) Resisted ankle movements.

(c) The expected outcome of the surgical procedure should be explained to the patient.

2. **Postoperative therapeutic regime**

First and second week

Physiotherapeutic measures:

1. Chest physiotherapy

2. Prevent pulmonary embolism and thrombosis

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3. Prevent muscle atrophy

4. Check the position of the limb and the traction

5. Vigorous isometric to the hip and muscles passing over the knee joint

6. Resistive exercises to the normal limb and ambulatory muscles of the upper extremities.

7. Strictly ensure that the immobilized limb is maintained to prevent dislocation of the prosthesis in the early postoperative period.

Third and fourth week

The traction is discontinued intermittently to initiate mobilization.

1. Small range of relaxed passive movements should be initiated at the hip. Begin with hip flexion and extension. Progress to abduction and rotation.

2. Full range active resistive movements to the knee and ankle.

3. Sitting: Initiate passive hip flexion up to 60 degrees by raising the head end or using a back rest, with the traction on.

4. Measures to prevent fixed flexion deformity (FFD) at the hip.

Fifth and sixth week

1. All the earlier therapeutic programmes should be intensified.

2. Suspension therapy can be given to promote mobilization.

3. Short periods of relaxed passive stretching of hip flexion, extension and abduction movements are important at this stage to avoid fibrosis.

4. Isometric contractions: The patient should be taught to actively

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contract gluteus maximus by pushing the limb against the mattress or pillow and sustaining it for 10–15 s.

Sixth week onwards

Traction is removed and the patient is put on vigorous exercises.

1. *Nonweight–bearing standing*: Bedside sitting and short-duration standing on the sound limb should be started.

2. *Intensive stretching*: Any limitation of ROM in the hip can be safely stretched to the maximum. Supportive modality in thermotherapy may be used.

3. *Continuous stretching*: To prevent hip flexion and adduction contractures, gentle sustained traction may be necessary. The patient should be encouraged to frequent prone lying and to perform isometrics to the glutei.

4. *Strengthening exercises*: Gravity resisted hip movements and graded exercises on static bicycle should be started to strengthen the hip muscles.

5. *Limb length disparity*: Limb length disparity should be accurately measured and compensated. However, there is another school of thought which prefers delay in correction in the limb length by at least 6 months for the fear of progressive upriding of the trochanter, due to weight bearing.

6. *Weight bearing*:

(a) PWB crutch walking should be initiated in parallel bars or with the help of double crutches.

(b) FWB: Total weight bearing should be started 12 weeks after the surgery. Partial compensation for limb shortening may be provided. Migration of the proximal

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end of the excised femur is a problem as it disturbs the stabilizing abductor mechanism.

Weight bearing may be started in parallel bars basically to train weight bearing and balancing on the operated leg alone, then progressed gradually to single crutch and cane. Cane may remain as a permanent aid, especially for outdoor walking. The patient should be guided to avoid undue weight bearing stresses to prevent further complications such as backache and early osteoarthritis of the normal hip and knee joints. Stair activities should be started along with ambulation on slope and rough surfaces.

With the help of regular home exercises, the patient should be independent by 14–16 weeks.

From our experience, we feel that patients with tuberculosis or infective arthritis generally do well as compared to the patients with ankylosing spondylitis (Joshi, 1979).

7. *Prone kneeling, cross-leg sitting*: These can be safely initiated and assisted to gain further range and strength in adopting these positions.

Caution

Postoperatively relaxed passive full range mobilization should be initiated and taken to the fullest range at the earliest. The movements of hip flexion and abduction with external rotation need to be emphasized in view of the functional postures of floor squatting and tailor sitting.

Prone lying and hip stretching into extension should be initiated early to avoid flexion deformity at the hip. Flexion deformity complicates efficiency in ambulation and produces excessive strain

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on the back.

Arthroplasty of the knee joint

Total knee replacement arthroplasty (fig. 24-11)

Total knee replacement (TKR) arthroplasty is indicated when there is unremitting severe pain in the knee with or without deformity. The pain or deformity may be due to osteoarthritis (primary or secondary), rheumatoid arthritis and various other nonspecific arthritides. TKR relieves pain, provides adequate mobility and corrects the deformity.

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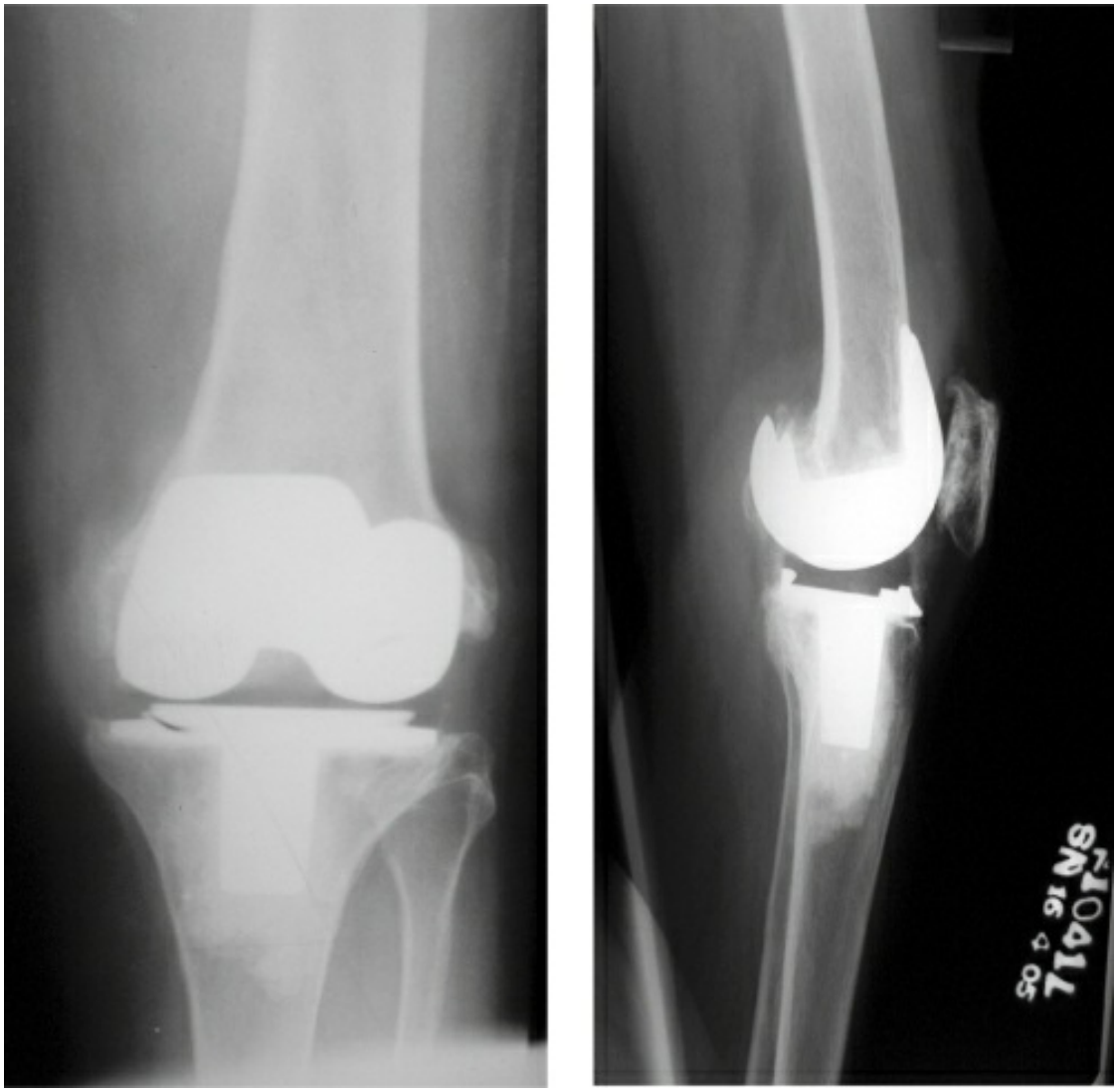

FIG. 24-11 AP and lateral radiographs showing total knee replacement arthroplasty.

TKR can be:

1. Unicompartmental (unicondylar)

2. Bicompartmental

3. Tricompartmental

1. *Unicompartmental arthroplasty: It is also called unicodylar arthroplasty (UKR).* The articular surfaces of the femur and the tibia of either the

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medial or the lateral compartment of the knee are replaced by an implant (Fig. 24-12). The other compartment of the knee joint is left intact. This type is obviously indicated for disease pertaining to one compartment only, e.g., osteoarthritis.

2. *Bicompartmental arthroplasty*: In bicompartmental arthroplasty, the articular surface of the tibia and the femur of both medial and lateral compartments of the knee joints are replaced by an implant. The third compartment, i.e., the patellofemoral joint, is however left intact.

3. *Tricompartmental arthroplasty*: The articular surfaces of the lower femur, upper tibia and the patella are replaced by prostheses. The prosthesis consists of a tibial component, a metal femoral component and a high molecular weight polyethylene (HMWPE) button for the articular surface of the patella.

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FIG. 24-12 Implant placed in unicompartmental arthroplasty of knee.

Postoperatively the knee is mobilized after about 4–5 days.

Physiotherapeutic management

The principal aim of the physiotherapy is to offer maximum static as well as dynamic stability to the knee. Severe pain, instability of the joint or deformity which cannot be corrected by osteotomy are the chief indications for total knee arthroplasty.

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Preoperative assessment: A thorough assessment is done prior to the surgery, and the postoperative regime of physiotherapy is explained to the patient.

- Pain: The degree, site and the positions aggravating/relieving the pain are recorded.
- Deformity: The degree of deformity is measured in weight bearing as well as nonweight–bearing positions. The degree of deformity is recorded when the whole body weight is borne over the affected knee alone, maybe with some support if required.
- ROM: Accurate measurements of the active as well as passive ROM at the knee are recorded. Patellar mobility is also checked and graded. Ligamentous stability around the knee is evaluated.
- Strength and endurance: Strength and endurance of the quadriceps, hamstrings and glutei are evaluated. The quality of quadriceps contractions need to be assessed in particular.
- Effusion and atrophy: The area and extent of effusion as well as muscle atrophy (especially of quadriceps) are documented.
- The other related joints, i.e., hip, ankle and foot are assessed for their alignments, ROM and strength.
- Complete gait analysis, status of ambulation and functional competence are documented.
- Physical requirements of the patient's working situation are reviewed.

Preoperative training: It includes the following:

- Explain to the patient the total postoperative regime. Biomechanics of the movements at the knee to be explained on the normal knee and the importance of regaining early ROM at the knee is

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emphasized.

- Educate the patient on the measures taken for prevention of oedema, deep venous thrombosis and chest complications.
- Training of isometrics (speedy as well as sustained) to quadriceps, hamstrings and glutei.
- Self-assisted passive mobilization, relaxed free movements, and assisted active and resistive exercises are taught on the sound limb.
- Put maximum emphasis on self-exercising methods to improve ROM and strength training mode.

Postoperative regime (Table 24-4)

Table 24-4
General Outline of Physical Therapy Schedule for Total Knee Replacement (TKR)

Day 1: 1. Chest PT 2. Vigorous toe and ankle movements 3. Maintain the limb in extension (with heel or lower leg resting on a pillow) 4. Static glutei by pressing the pillow below the heel 5. Gentle isometrics to quadriceps
Day 2–3: 1. Transfers in bed 2. Gentle patellar mobilization 3. Rapid isometrics to quadriceps (speedy and with 10 s hold) 4. Heel-assisted SLR 5. Stand and ambulate with a walker (WBTT for cemented and TDWB or PWB for noncemented) 6. Nontouch SLR – posterior aspect of the heel should not be allowed to touch the bed while bringing down the leg from the peak SLR position
Day 4–6: 1. Transfers in chair 2. Self-assisted passive knee flexion (a) Heel drag in supine (simultaneous hip and knee flexion in lying supine) position (b) Bedside sitting, relaxed knee movements with the help of sound leg (in unilateral TKR) (c) Sitting with feet planted on the ground, lift and push forward by raising trunk on arms 3. CPM 5–10 degrees daily (1 cycle per minute) • Range of knee flexion MUST NOT EXCEED 40 degrees because transcutaneous O2 tension of the skin near the incision decreases significantly after 40 degrees of flexion 4. Begin active or active assisted exercises, if the wound is clean and dry 5. Bedside active knee flexion–extension (self-assisted, if necessary) 6. Ambulation without plaster of Paris (POP) (can do 13 continuous nontouch SLRs without POP)
Day 7–10:

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1. Work up towards 90 degrees knee flexion by 10–14 days 2. Hamstrings strengthening 3. Assisted step and stairs
Day 11 to week 3: Progress all exercises
Week 4–6: 1. Work up towards knee flexion 110–115 degrees 2. Quadriceps dips and steps up 3. Stationary bicycle 4. TWB with cane
Weeks 6–11: Progressive weight bearing walking with cane, FWB by 12 weeks

First week

- Appropriate chest physiotherapy.
- Limb positioning to avoid rotation and encourage knee extension. Ideally, the heel resting on a pillow and pressing the pillow will encourage static quadriceps and gluteus maximus contractions along with extension stretch to knee.
- Gentle isometrics to the quadriceps could be started. It should be progressed to rhythmic speedy quadriceps contractions and relaxations which will promote patellar excursion and reduce oedema.
- Sustained isometrics to quadriceps, reinforced by simultaneous strong dorsiflexion of the ankle, are ideal. Slow isometrics should follow the rule of 'tens', i.e., holding maximum contractions for at least 10 s, to be done 10 times in each session and each exercise session to be done 10 times a day.
- Isometrics to hamstrings, glutei and hip abductors should also be included.
- Supported SLR could be initiated with simultaneous isometrics to quadriceps and ankle in maximum dorsiflexion (initially, with assistance under the heel).
- Bed transfers, standing or even well-assisted ambulation with walker could be attempted by third or fourth postoperative day.

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- For cemented prosthesis, weight bearing to tolerance (WBTT) or PWB can be initiated while toe down weight bearing (TDWB) is done for noncemented TKR.

- The patient should be educated on relaxed self-assisted passive or active free knee flexion extension in small range or CPM with a speed of one cycle per minute. CPM angle should progress 5–10 degrees daily (Coutts et al., 1989). However, the range of flexion should never exceed 40 degrees within the first 3 days.

- If the wound is dry and clean, assisted active or active knee mobilization can be started.

Second week

- SLR should be made intensive by slow speed SLRs with self-generated tension in the quadriceps without relaxation in between SLRs.

- Intensify relaxed passive and assisted active knee flexion exercises. By this time the range of knee flexion should reach 90 degrees or close to it.

- At the same time, independent SLR without reflex inhibition of quadriceps should be achieved.

- Once three independent SLRs against gravity in supine position are achieved, ambulation without immobilizer can be started.

- Weight transfers and PWB on the operated limb may be started on crutches.

Three to six weeks

- Work up to achieve knee flexion close to 110–115 degrees.

- Single crutch walking and well-assisted stair activities should be

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introduced.

- Sessions on pedo cycle or even stationary bicycle could be started.
- Gait training with emphasis on free knee swinging can be started with a cane and progressed from PWB to total weight bearing.
- Hydrotherapy or pool exercises are ideal at this stage if the surgical wound has healed.
- Quadriceps dips and step and stairs in normal pattern could be initiated with assistance.

Six weeks onwards

- The patient's gait with cane should be assessed for any deviation. Also ensure that both the tibio-femoral compartments of the prosthesis are loaded evenly and not like a normal knee joint where the loading is predominantly medial.
- Specific exercise for the still persisting deficiencies to be planned and taught.
- Guided assistance may be provided for the higher levels of functional and ambulatory activities.
- Cane should be discarded by assuring normal gait pattern and the degree of stress during job requirements by 12 weeks.

Caution

- The range of knee flexion must not exceed 40 degrees within the first three postoperative days as the transcutaneous oxygen tension of the skin near the incision decreases significantly when the knee is flexed above 40 degrees. This may delay wound healing.
- Lack of patellar mobility and weak quadriceps have been found to

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be the cause of pain persistence. These two aspects need special emphasis (Dorr & Boiardo, 1986).

- The chances of developing quadriceps lag due to reflex inhibition postoperatively must be observed carefully and taken care of.
- Activities causing undue compression at the knee joint should be avoided (e.g., excessive sitting–standing or stairs activities).

Arthroplasty of the ankle joint

Total joint replacement of the ankle is indicated in selected cases of rheumatoid arthritis, osteoarthritis and haemophilic arthropathy. On the contrary, arthrodesis of the ankle joint is still a common procedure.

The presently available ankle joint prosthesis consists of a metal plate over the dome of the talus which articulates with a platform, consisting of HMWPE, attached to the lower end of the tibia (Fig. 24-13).

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FIG. 24-13 Total ankle joint replacement arthroplasty.

Postoperatively, mobilization is begun as soon as the pain permits and weight bearing is allowed after 2 weeks.

Physiotherapeutic management

Preoperative evaluation

- Passive and active ROM at the ankle
- Muscle power, endurance of the muscle groups around ankle and foot
- Ligamentous stability and joint stability

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- Gait pattern
- Adopting functional positions like floor-squatting and cross-leg sitting

Postoperative management: The ankle and foot are immobilized in a pressure bandage or a sling for 3 weeks.

- Limb in elevation, repeated toe movements to reduce oedema to be concentrated.
- Active movements of the hip and knee joints to improve the overall circulation to the operated area.
- Totally supported relaxed small range dorsiflexion and plantar flexion may be initiated by the fifth day, if wound healing is progressing well. The pressure bandage may be reduced.
- Active ROM exercises, in assisted form, to be started after the sutures are removed.
- PWB can be initiated by 2 weeks if the wound has healed completely and pain and discomfort are minimal.
- Walking with PWB by using elbow crutches is ideal for gradual increase in weight bearing and re-education of gait.
- While working on the ROM, dorsiflexion should be emphasized to facilitate functional floor-squatting posture.
- Stretching of the scar and the replaced joint should always be carried out in a controlled manner with relaxed passive sustained stretching, and guided for self-stretching mode.
- If the gait is near normal and weight bearing is not very painful, a cane may be used instead of elbow crutches.

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- Functional activities like squatting with assistance of wall bars and standing ankle stretches with minimal discomfort could be initiated to gain further range of plantar flexion and dorsiflexion.

- Negotiating steps with the normal leg leading while going up and the operated leg leading while coming down is taught, with minimal assistance.

- Cane support is reduced and progressed to independent walking only when the pain is minimal and there is no limp.

- The patient should be back to his/her normal activities by 8–10 weeks.

Caution

Prosthetic loosening and deep infection are the common complications to be watched for during rehabilitation. The results have been generally superior in rheumatoid arthritis as compared to posttraumatic arthrosis (McGuire et al., 1988).

Arthroplasty in the upper limbs

Arthroplasty of the shoulder joint

Like the hip, the arthroplasty of the shoulder is also of two types:

1. Hemireplacement arthroplasty

2. Total joint replacement

Hemireplacement arthroplasty

It is indicated in severely comminuted fractures of the proximal humerus. In this procedure, the fractured humeral component is replaced by a prosthesis and fixed with the help of bone cement (Fig. 24-14A and B).

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(A)

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(B)

FIG. 24-14 **(A)** Preoperative radiograph showing comminuted fracture of the proximal humerus. **(B)** Postoperative radiograph showing prosthetic replacement in situ.

Total joint replacement

In total shoulder arthroplasty, the humeral head and the glenoid articulating surfaces are replaced by prosthetic components. total shoulder arthroplasty may be indicated in severely comminuted fractures of the shoulder, secondary osteoarthritis or rheumatoid arthritis of the shoulder joint.

The Neer prosthesis (Neer and Watson, 1982) is most commonly used. In this, the scapular surface is replaced by a shallow cup while the humeral surface is replaced by a ball (Fig. 12-15).

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FIG. 24-15 Total shoulder arthroplasty.

The Liverpool (reverse) shoulder prosthesis (Beddow & Elloy, 1977) has a reverse ball and socket arrangement, the ball being on the scapular side and the cup on the humeral side (Fig. 24-16). Although technically it is a demanding surgical operation, excellent pain relief has been reported apart from a sound scapular fixation.

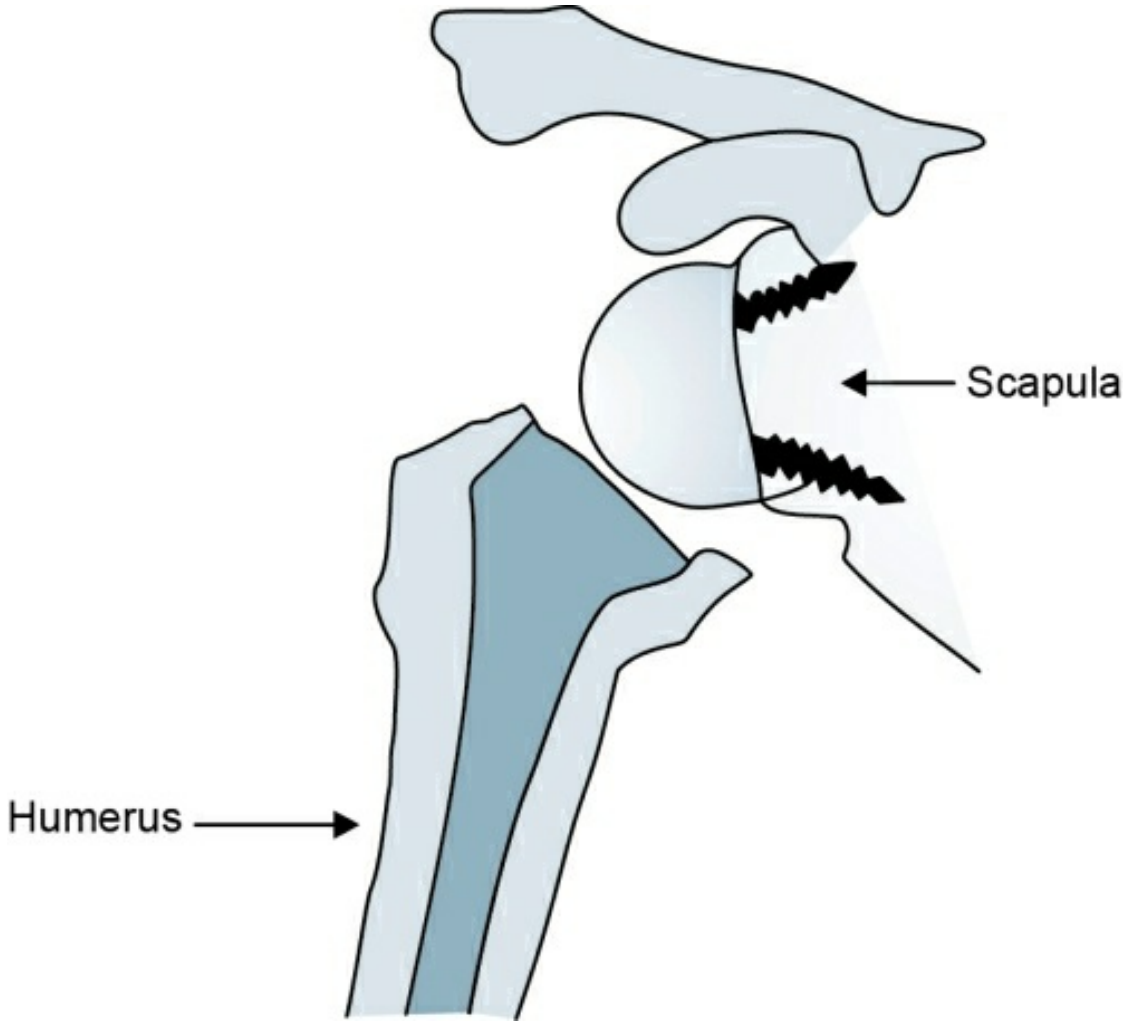

FIG. 24-16 Reverse total shoulder joint replacement.

The shoulder joint is mobilized 2–3 weeks after the operation.

Physiotherapeutic management

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Normally the shoulder joint is an unstable joint which owns its stability to the strong muscles and ligaments around it. Laxity of ligaments due to rheumatoid arthritis, weakness of muscles due to mechanical disadvantage, nonuse or partial use, or even ruptures of the rotator cuff pose the problem of return of early and strong movements following surgery. The movement of rotation is prone to precipitate dislocation and needs careful monitoring. Therefore, the physiotherapy should be planned keeping note of all these situations.

Preoperative assessment

- ROM active as well as passive
- Functional status of the whole limb
- Muscle power of the shoulder girdle muscles
- Professional or daily activities of the patient

Postoperative regime

First two weeks

- The arm is immobilized in a sling under the clothes.
- No shoulder movement is attempted.
- Active movements to the wrist, hand and fingers are encouraged and repeated as often as possible.

Three to six weeks

- The sling can be worn outside the clothes and graduated mobilization is begun.
- Relaxed passive swinging of the shoulder in a small range of flexion–extension is begun in stoop standing with sling.
- Abduction and adduction can be initiated in sling suspension with

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total arm support or only as a small range of relaxed passive movement in supine position, or with CPM.

- Active assisted flexion–extension and abduction–adduction are initiated with the patient in supine position with the elbow maintained in 90 degrees of flexion throughout. The physiotherapist stabilizes the shoulder girdle and takes total weight of the arm. Alternatively, CPM can be used to a great advantage.

- No attempt should be made to perform rotation, either passive, active or active assisted.

- Regular increase in the ROM is to be assured. In standing, swinging arm with elbow in extension is encouraged.

- Assisted programme should be progressed to active or if possible with small and graded resistance.

- Passive range of 90–120 degrees of flexion elevation and 70–90 degrees of abduction should be attained by this time.

After six weeks

- Passive range of lateral rotation to be initiated gradually, beginning with arm by the side of the body.

- Other movements to be progressed to active resistive regime. Passive stretching, hold-relax PNF techniques, passive self-stretching sessions in supine position to be concentrated to gain further ROM.

- Introduction of functional activities with guided resistance or assistance should be encouraged. In the majority of cases, adequate functional ROM and muscle power should be regained by 10–12 weeks.

- Normal to near-normal functional shoulder should be restored by

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10–12 weeks.

Caution

The movement combination of abduction with external rotation, and adduction with internal rotation should be avoided to prevent dislocation.

Note: If a strong shoulder is not restored, the patient has a tendency of insecurity while performing ADLs.

Arthroplasty of the elbow joint

Arthroplasty of the elbow joint is indicated in posttraumatic stiffness of the elbow, rheumatoid arthritis and arthritis secondary to inflammatory or degenerative disease.

Types of arthroplasty:

1. Resection (excisional) arthroplasty (Fig. 24-17A)

2. Interpositional (fascial) arthroplasty (Fig. 24-17B)

3. Implant (total joint replacement) arthroplasty (Fig. 24-18A–D)

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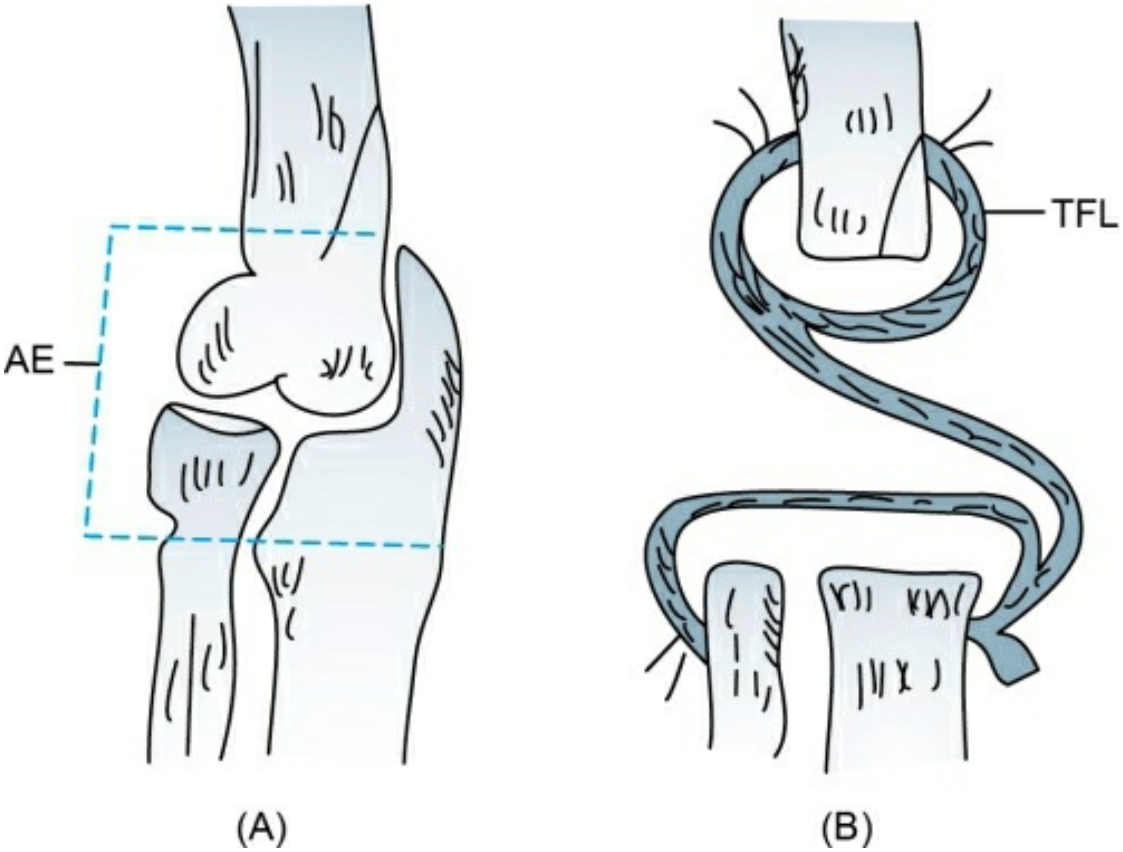

FIG. 24-17 Excisional arthroplasty. **(A)** AE: area of excision of bones. **(B)** TFL: covering the excised ends by interposing a strip of tensor fascia lata to form arthroplasty.

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(A)

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(B)

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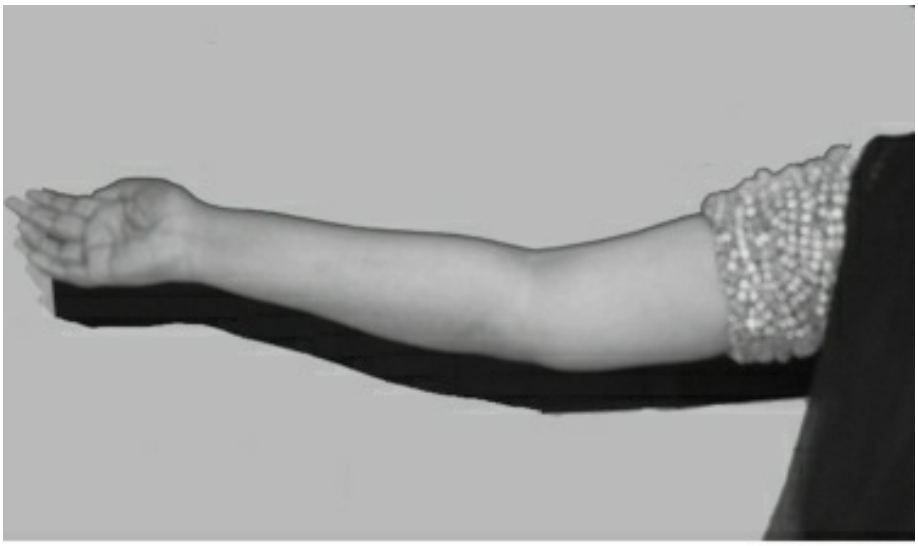

(C)

(D)

FIG. 24-18 Total elbow joint replacement arthroplasty. **(A)** Preoperative and **(B)** postoperative radiographs. **(C and D)** Result showing good range of movement.

Excisional arthroplasty

It is indicated in a stiff (ankylosed) elbow joint due to rheumatoid arthritis or trauma.

In this operation, a gap is created by excision of the lower end of the

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humerus and/or upper end of the ulna and radius (Fig. 24-17A). Some surgeons prefer to use a strip of fascia lata to interpose between the cut ends of these bones (Fig. 24-17B).

Postoperative regime: The elbow is immobilized in an above-elbow POP slab after the operation. The slab is removed after 2–3 days and the limb is given a below-elbow skin traction and suspended in an overhead traction. Mobilization of the elbow in traction is started as soon as the pain permits. The traction is removed at the end of 2–3 weeks after operation and the mobilization programme is intensified.

The patient may regain a functional range of elbow movement but may lose stability and strength at the elbow to a certain extent. Notwithstanding these limitations, patients generally do well.

Physiotherapeutic management

Elbow joint management whether surgical or conservative always poses problems, especially in adults.

Excisional arthroplasty gives a mobile elbow joint but at the cost of its stability. Therefore, physiotherapy is mainly directed to achieve active mobility of the joint. This includes painful, tiring and concentrated efforts by the patient. The management falls into two phases:

1. Preoperative assessment and training

2. Postoperative hard work

1. **Preoperative assessment and training:** Assess the elbow joint thoroughly and objectively for:

(a) The strength of the muscles around the elbow joint

(b) Active as well as passive ROM of elbow flexion–extension, pronation and supination

(c) Assessment of the range of motion and muscle power at

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the adjacent joints

The physiotherapist should explain to the patient the postoperative regime of exercises. The preoperative training can be practised on the normal elbow. Electrical stimulation can be used as an adjunct to educate as well as to strengthen the flexor and extensor muscles of the stiff elbow joint. When the joint is not totally ankylosed, surgery should be undertaken only after strengthening the muscles around the elbow joint. These include repeated self-resisted isometric and isotonic contractions of the flexor and extensor muscles as well as pronator and supinator muscles.

Ideally the surgery should never be undertaken without enough preoperative physiotherapy or enough strength in these muscle groups.

2. **Postoperative physiotherapy:** *Immediate postoperative phases*

- Maintain operated limb in elevation (sling suspension)
- Deep breathing exercises and coughing to avoid chest complications
- Pulsed electromagnetic therapy like diapulse can be given over the cast
- Initiation of static contractions inside the cast ensure its efficacy by palpation

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- Full range of movements to the shoulder, wrist and hand should be given as soon as pain permits. Repeated movements to the related joints promote reduction in pain and swelling by improving circulation.

- Repetitive self-assisted shoulder movements (relaxed rhythmic pendulum mode) are ideal.

Third day to tenth day

1. Intermittent removal of cast and initiation of small range of relaxed passive movements, if the pain and swelling permit. Small range CPM roller skates are helpful.

2. Vigorous isometric contractions should be done for 5 min every hour.

3. Sessions of electrical stimulation synchronised with active effort by the patient are very useful during this period. It promotes re-education of the muscle power.

From tenth day to 3 weeks

This is the most crucial period which needs concentrated effort. By now the stitches are out and the swelling and pain are less.

Mobilization: There are two methods of mobilization which are more acceptable to patients.

1. Small-range pendular movements of flexion–extension: The patient assumes prone-lying position with the shoulder in 90 degrees of abduction, elbow hanging over the edge of the plinth (see Fig. 7.3) and does self-controlled relaxed free movements of elbow flexion–extension.

2. Arm well supported over a sand bag and placed on the table with the shoulder in abduction and a few degrees of horizontal abduction.

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The physiotherapist stabilizes the humerus just above the elbow joint (Fig. 24-19). Roller skates can be used to perform small range of active free movements of elbow flexion–extension (see Fig. 7.3B). This should be performed several times a day.

3. Pronation–supination can be initiated by the patient sitting with the back against the wall and the posterior aspect of the elbow touching the wall. The physiotherapist stabilizes just above the elbow joint. The patient with his/her normal hand supports just above the wrist and performs relaxed assisted movements of forearm pronation–supination (see Fig. 8.5).

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FIG. 24-19 Active assisted, gravity eliminated elbow flexion–extension.

Caution

While doing this exercise, the elbow, flexed to 90 degrees, should be kept in contact with the trunk. This will avoid tricky movements in which the patient has a compensatory tendency to abduct the shoulder for pronation and adduct it for supination.

4. Vigorous progressive resistive exercise programme for the wrist

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and finger flexors as well as for the extensor muscles is of immense value. Strengthening of these muscles improves the stability of the elbow joint.

5. The range of motion and muscle power are reassessed.

6. Hydrotherapy can prove very effective at this stage.

Though the elbow flexors are functionally important, extra attention is necessary to strengthen the triceps. The posterior surgical approach involves incision of the triceps which causes great mechanical disadvantage to the action of the triceps resulting in weak extension of the elbow. By the end of 3 weeks, a definite trend of improvement should be noticed.

After 3 weeks

This is the phase of vigorous physiotherapy to regain maximum mobilization and muscle strength. However, pain may be aggravated during this period as gentle sustained stretching techniques are incorporated.

Stretching for flexion

This is done by the assistance of gravity and if possible with small weight (e.g., 1/2 lb weight belt). We use a knee rachet in this technique.

The patient is in supine position; the operated arm is well secured over the ratchet. Initially, relaxed active movement of flexion is performed towards gravity. After doing it several times, a small weight is added. The patient relaxes the elbow joint to the maximum and the flexion is facilitated by weight and gravity (Fig. 24-20A). If painful, the patient can support forearm by the contralateral hand.

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(A)

(B)

FIG. 24-20 **(A)** Gravity, weight-assisted flexion. **(B)** Extension on knee rachet.

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For extension, hinge of the rachet joint is straightened and the same principle is used to promote extension (Fig. 24-20B).

Programmes of mobilization with roller skates and strengthening are made vigorously.

The patient should be made to hold this position with active effort. By this time, pronation–supination should be near normal.

If the skin condition and the surgical incision are healthy, paraffin wax bath preceding mobilization and stretching manoeuvres provides excellent relaxation for the afore-mentioned procedures.

Progressive strengthening exercises for the biceps brachii against graded weights can be given by holding wand and weight in sitting. For the triceps, the position should be prone lying with the shoulder in abduction and the forearm hanging over the edge of the plinth.

Functional use of the hand in activities like eating, lifting and placing light objects, combing hair, shaving, buttoning, dressing and scratching the back should be encouraged, may be with little assistance. These natural movement patterns are effective means of treatment.

Judicious planning and executing the regime of exercises can result in a functionally useful elbow within 8–12 weeks of surgery.

Note:

- After each exercise session, the elbow should be maintained in the position of maximum flexion achieved with exercise.
- At this stage, guiding and supervising the patient in performing self-strength mode is a must.

Observations

1. Excessive surgical excision of the joint can result in flail and unstable elbow. The relative lengthening of the common flexor and extensor groups renders great mechanical disadvantage to the effective action of these muscles. Therefore, it results in an unstable and weak elbow joint where flexion and extension more or less remain

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only a passive entity. In these patients, a brace with an elbow hinge provides a mechanical advantage to facilitate muscle action, and strengthening. In case of a weak elbow, the brace can be locked at a desired angle for functional use.

2. Surgery in long-standing ankylosis may give a partially mobile but weak elbow joint. This may be due to the marked disuse atrophy of the muscles.

Interpositional (fascial) arthroplasty

In this procedure, the lower end of the humerus and the upper end of the ulna are excised. The exposed ends of both these bones are covered by fascia lata strip.

The postoperative management including physiotherapy is similar to that of excisional arthroplasty.

Implant (total joint replacement) arthroplasty

Total replacement of the elbow joint is undertaken when there is massive destruction of the joint due to rheumatoid arthritis, posttraumatic arthritis, etc., and as a reconstructive procedure after tumour resection.

In total replacement arthroplasty of the elbow, the joint is replaced by metal or plastic hinge prosthesis.

This procedure succeeds in providing adequate stability and mobility to the joint to a limited extent, allowing light sedentary functions.

Physiotherapeutic management preoperative assessment:

It consists of evaluation of:

1. Range of motion, passive as well as active

2. Muscle power and endurance of the flexors, extensors, pronators and the supinator groups

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3. Degree of deformity

4. Sensory status of the arm, forearm, wrist and hand

5. Integrity and functional efficiency of the shoulder, wrist and hand

Preoperative training

1. In view of the expected postoperative weakness, vigorous exercise regime is taught to improve the strength and endurance of the elbow flexors, extensors and forearm rotators. The programme of training should be initiated on the normal/better limb.

2. To improve the overall functional efficiency of the extremity as a whole, free and strong range of movements should be achieved at the related joints. This will facilitate function in the presence of moderately stiff and weak elbow joint.

Postoperative phase

During immobilization (first week)

The limb is immobilized in elevation with pressure bandage and posterior plaster shell. The physiotherapy is aimed at:

1. Reduction of inflammation

2. Thorough check on positioning and immobilization

3. Early active movements to the fingers and thumb

4. Checking the integrity of the radial, median and ulnar nerves

5. Examining the status of circulation

6. Initiating isometric light contractions to biceps brachii and triceps within the limit of pain

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Mobilization (second week onwards): If the soft tissue healing is satisfactory and the reconstructed joint is stable in the optimal position, low-grade mobilization may be initiated at the earliest. The splint is removed temporarily for exercises.

1. Initiation of movements: Elbow is put in a gravity eliminated position over the top of the table with the shoulder in full abduction and 30 degrees of flexion. The arm is supported by a thick pad from axilla to well above the elbow joint. This allows the elbow to be free from any friction. Physiotherapist stabilizes the arm above the elbow with one hand, and totally supports the forearm just proximal to wrist from below by the other hand (Fig. 24-20). The patient then actively attempts to flex the elbow. He/she is trained to reinforce elbow flexion by clinching fingers and holding wrist in flexion, while attempting flexion. The whole procedure is reversed to initiate extension. The elbow is put back in the splint after exercises.

2. Isometrics are made vigorous within the splint.

3. Gravity-assisted flexion with arm secured on a rachet (as described earlier for elbow mobilization) should be started.

4. If feasible, CPM or roller skates could be used to great advantage.

5. The movements of pronation and supination initiated as relaxed passive procedure may be progressed to assisted

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active and active movements.

6. Functional training in sedentary activities to be instituted and encouraged. Heavy movements like carrying or lifting weights are to be discouraged. Similarly, using the arm for weight bearing, like supporting over the arm rest of a chair while getting up or sitting is to be strictly avoided.

Fairly useful function should be regained by 8–12 weeks.

Arthroplasty of the WRIST joint (fig. 24-21A and B)

Total replacement of the wrist joint has not been in much demand because of two reasons:

1. It is difficult to achieve balanced action of the wrist flexor and extensor muscles due to the extensive destruction of the tendons with anterior subluxation as in rheumatoid arthritis.

2. Arthrodesis provides better functional stability to the wrist which facilitates hand function.

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(A)

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(B)

FIG. 24-21 **(A** and **B)** Total wrist joint arthroplasty.

However, a total joint prosthesis allows limited mobility and pain relief. The metacarpal component is fitted into the capitate, third metacarpal bed, and the radial component is fitted with cement into the distal radius.

After operation, the wrist is immobilized for about 8–10 days, after which gradually the mobilization is begun. However, a splint is used intermittently for the next 6 weeks.

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Physiotherapeutic management (table 24-5)

Preoperative assessment: Wrist joint is evaluated for:

- Active as well as passive range of motion
- Muscle power and endurance of the wrist flexors and extensors
- Grip and pinch strength measurement by dynamometer
- ROM and strength of the other joints of the extremity

Table 24-5
Physiotherapy Schedule for Total Wrist Arthroplasty

First week
Hand splinted in slight radial deviation to counter ulnar deviation forces; repeated movements of shoulder, elbow and fingers to be done
Second week to fifth week
Relaxed passive and active assisted wrist movements, avoiding ulnar deviation, should be initiated and progressed Selective strengthening of wrist extensors, to strengthen the grip Dynamic splint should replace the static hand splint
Sixth and seventh week
Initiate full range passive movements without ulnar or radial deviationConcentrate strengthening all the hand grips as well as the coordinated movements of hand in relation to shoulder, elbow and forearm
Caution
No lifting of heavy weight of more than 5 lbs in future; no heavy pulling or pushing using operated hand; body weight stretch like putting body weight on arms are contraindicated

Note: Wrist is the only joint where arthrodesis is a preferred method of treatment as stability is a better choice than weak functional mobility.

Preoperative training: It is basically directed towards the following:

- Strengthen the flexor and extensor muscle groups at the wrist. These muscles are usually weak because of the distortion of the joint. They are at a great mechanical disadvantage to act effectively. Strengthening procedures are taught with correct stabilization of both the segments (distal part of the forearm and proximal portion of hand). Isometrics are extremely valuable. Isotonic in a limited

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pain-free ROM should be autoresisted and in the correct groove of movement.

- Stiffness or weakness at any other related joints of the extremity should be treated to increase the strength and freedom of the movements to the maximum.

- Teaching of postoperative physiotherapy regime.

Postoperative regime: The wrist and the hand are fixed with dressing plaster splint. The arm is kept in elevation.

- Careful check of the immobilization is done.

- Status of circulation, sensation and any nerve compression symptoms are checked.

- Early initiation of finger, shoulder and elbow movements supporting the operated arm is taught to the patient. These self-assisted movements should be performed in the maximum possible range.

Mobilization

When the cast is removed, wrist mobilization and strengthening techniques should be initiated and progressed gradually.

- Relaxed passive wrist flexion and extension is initiated in a gravity-eliminated position with full support and secured stabilization (on the same lines as for elbow).

- Active and active assisted movements to be made intensive. Functionally important position of wrist extension needs extra emphasis.

- Functional activities (self-assisted) to be initiated and progressed at the earliest.

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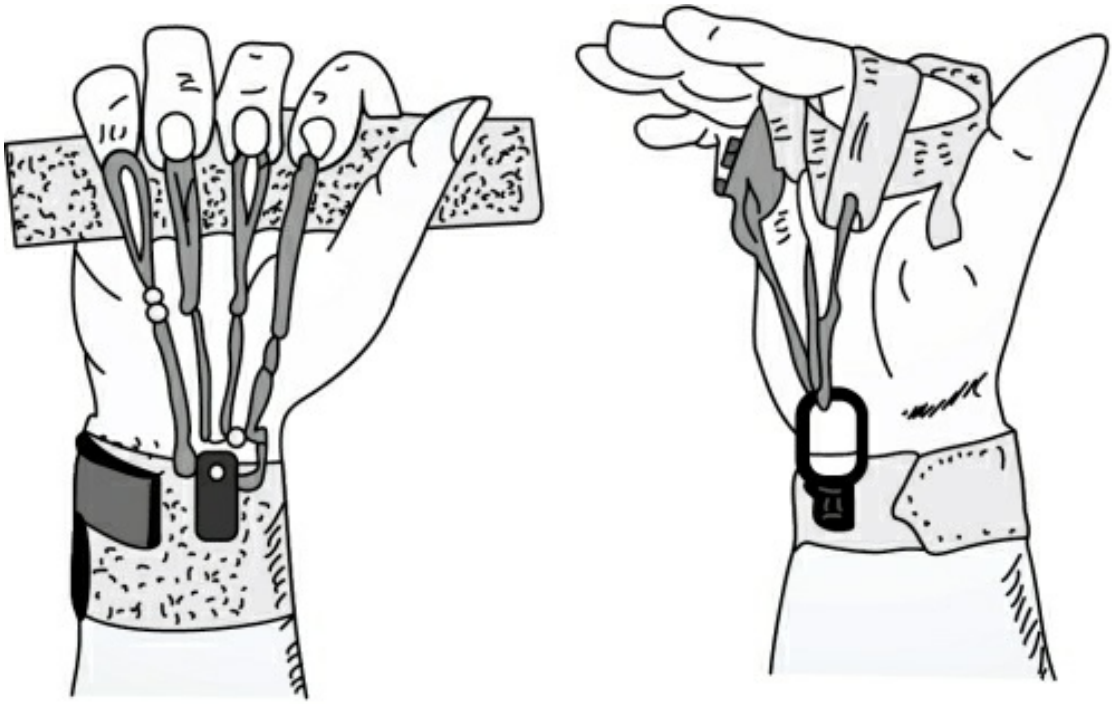
- Functionally useful, painless wrist joint should be regained by 4–6 weeks.

Arthroplasty of the hand

Arthroplasty of the joints of the hand is indicated in painful stiff joints and/or in case of deformity preventing hand function, following rheumatoid arthritis, degenerative or traumatic conditions or crush injury.

Excisional (resection) arthroplasty

Excisional arthroplasty of the proximal interphalangeal (PIP) joints of the finger is rarely indicated in cases of infective arthritis. In this operation, the head of the proximal phalanx is excised, the wound is closed and the finger is given traction through the distal phalanx (Fig. 24-22) for about 6 weeks. The patient may regain some degree of useful movements at the PIP joint but usually instability at the joint persists.



(A) (B)

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FIG. 24-22 **(A)** Resection arthroplasty splint with traction through the distal phalanx. **(B)** Implant arthroplasty. Splint holding metacarpophalangeal (MCP) joints in maximum corrected position.

Implant (replacement) arthroplasty

This type of arthroplasty is commonly indicated in MP joints and occasionally in PIP joints. Swanson (Swanson et al., 1982) silicon prostheses are most commonly used in this procedure. The articular surfaces of the two adjoining bones of a particular joint of the finger are excised and the stems of the finger joint prosthesis are fixed into the medullary canals of the two bones (Fig. 24-23). Postoperatively the joint is mobilized after a week or 10 days.

(A)

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(B)

(C)

FIG. 24-23 Rheumatoid hand – implant arthroplasty. **(A)** Preoperative – ulnar deviation of fingers. **(B)** Postoperative photograph after MCP joint arthroplasty – deformity corrected. **(C)** Postoperative radiograph – after MCP joint arthroplasty.

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Physiotherapeutic management

Aim: Return of optimal pain-free maximal functions of the hand.

Preoperative assessment

- Evaluation of the active and passive ROM of the concerned joint
- Evaluation of strength and endurance of the related muscle groups
- Evaluation of strength of hand and pincer grip by dynamometer
- Evaluation of degree of pain and its character
- Overall functional evaluation of the whole limb and in relation to the ADLs
- Education on the postoperative regime
- Evaluate and analyse the difficulties of the patient in performing certain ADLs, to facilitate focused therapeutic procedures

Excisional or resection arthroplasty

Postoperative regime

- Check the alignment of the traction and circulation to the finger
- Prevention of inflammation and its complications
- Active resistive movements to the joints free of immobilization

Instability at the resected joint is the major drawback of this surgical procedure. Therefore, maximum emphasis is on various strengthening procedures to the flexor and extensor groups. As soon as traction is discontinued, graduated mobilization is given to the metacarpophalangeal (MCP), PIP and distal interphalangeal (DIP) joints.

Isometric and isotonic exercises for both flexor and extensor muscle groups are concentrated at the PIP and DIP joints.

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- Active use of hand is encouraged. A splint may be necessary to stabilize the MCP joint.

- Resistive exercises should be initiated as early as possible to regain full function.

Implant arthroplasty

Early postoperative regime is the same as described for resection arthroplasty. A dynamic splint holding the MCP joints in maximum corrected position and offering resistance to flexion can also be applied.

Postoperative regime: After surgery, the hand is supported in a pressure dressing with elevation.

1. Control inflammation.

2. Full arc movements to the shoulder and elbow help improve circulation to the operated area.

3. Fingertips and thumb should be checked for the status of circulation.

Mobilization: Controlled mobilization by dynamic flexion assist splint plays an important role in the return of function following implant arthroplasty. The methods of mobilization fall into three types as advocated by three eminent hand surgeons.

1. Madden (1977) advocated the use of dorsal splint stabilizing the wrist in 15–20 degrees of extension. The splint has an adjustable transverse bar to secure a rubber band and loop for each finger. This splint is applied as soon as the swelling is reduced. He recommended early initiation of passive movements with prolonged use of the dynamic splint.

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2. Wynn Parry (1981) preferred plaster cast for a long duration till healing of the extensor expansion was complete up to 3 weeks. MCP flexion is limited to 30 degrees but full flexion–extension is allowed at the interphalangeal joints. After 3 weeks, the exercise programme is gradually progressed from relaxed passive movements to resisted movements of the MCP joints.

3. Swanson regime: As soon as swelling of the hand is reduced, protective movements are initiated on the third or fifth postoperative day. Dynamic splint with rubber outrigger is positioned accurately to prevent ulnar deviation, and allows 70 degrees of flexion at the MCP joints. Maintenance of flexion in 70 degrees is of vital importance during the period of 3 weeks. The brace needs to be continued in the event of extensor lag, tendency for ulnar deviation or flexion contracture.

ADL using the affected hand is encouraged along with other progressive procedures of improving strength, ROM and endurance. Periodical monitoring of grip and pinch strength is done to assure improvement.

Fully functional hand should be restored within 3 months of surgery.

Arthroplasty of the PIP joints

As this operation does not involve tendon reconstruction, active physiotherapy can begin early.

- A splint is applied to maintain neutral position of the PIP joint.
- Active flexion can be started as early as 3–5 days, postoperatively.
- Adequate measures should be adopted to evaluate and treat

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extensor lag, which is a common feature following this operation.

- Proper watch should also be kept on the development of angular deformity. Strapping of the aluminium splint to the appropriate side of the finger may be necessary to control angular deformity.

Osteotomy

The major objective of this procedure on the bones is to improve the functional status of the limb.

It is achieved either by surgical correction of the bony deformity or by providing stability to the joint.

It is done by dividing or cutting the bone wedge and realigning or reconstructing the joint.

Basically, it converts the shearing force into a compressive force by changing the line of weight bearing.

It is performed in three distinct stages.

Stage I: A stage of division of the bone

The bone is cut or divided close to the deformity by (a) single transverse cut, or (b) by removing a piece of bone (wedge), (c) by reconstructing the joint following division, the two ends of the bone are brought together to correct the anatomical alignment, or reconstructed to provide stability to the joint, or by altering shearing forces at the fracture site into compressive forces by changing the line of weight bearing (Fig. 24-24).

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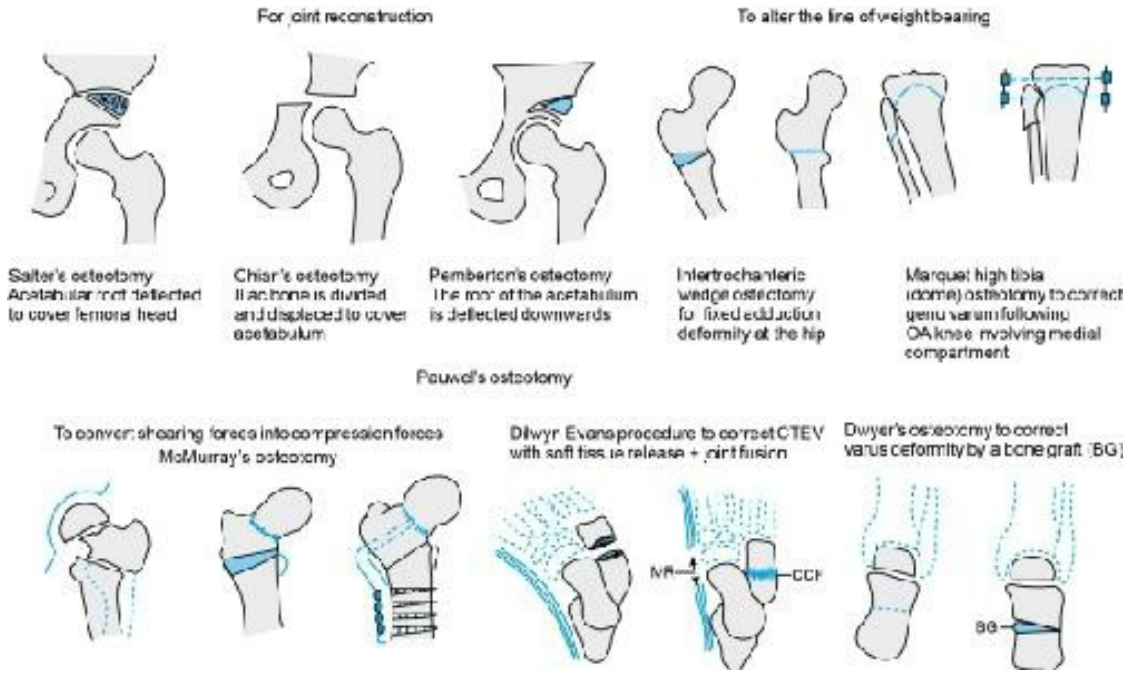

FIG. 24-24 Some osteotomy procedures.

Stage II: A stage of immobilization

After achieving the objective of correct anatomical alignment or stability to the joint, immobilization is done in this position either by POP cast, internal fixation or by external fixation as feasible.

Stage III: A stage of achieving the optimal functional restoration

Once the proper consolidation of osteotomy is ensured, vigorous physiotherapy is required to restore the optimal function of the concerned joint or limb.

Osteotomy is indicated in several bony and joint dysfunctions or bony deformities for various purposes (Tables 24-6–24-8).

Table 24-6

Indications for Osteotomy

Objective	Indication
• To correct the bony deformity (e.g., angulation, bowing or rotation)	• Malunited fractures • Structural bony deficiencies

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• To centralize the long axis of a limb or joint to control deformity, pain and progressive worsening	e.g., rickets, Paget disease • Compartmental degenerative joint changes • Unequal bone growth due to epiphyseal injury or disease
• To correct joint subluxation, dislocation, or slipping of the epiphysis (slipped upper femoral epiphysis) by bony reconstruction	• Perthes disease • Congenital dislocation of hip (CDH) • Slipped femoral epiphysis
• Correction of the fixed joint deformities obstructing the joint function	• Fixed deformities at the shoulder or hip joint
• To augment union in ununited fractures	• Old ununited fracture of femur, nonunion fracture of the neck of femur
• To correct cosmetic defects	• Excessive bowing or angulation, etc.
• To correct leg length disparity	• Shortening or lengthening the bones

Table 24-7
Osteotomies in the Upper Extremities and Spine

Shoulder joint (scapula) Stamm's glenoid osteotomy	Painful arc syndrome of shoulder
Humeus (upper) • Abduction osteotomy	• When the shoulder joint has fixed in adduction and internal rotation deformity
Elbow • Wedge osteotomy (French osteotomy)	• To correct marked cubitus varus by removing wedge on the lateral side of the humerus • To improve elbow flexion by inserting a bony wedge posteriorly into the lower end of the humerus
Forearm and wrist • Fernandez and Campbell's distal radius osteotomy	• To correct deformity following malunited Colles' fracture
Spine	
Vertebral osteotomy	• When there is lumbar spinal fusion (severe fixed flexion deformity occurs at the lumbar region) following ankylosing spondylitis; posterior wedge osteotomy from the bodies of the two adjacent vertebrae helps produce angular lordosis at the lumbar region

Table 24-8
Osteotomies in the Lower Extremities

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Bone or Joint	Purpose
Pelvis • Salter's osteotomy • Chiari's osteotomy • Pemberton's osteotomy • Pauwel's osteotomy	To prevent or control congenital dislocation of hip (CDH), OA hip, fracture of femoral neck
Hip joint • Coxa valga (McMurray's displacement osteotomy) • Coxa vara (McMurray's intertrochantric osteotomy)	• To correct valgus deformity by varus osteotomy • To correct varus deformity by valgus osteotomy in old fractures of the femoral neck
• Intertrochantric triplane osteotomy or Dunn's procedure of cervical osteotomy • Pauwel's osteotomy • Shaft of the femur or tibia corrective osteotomy • Lower tibial osteotomy	• When the fusion of the epiphyseal plate has taken place • When epiphyseal plate is not closed • OA hip or nonunited fracture of the neck of the femur
Knee joint *(Genu valgum or fixed flexion deformity)* • High tibial osteotomy, femoral supracondyler osteotomy or Maquet's dome osteotomy (genu varum) • High tibial osteotomy or femoral (supra-condyler osteotomy)	• Varus osteotomy to correct valgus deformity, e.g., OA knee • Valgus osteotomy to correct varus deformity, e.g., OA knee • Bowing or angulation following rickets, fibrous dysplasia, or malunited fractures or Paget disease • To prevent secondary OA changes following malunited fracture at the ankle
Ankle and foot • Dawyer's osteotomy • Dilwyn Evans osteotomy	• To correct foot deformity in CTEV • To correct varus foot in CTEV
Toe • Osteotomy of first metatarsal • Osteotomies at • Calcaneous • Mid tarsal joints • Tarso-metatarsal regions	• To correct hallux valgus deformity • To correct talipes equinovarus, claw foot

Note: There is a long list of such corrective and stabilizing osteotomies. The surgical procedures of various osteotomy sites are presented with each joint in the relevant chapters.

Physiotherapeutic management following osteotomy

Objective: To improve both ROM and muscle functions.

Pre-operative education

■ The related musculoskeletal structure of the joint to be operated should be given special sessions of exercise and movement training. It may include compensatory trick movements, postural adaptations, orthotic aids, etc. to perform functional tasks (e.g., substitution of shoulder abduction by shoulder girdle elevation,

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trunk lateral flexion to the opposite side – a planned shoulder joint arthrodesis).

- If not, restore full ROM with improvement of strength, endurance and flexibility of the related joints of the joint to be arthrodesed.

During immobilization

- Measures to reduce pain and swelling, placing a limb in comfortable relaxed position.
- Keeping a watch on the expected postsurgical complications as related to the procedure of surgery and the site.
- Ensure the stability of the operated joint.
- Initiate repetitive isometrics in repetitive small bouts to the muscle groups under immobilization.
- Strong active movements to the joints free of immobilization and the functional muscle groups.
- Initiate preliminary functional activities with guidance and assistance (e.g., shifting in the bed, sitting up, supported standing progressing to non-weight bearing (NWB) ambulation or using operated upper extremity as an assisting arm).

During mobilization

- Improving all the functions of the muscle groups, especially around the operated joint and concentrated mobility exercise training to improve the ROM should be initiated immediately. Objective training on tricky movements.
- Isometrics and self-resistive type of exercise training to improve strength and endurance and relaxed free repetitive movements are the mainstay as soon as the immobilization is discontinued.

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- Adjunctive procedures of thermotherapy like hydropack around the operated area (excluding skin incision) are ideal to induce relaxation and comfort before mobilization.

- Initially well-supported objective functional re-education should be begun as early as possible in a graded manner and guidance.

- Manual therapy procedures and PNF techniques play an important role in achieving early optimal functional restoration.

Note: Longer period of immobilization is always associated with limitation of joint movement and disuse atrophy of the muscle groups under immobilization needs extra efforts and early attention.

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CHAPTER 25

Amputations

OUTLINE

- Definition
- Indications for amputation
- Level of amputation
- Foot amputations
- Prosthesis
- Prosthesis for lower limbs amputations
- Prosthesis for upper limbs amputations
- Upper and lower limb combination
- Instant prosthesis

Definition

Removal of limb, partly or totally, from the body, is termed as *amputation*. *Disarticulation* is removing the limb through a joint. Amputations are more common in men and more often in the lower limbs.

Indications for amputation

1. *Trauma:* With an alarming incidence of road traffic accidents

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(RTAs), amputation following trauma has become a common feature. Attempts are always made to save the limb as far as possible. When there is extensive loss of tissue and disruption of blood supply, no other alternative is left to the surgeon but to amputate.

2. *Malignant tumours:* Amputation is considered for extensive malignancy. This is done to save life and to prevent recurrence. However, the increased use of limb salvage procedures has reduced the need for amputation.

3. *Nerve injuries and infections:* Anaesthetic limb often develops ulcerations, infections and severe tissue damages. The tissue damage due to repeated infections and ulcerations may lead even to autoamputation in neglected patients (e.g., Hensen disease). When ulceration and infection persist and fail to respond to the medical treatment, amputation is performed.

4. *Extreme heat or cold:* Injuries following electrical burns, accidental burns as well as exposure of the limb to extreme cold conditions may need amputation. Thermal injuries may at times lead to extensive tissue destruction or deformities. Prolonged exposure of the limb to extreme cold conditions results in the blockage of the blood circulation leading to gangrene.

5. *Peripheral vascular insufficiency*: Irreversible loss of vascularity to a limb due to diseases like diabetes, Berger disease, atherosclerosis, embolism, arterial thrombosis, arteriovenous aneurysms or trauma, leading to gangrene are absolute indications for amputation. Advances in arterial surgery have reduced the incidence of amputation following these conditions. However, in neglected cases, many a time massive tissue destruction and gangrene leave no alternative, other than amputation.

6. *Congenital absence of limbs or malformations:* Various types of congenital malformations and the absence of bones are not uncommon. There may be an incidence of rudimentary limb

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structures proximally with apparently normal terminal segment or its reverse. Bilateral rudimentary distal segment amputees can be managed with bilateral orthoses specially designed to accommodate the deformity. But, when rudimentary portions of limb interfere with fitting of the prosthesis, amputation becomes necessary.

Reconstructive procedures with repeated surgery in childhood many a times result in severe limb length discrepancies incompatible with normal walking, and hence may need an amputation/disarticulation. An example can be proximal focal femoral deficiency (PFFD) where severe shortening may necessitate amputation and a proper prosthetic fitting.

7. *Severe infection:* Severe infections like gas gangrene, or chronic intractable infections like osteomyelitis and unstable diabetes mellitus may also need amputation.

Level of amputation

In a limb, an amputation is carried out at a level which will give the stump an optimum length to facilitate subsequent prosthetic fitting. For example, for an above-knee amputation (now termed as *transfemoral amputation*), the optimum length of the stump is taken as 25–30 cm as measured from the tip of the greater trochanter. Similarly, for a below-knee (transtibial) stump, the suggested optimum length is 15 cm as measured from the tibial tubercle. However, with recent developments in the fabrication and fitting of prosthesis, it is not necessary to stick to these stump lengths. The prosthesis (artificial limb) can be custom-made to fit at different lengths. The level of amputation is determined by the viability of the tissues. It is, however, important that the stump should have a well-healed, nontender, supple scar. It is also important that a joint must always be preserved, whenever possible.

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Upper extremity (fig. 25.1A–C)

- *Forequarter amputation* (scapulothoracic amputation) is carried out proximal to the shoulder joint. It is indicated for malignant bone tumours of the upper end of the humerus. In this type of amputation, part of the scapula and clavicle are removed along with the shoulder girdle muscles.

- *Shoulder disarticulation* is generally not so popular in the upper limb except at shoulder. Even in disarticulation of shoulder, the head of the humerus is preserved, wherever possible, to maintain the contour of the shoulder for cosmosis.

- *Above-elbow (AE) amputation* (*transhumeral* amputation): A 20-cm-long stump as measured from the tip of the acromion is ideal (Fig. 25.1C).

- *Below-elbow (BE) amputation* (amputation through the forearm bones, now termed as *transradial amputation*): The optimum length of a BE stump is 20 cm as measured from the tip of the olecranon (Fig. 25.1C), with a minimum length of 7.5 cm.

- *Krukenberg amputation:* This is performed in patients, usually with bilateral BE amputations, who have a sufficiently long BE stump. In this operation, the forearm is split between the radius and the ulna to provide the pincer grip. The patient can hold a spoon or lighter objects with this 'fork'. For cosmetic purposes and for lifting heavy objects, a BE prosthesis or a 'hook' prosthesis, respectively, can be put over this stump.

- *Amputation through the hand:* This is designed to preserve as much length as possible to contribute to the overall function. Exception to this dictum is traumatic amputation through the proximal phalanx of a finger. Here the short stump is of no use and, in fact, hinders with the function of the hand, as things keep falling through the gap. Therefore, the ray is removed by amputation through the neck

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of the metacarpal. Ray amputation through the neck of the metacarpal is also done in index and little fingers for cosmetic reasons. However, in case of thumb amputations, the maximum possible length is preserved without any reservations. Subsequent reconstructive procedures, such as metacarpal lengthening (Fig. 25-2) or composite bone grafts or toe transfer, are performed for a thumb with a short stump.

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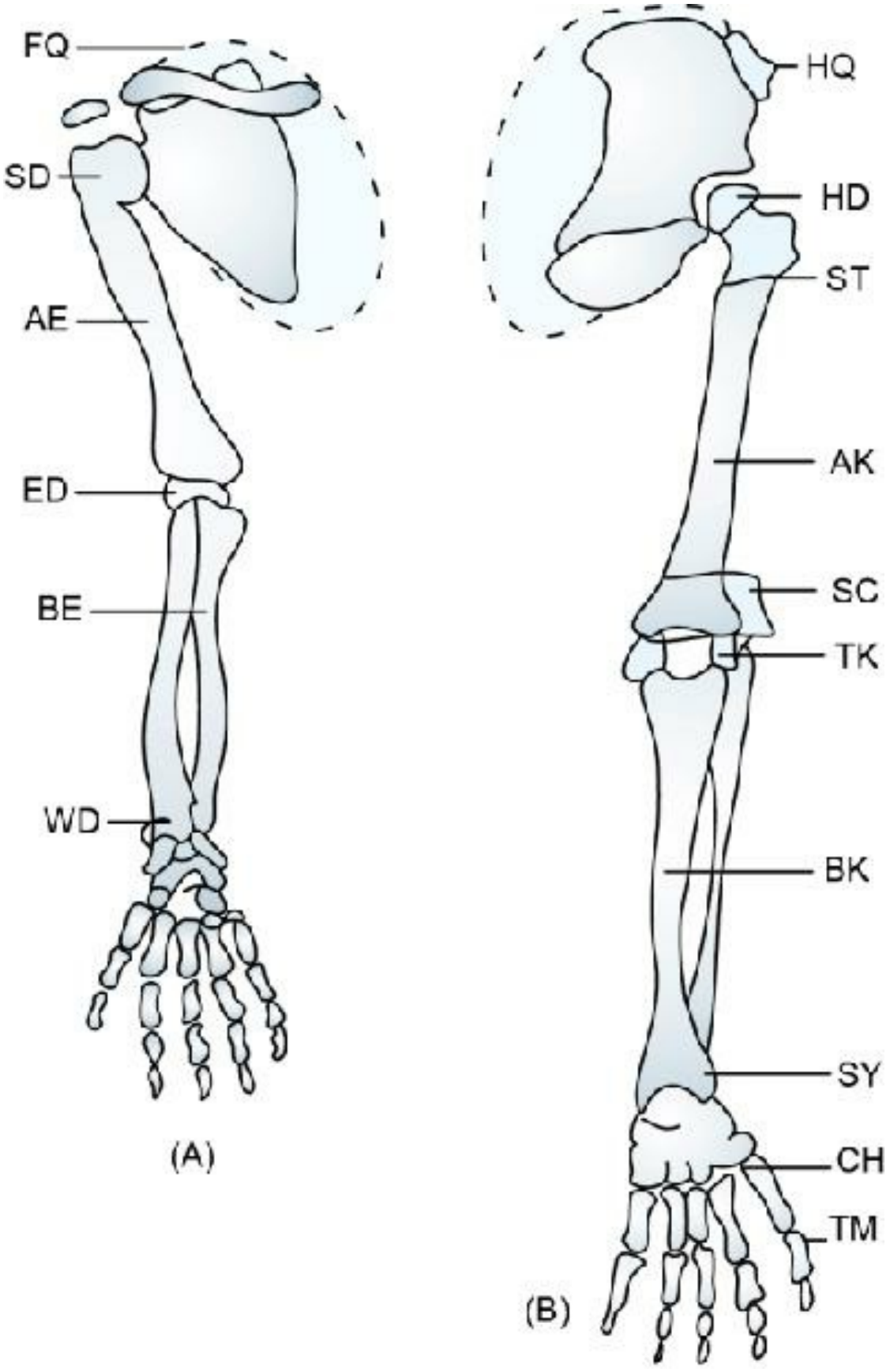

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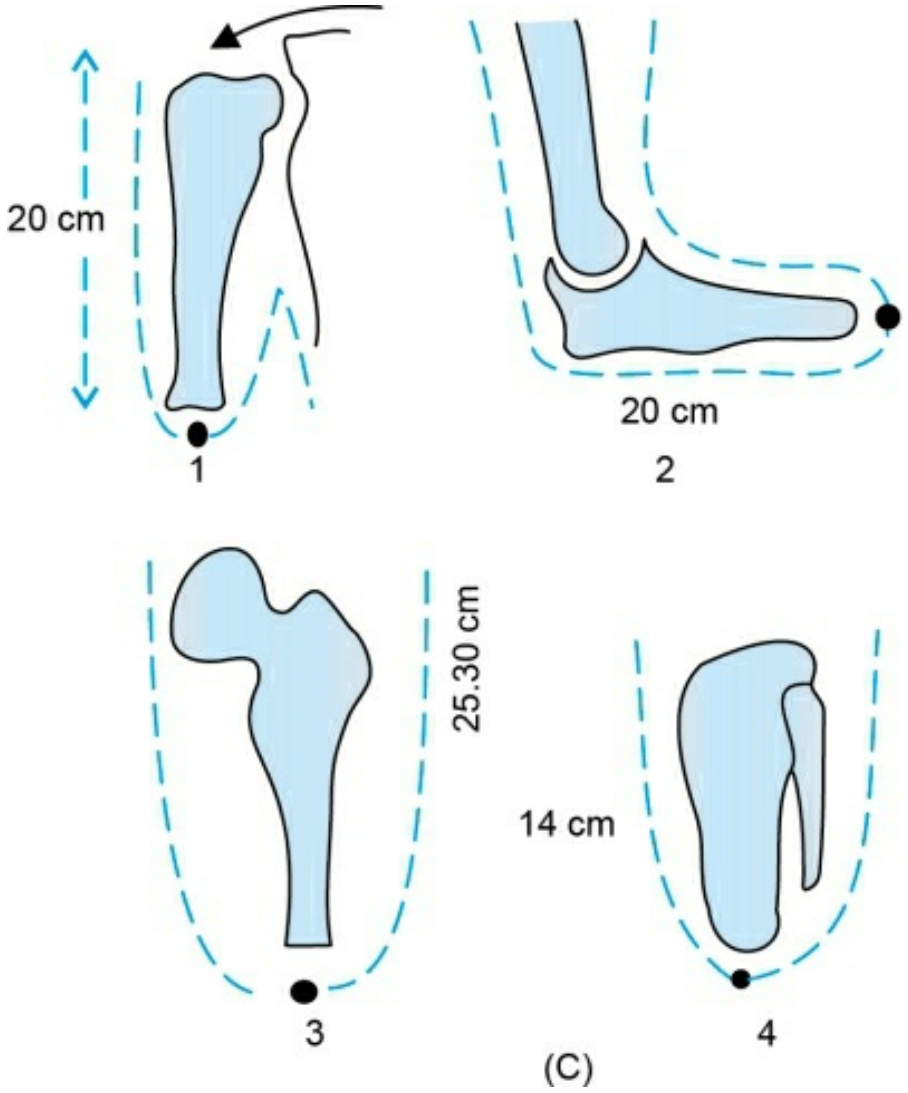

FIG. 25-1 Levels of amputation. **(A)** Upper extremity. FQ, forequarter; SD, shoulder disarticulation; AE, above elbow; ED, elbow disarticulation; BE, below elbow; WD, wrist disarticulation. **(B)** Lower extremity. HQ, hind quarter; HD, hip disarticulation; ST, subtrochanteric; AK, above knee; SC, supracondylar; TK, through knee; BK, below knee; SY, Syme's; CH, Chopart; TM: transmetatarsal. **(C)** Ideal length of the stump at various levels: 1. above elbow (20 cm), 2. below elbow (20 cm), 3. above knee (25–30 cm), 4. below knee (14 cm).

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(A)

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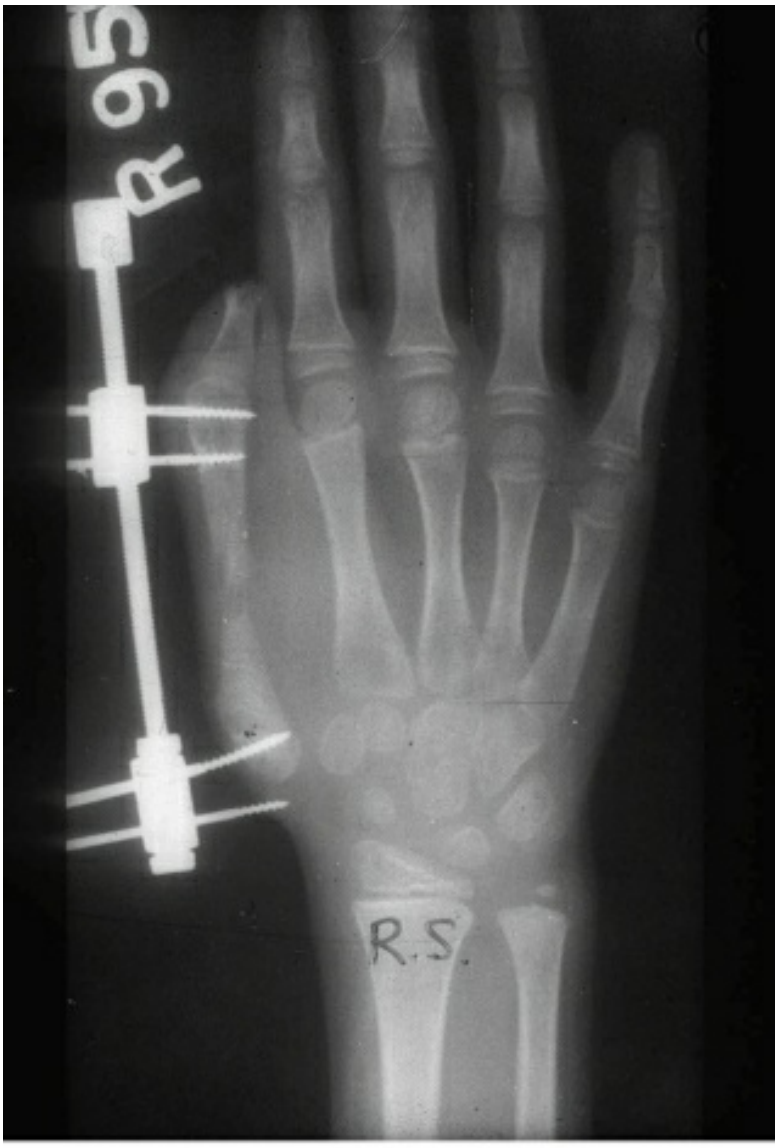

(B)

FIG. 25-2 Metacarpal lengthening for a thumb with a short stump. **(A)** Preoperative radiograph. **(B)** Lengthening is being done after corticotomy of the metacarpal and distraction by an external fixator.

Lower extremity (fig. 25-1B and C)

- *Hindquarter amputation (transpelvic amputation):* It is indicated for malignant tumours at the upper end of the femur or in pelvic bones. In this operation, part of the pelvis is removed along with the lower extremity.

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- *Hip disarticulation: It is an occasionally performed operation where the femur is removed from the acetabulum. It is not a usual operation as the prosthesis has high-energy requirements for walking.*

- *Above-knee amputation* (amputation through the thigh, now termed as *transfemoral amputation*): The optimum length of the above-knee stump is about 25–30 cm as measured from the tip of the greater trochanter (Fig. 25.1C). The minimum length for a useful stump is about 7.5 cm.

- *Knee disarticulation:* It can be done through the knee as well. However, through knee disarticulation is cosmetically unacceptable in women as the prosthesis required is rather bulky at the knee and hence not attractive. *Transtibial* amputation is generally preferred to the through knee disarticulation. However, a well-performed amputation may provide a good weight-bearing platform.

- *Below-knee amputation* (now termed as *transtibial amputation*): It is the most commonly performed amputation, mostly following severe trauma to the foot and leg and gangrene of various aetiology.

- Crush injuries of the foot.

- Malignant bone tumour of the lower end of tibia.

- The amputation is performed through the leg bones. The optimum length of the below-knee stump is 14 cm from the tibial tubercle (Fig. 25.1C). A patellar tendon bearing (PTB) prosthesis can be fitted over a stump of adequate length, while for a very short stump, the conventional below-knee prosthesis is the only alternative. The energy consumption for walking in a transtibial amputee is less because the knee joint is preserved.

- *Syme's amputation:* In this operation, the tibia and fibula are divided just above the ankle joint. The intact skin over the heel is attached back to the end of the stump with or without a part of the calcaneum (Fig. 25-3). Because of the intact heel, it becomes an end-bearing

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stump and the patients generally manage very well walking even bare foot after this type of amputation.

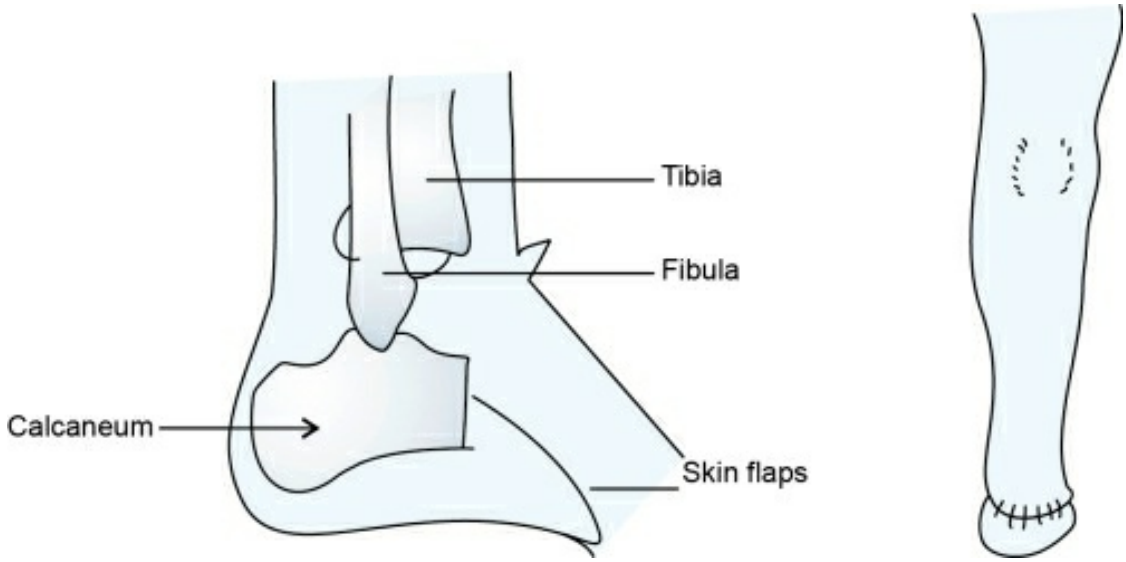

FIG. 25-3 Syme's amputation.

Foot amputations

- *Toes*: Amputation of great toe and other toes.
- *Metatarsals*: Amputation through metatarsal bones.
- *Lisfranc amputation*: Amputation at the level of tarso-metatarsal joints.
- *Midtarsal joint amputation*: Also known as *Chopart's amputation*, where the amputation is performed at the level of midtarsal joints.

Amputation through various parts of the foot has almost become obsolete these days. Wherever possible, a below-knee amputation is preferred.

Types of amputation

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There are two types of amputation: (i) closed amputation and (ii) open amputation.

Closed amputation

In this type of amputation, the stump is closed primarily over the bony stump by retaining skin and muscles at least 5 cm distal to the bone end to facilitate closing of the stump. All elective amputations are closed amputations.

Sequential steps in a closed amputation

Level of amputation

Amputation is performed retaining skin and muscles at least 5 cm distal to the bony ends to facilitate stump closure. The muscles provide a cushioning effect to the bone ends.

- The edges of the tibia are bevelled.
- Myoplasty is performed.
- Final closure of the stump with the skin is done.
- Fibular stump is always kept at a higher level than the tibial stump.

Open amputation (guillotine amputation)

It is undertaken as an emergency procedure and is also called *guillotine amputation*. In this type of amputation, the skin is not closed over the amputation stump. After amputation, the stump is left open and dressed regularly till the infection subsides and the stump wound becomes healthy. The stump is then covered by skin grafting or secondary closure.

Open amputation is indicated in cases where the wound is grossly contaminated or in cases of severe infections.

Care during the process of amputation

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- **Tourniquet:** Except ischaemic limbs, malignancies or infections, for the fear of spread of the disease, tourniquet is commonly applied during amputation.

- **Skin flap and scar:** Stump must always be covered with a healthy skin flap. Care should be taken not to allow the scar to be adherent to the bone.

- **Blood vessels:** Should be individually isolated and ligated with double ligation of the major vessels.

- **Nerves:** Must be isolated carefully, pulled and divided to avoid stump neuroma.

- **Muscles:** They should be divided distal to the level of the bone cut. Opposite groups of muscles are sutured together distal to the bone, it (myoplasty). When the muscles are sutured to the end of the bone, it is called myodesis.

- **Bone:** Excessive stripping of the periosteum may cause ring sequestra and as such is contraindicated. The bone must be bevelled or rasped to avoid bony prominences jutting at the skin.

- **Drain:** To prevent haematoma formation, suction drain is applied.

These factors will largely prevent post-operative complications.

Postoperative management

The postoperative management of the stump is done by the following two techniques:

1. ***Immediate postsurgical prosthetic fitting***

A plaster cast mould is applied over the amputation stump immediately after surgery to which a temporary prosthesis

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(pylon) is attached the next day (Fig. 25-4). The patient is then allowed partial weight bearing as early as the pain permits. It has many advantages:

1. The plaster cast forms a protective cover over the stump, preventing infection, etc. from outside.

2. Early ambulation improves circulation in the stump, thereby facilitating healing.

3. Early ambulation in a temporary prosthesis instills confidence in the patient and increases the chances of early acceptability of a permanent prosthesis.

It, however, involves teamwork, and a perfect coordination between the surgeon, the orthotic expert and the physiotherapist.

2. ***Soft tissue technique***

In cases where a temporary prosthesis is not fitted immediately after surgery, an elastocrepe bandage is used after applying sterile dressing. The stitches are removed after 2 weeks.

The use of a crepe bandage, however, is continued for another 3 weeks. It helps in shaping the stump well into a conical shape which is considered ideal for the subsequent prosthetic fitting.

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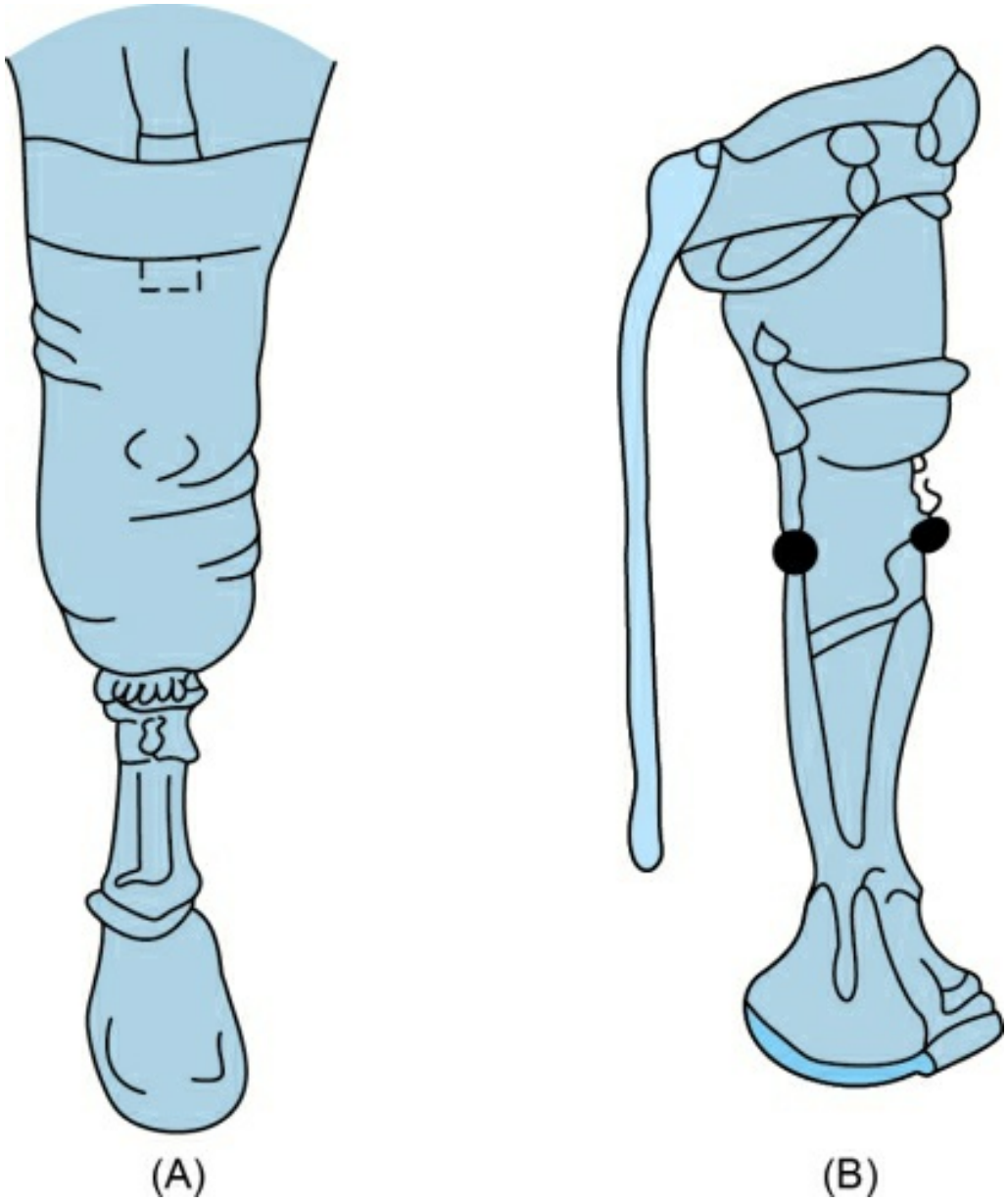

FIG. 25-4 **(A)** Immediate postsurgical BK prosthesis. **(B)** Temporary pylon with rocker bottom.

Physiotherapeutic management of the amputee

Physiotherapy plays the most significant role in the management of an amputee from the time the surgeon decides for amputation till the patient is back to his work. It involves an intensive course of purposeful training and repeated long sessions of untiring effort.

The basic approach of physiotherapy is to establish a new

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proprioceptive system of integrated impulses, which the nervous system can understand, by vigorous training and association. To be effective, it has to be adequately supported by visual and auditory feedback. The management can be divided into three stages:

1. Preoperative stage

2. The early postoperative stage

3. The mobility stage

Stage wise principles of physiotherapy

1. During preoperative stage:

   (a) Assurance

   (b) Critical examination and assessment

   (c) Education of major cares and graduated exercise along with self-management procedures

2. During early postoperative stage

   (a) Measures to prevent postsurgical complications

   (b) Maintenance of strength and mobility of the joint adjacent to the operated limb

   (c) Management of the stump

   (d) Stump conditioning

3. A stage of mobility and self-sufficiency

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(a) Thorough checking of the fabricated prosthesis for a comfortable fit

(b) Training on the methodology of applying prosthesis; its care and maintenance

(c) Functional training and re-education with prosthesis towards optimal self-sufficiency

1. **Preoperative stage:** It has the following functions:

(a) Assessment

(b) Preoperative training

(c) Reassurance

(a) ***Assessment:*** The preoperative assessment of the affected limb as well as the patient as a whole is conducted thoroughly. The ROM, muscle power, condition of the skin, status of circulation and sensory index need to be evaluated critically. The status of vision and hearing, which plays an important role in training, should also be assessed. The overall functional status of the amputee, before surgery, needs to be analysed and recorded.

The other important aspects like age, sex, occupation, general physical status and the level of intelligence should be observed carefully before planning the therapeutic regime and the type of prosthesis. The underlying condition necessitating amputation also needs careful consideration, as it may be associated with future complications, e.g.,

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vascular disease like atherosclerosis, systemic disease like diabetes mellitus, trauma, tumour and congenital defects.

Assessment of the psychological status is extremely important. The idea of losing a limb itself produces great psychological trauma leading to depression. The degree of psychological trauma to the patient is so high that on many occasions, it is experienced that the patient prefers to have his own functionally useless limb rather than having a functionally working artificial limb. In the words of Gordon Taylor, 'It is no small presumption to dismember the image of God'. The physiotherapist, due to his/her constant association, is in the best position to convince and boost the morale of an amputee, thereby greatly assisting in improving the psychological status.

Besides these factors, it is important to know about the environment of the patient's home and his/her working place, and also the nature and extent of the support he/she is likely to get from friends or relatives.

(b) ***Preoperative training:*** Once the decision is taken on the future plan of treatment, it is important to train the patient on the postoperative therapeutic regime.

The basic aim of the preoperative training is to prevent the complications of the postoperative phase, thereby reducing the cost and the period of rehabilitation.

The preoperative training programme depends upon the area of involvement, the methodology of management and the ultimate objective of amputation. The programme

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includes:

(i) Prevention of thrombosis by maintaining circulation through movements of the other good limbs.

(ii) Prevention of chest complications by deep breathing, coughing and postural drainage.

(iii) Preserve mobility of all the joints with emphasis on the susceptible joints.

(iv) Improved mobility of other related areas like trunk, pelvis or shoulder girdle to compensate for deficiencies and restrictions due to prosthesis.

(v) Teach the methodology to be adopted for mobility and limb positioning in bed.

(vi) Educate the patient on the techniques of transfers, monitoring the wheelchair, single limb standing and balancing.

(vii) It is necessary to explain to the patient all the important aspects of balance, equilibrium, standing and walking techniques he/she is supposed to adopt later on. Ideally, this can be done by showing a video recording of a patient using a similar prosthesis.

(viii) The patient should also be educated to detect possible complications like soft tissue tightness, care of the pressure points, and be made aware of the expected degree of pain and phantom sensation.

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(ix) Last but not the least, emphasis on training the exercise techniques should be concentrated upon. Self-resistive exercises, progressive resistive exercises as well as simple techniques to improve endurance are taught on the sound limb and their efficiency checked.

(c) ***Reassurance:*** Psychological reassurance plays a dominant role in the recovery following amputation. Reassurance with all possible encouragement is absolutely necessary. It can be best done by practical demonstration by a patient who has undergone similar surgery and is now physically independent.

2. **Early postoperative stage**

(a) ***To check the efficacy of preoperative training:*** To check and efficiently conduct the measures taught to prevent chest complications. Provide guidance and assistance.

(b) ***Prevention of contractures and deformities:*** The common contractures are adduction and rotation contractures in upper extremity amputees; hip flexion and abduction contractures following an above-knee amputation and knee flexion contractures after below-knee amputations. Bilateral amputees are more prone to develop hip and knee contractures due to decreased mobility and prolonged sitting postures, and need special attention. These contractures can be prevented by proper training in the positioning of the amputated limb, at all the times – right from the day after surgery. The common practice of using a pillow under the thigh or the knee, although relieving pressure over the end of the

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stump and giving comfort, is one of the commonest causes of soft tissue contracture; therefore, it should be discouraged. Hip flexion contracture can be prevented by sessions of prone lying, initiated as early as possible. It is also important to inspect and train to maintain the proper level of the pelvis in all the postures.

Long periods of sitting as well as soft mattresses can predispose to the development of flexion contracture at the hip; hence, it should be avoided. Simple methods like repeating sustained isometrics to the susceptible areas and repetitive periods of lying prone can effectively prevent development of flexion contractures at the hip, the most disabling state to fit prosthesis as well as in performing ambulatory activities. Repetitive check to prevent flexion contracture at the hip is a must.

(c) ***Maintenance of strength and mobility:*** The patient should be encouraged to move in the bed by pushing up the body on the arms rather than dragging or using monkey rings. This push-up exercise has the added advantages of strengthening the muscle groups which may be necessary for using ambulation aids at a later stage, especially in bilateral amputees or in the older age group. Vigorous ROM and strengthening exercises should be given for the whole body except for the joint proximal to the amputation. Bed activities like bridging and rolling can be useful to initiate bed mobility.

After 3–4 days of surgery, stump exercises can be initiated as active assisted or self-resisted exercises in a small range of motion. This can be best done by the patient himself.

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Assisted hip flexion, abduction and adduction movements can be performed in back-rest sitting. Frequent periods of prone lying and attempted hip extension with strong and sustained contractions of the gluteus maximus are valuable. Strong isometrics and slow self-generated tension exercises provide good endurance training, as they are less painful. They should be performed repeatedly for the important functional muscle groups. If the patient is able to sit and push his body in sitting, transfer activity can be safely introduced at this stage.

Management of the stump: Improper management of the stump is one of the major causes of delayed rehabilitation. Stump oedema delays the prosthetic fitting and amputation.

Causes of stump oedema

- Surgical trauma itself – most common
- Incorrect bandaging of the stump
- Incorrect stump positioning
- Associated degenerative joint disease
- Uncontrolled diabetes
- Atherosclerotic disease
- Renal disease

The following measures should be taken to control oedema of the stump:

1. Stimulation with limb in elevation with elastic bandage.
2. Resistive exercises to the stump and the rest of the joints.

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3. Stump bandaging and conditioning: Bandaging plays an important role in conditioning and shaping the stump by reducing stump oedema. It accustoms the stump to the conditions of pressure. A crepe or elastic bandage of sizes 4 or 6 inches is necessary. Usually a six-inch bandage is used for above-knee stump and a four-inch bandage for below-knee stump. The bandage should be worn during the night and taken off during exercises.

Principles of bandaging the stump (Fig. 25-5)

1. The pressure of the bandage should be moderately firm and evenly distributed, decreasing proximally. Extra pressure is necessary over the corners to obtain a conical shape of the stump.

2. Diagonal, oblique or spiral turns should be used while bandaging, as circular turns may produce a tourniquet effect leading to 'choking' of the stump.

3. In case of an above-knee amputation, the bandage must extend up to the groin to prevent a roll of flesh forming over the adductor tendons which may later on lead to follicle infection due to friction with the socket of the prosthesis.

4. An above-knee stump should be bandaged with the hip in extension and adduction. The below-knee stump should be bandaged with knee in slight flexion.

Intermittent variable air pressure machine: This machine, also known as a *controlled air pressure machine*, is used to control oedema and preserve tissues by normal gaseous and water exchange. It works on the principle of varying air pressure around the stump, modifying the circulation of blood and lymph.

Shrinker socks: An otherwise healed stump but with the

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problem of persistent oedema can be managed by elastic stump socks.

Rigid dressing: Below-knee amputation in young patients without associated problems can be given a rigid plaster of Paris dressing. Fitting of an early POP socket or a socket made of thermoplastic material may be provided for upper extremity amputees. This will reduce the oedema as well as provide an attachment to the early postoperative prosthetic device.

Caution

In patients with peripheral vascular disease and/or diabetes, stump bandaging has to be done with utmost care, because when the pressure of the bandage in these conditions exceeds the arterial pressure in the stump, it causes pressure necrosis. Therefore, the bandage should be applied with mild pressure. In these patients, the stump must be checked repeatedly for any signs of pressure necrosis to avoid revision of amputation.

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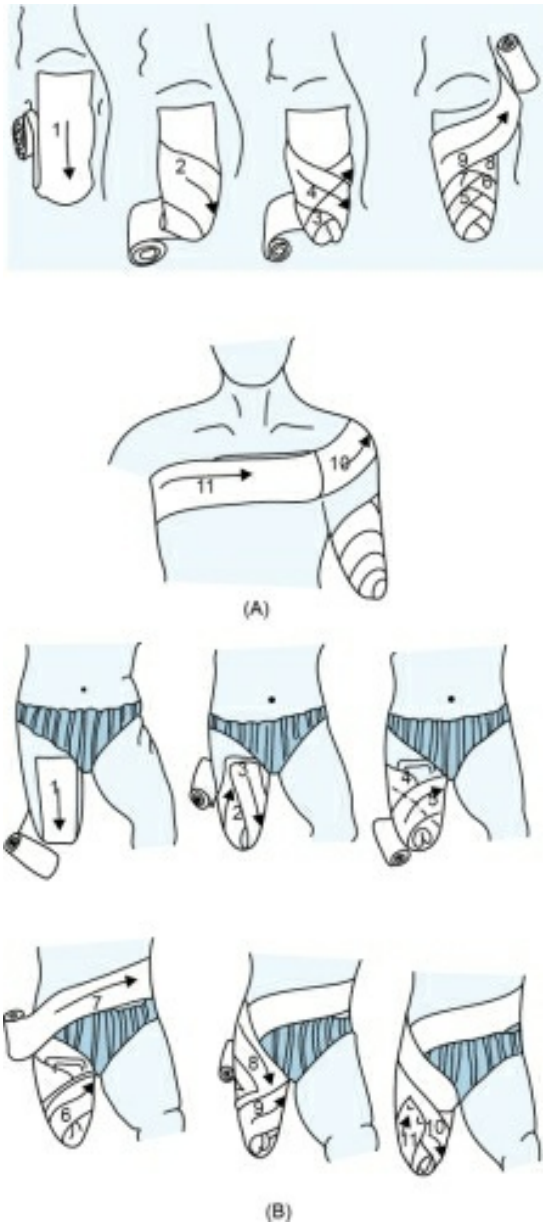

FIG. 25-5 Stump bandages. **(A)** Above elbow. **(B)** Above knee.

Stump hygiene: This includes regular washing of the stump with warm disinfected soap water and thorough drying. The patient should also be educated on protecting the areas and positions causing undue pressure on the raw areas of the stump.

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After removal of stitches: When the stitches are removed and the suture line healed satisfactorily, the most important aspect is stump conditioning.

Stump conditioning: This is to acclimatize the stump to various situations of pressure to be experienced after the fitting of the prosthesis.

An ideal stump is one which is well healed, firm, conical and with minimal flabby tissue.

(i) *Bandaging:* Firmness of the stump to withstand all the conditions of pressure can be achieved by constant and proper application of elastic bandage.

(ii) *Exercise:* By repeated sustained isometric exercises for the muscles of the stump, especially the two joint muscles, which originate above the joint proximal to the amputation. Educate the patient on the correct methods of self-resistance mode of exercise with emphasis on its repetitive performance. Ensure that a programme of strong and sustained isometrics to the important functional muscle groups is continued.

(iii) *Massage:* Massage or repeated tapping can be a stage of mobilization and restoration of function used for improving the tone of the muscles.

(iv) *Stimulation:* Electrical stimulation with the stump in elevation can improve the muscle tone as well as reduce oedema.

(v) *Pressure:* Exposing the stump to pressure either by early use of pylon or gradual training of bearing weight on the terminal weight-bearing area of the stump. This can be done by providing soft cushioning and adjusting the height of the stool in parallel bars (Fig. 25-6). Crawling or knee walking on a mattress placed over a bed with hardtop is ideal as a pressure bearing technique for the above-knee or

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through-knee amputations.

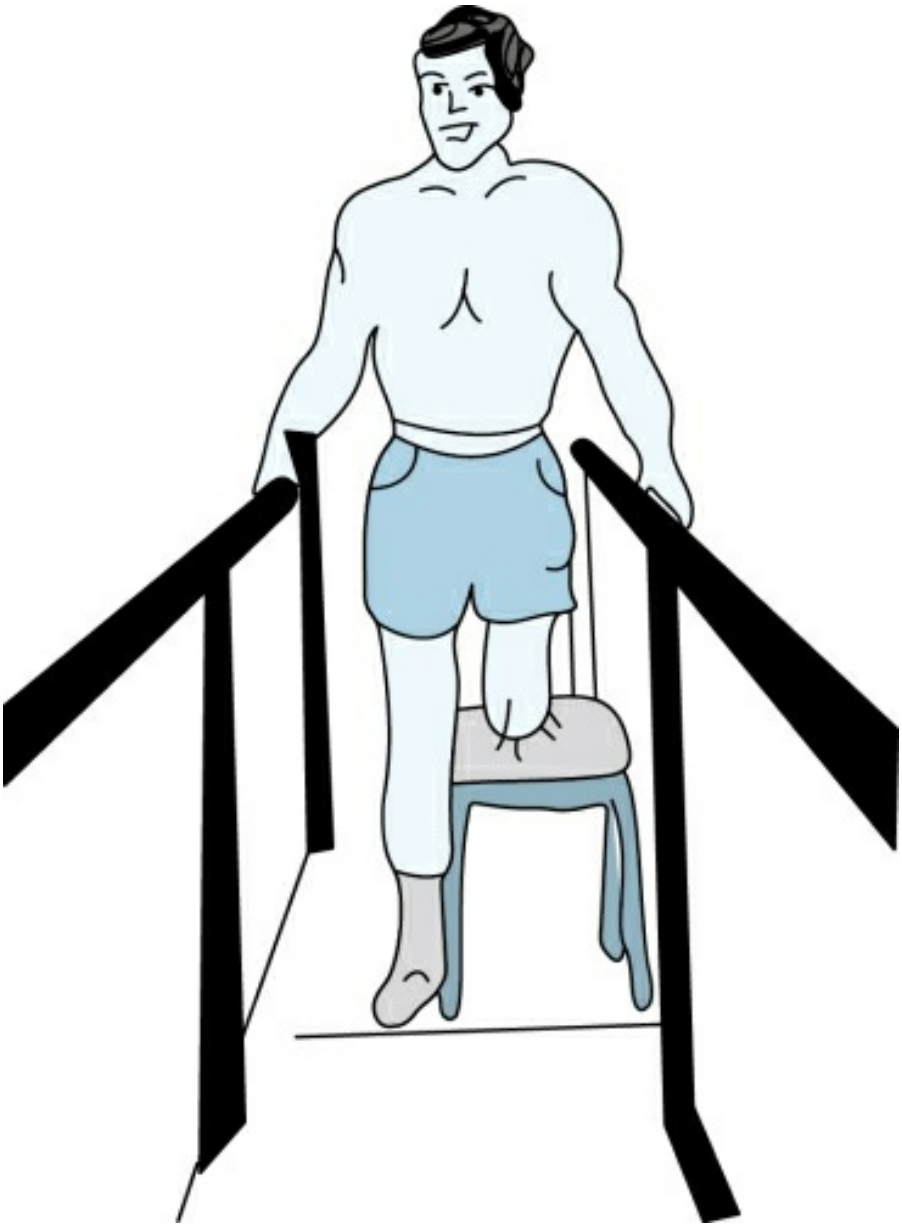

FIG. 25-6 Initiating early graded weight bearing and balancing on the stump in parallel bars.

The patient exerting axial pressure and approximation over the end of the stump by using his hands is also another self-controlled technique for conditioning in parallel of the stump.

Prevention of contractures: Development of soft-tissue contractures

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is a common complication following amputations. If neglected, it may present the following problems.

1. Hinders the fitting of prosthesis.

2. Even though the prosthesis may be well fitting to the stump, the patient is unable to bear weight during the single-leg weight–bearing phase.

3. Attempted weight-bearing effort results in:

- Marked imbalance
- Pain and discomfort
- Needing excessive supporting aid

(e.g., a patient who should be able to manage ambulation unsupported needs walker or remains nonambulatory).

4. Marked gait deviation with tendency for antalgic gait.

Common sites of developing contractures

- Hip-flexion or abduction contracture
- Knee-flexion contracture
- Ankle-fixed plant or flexion or equinus
- Shoulder-adduction rarely abduction contracture
- Elbow-flexion contracture

Prevention of contractures therefore is the total responsibility of the

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physiotherapist.

Methods of prevention of contractures

1. Early identification

2. Postural guidance

3. Strong exercise to the antagonistic muscles of the responsible agonists and their associated soft tissues

4. Use of sustained low-weight traction

5. Corrective splint at a very initial stage of formation of contracture

6. Repetitive strong isometrics to the gluteus maximus

7. Long periods of lying prone

Early identification: Tendency for development of contraction at the possible sites must be carefully checked at every visit. An early sign of developing contracture is a tight feeling with pain at the end range of passive antagonistic movement.

Immediate sessions of repetitive sustained stretches (manual therapy) should be introduced.

Postural guidance: The posture which keeps the tightness prone area stretched should be emphasized (e.g., prone lying for suspected contracture of hip flexors) besides this, postures promoting development of contracture (e.g., keeping soft pillow under the stump in sitting or supine lying) should be discouraged. At the same time, the patient should be taught to carry out sessions of self-stretching as much and as many times as possible.

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Orthotic devices, weight belts or sandbags can be used to provide sustained stretch by the patients themselves. Sessions of sustained stretches should be preceded by relaxed passive mobilization.

Strengthening exercises: PRE against gravity to the anatagonists of the tight muscle groups are important. Proprioceptive neuromuscular facilitation (PNF) and mobilization techniques are ideal.

Use of traction: Sustained sessions of gentle traction to stretch the contracture developing areas like hip or knee flexors.

Use of corrective splint: Corrective splint with adjustment to increase the pull gradually (velcro straps, buckles and/or broad cuffs can be extremely useful to induce low-intensity sustained stretching).

Remember

Flexion contracture at the hip is

- the commonest,
- most misleading,
- most difficult to eliminate and
- causes maximum instability in upright functional tasks (e.g., standing balance and ambulation).

As such, it needs regular monitoring and preventive procedures right from the initial stage following lower extremity amputations.

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Prevent persistence of haematoma: Persistence of haematoma has several risks, e.g., it increases the risk of infection by acting as a nidus for causing infection, besides causing delay in the process of wound healing.

Therefore, it should be prevented by the use of suction drain and proper haemostasis. When present, aspiration followed by firm compression dressing must be done.

Prevent infection: Patients with peripheral vascular disease or diabetes are easy targets for infection. Appropriate antibiotics following culture and sensitivity tests should be started urgently.

Prevent necrosis: Development of necrosis may occur in poorly prepared skin flaps with compromised vascularity.

Prevent neuroma: The cut end of the nerve may develop into a painful stump neuroma when it gets adherent to the scar tissue. This can be prevented by incising the nerve deep in the soft tissue.

3. **Mobility stage:** This is the stage of mobilization and restoration of functional independence. It starts with crutch walking at the earliest opportunity. The normal alignment of the pelvis and the reciprocal movement of the stump should be maintained during walking. It has been observed that patients usually tend to walk on crutches holding the stump in flexion; this needs immediate attention. Elderly patients may need initial ambulation practice in parallel bars. Freedom of managing various activities with crutches is very important. The patient may have to remove the prosthesis temporarily for certain postures and activities. Ladies generally prefer to remove the prosthesis for toilet activity. Therefore, functional training with

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crutches should be given to all hemipelvectomy, hip disarticulation and above-knee amputees. Resistive mat activities using PNF techniques are valuable to offer easy and stable mobility.

Mobilization and strengthening exercises: Mobility of the body segment proximal to the amputation and strengthening of the functionally important muscle groups need special emphasis (Table 25-1).

PNF techniques, PRE and strong endurance exercises to the specific muscle groups are needed to facilitate effective body functions with the prosthesis.

(a) Disarticulation of the arm: Shoulder elevators, depressors, protractors and retractors. Mobility exercise to the neck and trunk are also important.

(b) AE amputation: Flexors, abductors and extensors of the shoulder; scapular elevators and retractors on the normal side.

(c) BE amputation: Elbow flexors, extensors, pronators and supinators of the forearm with mobilization of the trunk.

(d) Hip disarticulation: Pelvic rotators and elevators

(e) Above-knee amputation: Hip extensors, abductors, flexors and shoulder girdle muscles

(h) Below-knee amputation: Knee extensors and flexors, hip abductors and extensors

(g) Syme's amputation: Same as in below-knee amputation

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ROM exercises: Full ROM exercises are regularly given to the joint proximal to the stump and also to other joints susceptible to developing contractures. Longer periods of prone lying should be encouraged.

Table 25-1

Guidance to Emphasize Optimal Strength, Endurance and Mobility Training to the Muscle Groups Following Amputation at Various Levels

Level of Amputation	Muscle Group to Optimize Strength and Endurance	Mobility Exercise
1. Disarticulation of the shoulder joint	Shoulder girdle muscle elevators, depressors, protractors and retractors on the side of the proposed amputation as well as on the contralateral limb	• Neck and trunk • Excessive stretching at the terminal ROM of the normal limb (to provide better assistance to the prosthesis limb)
2. AE amputation	• Flexors, extensors, abductors and adductors of the shoulder • Scapular elevators and retractors to facilitate movements of the prosthetic elbow joint	Mobility of the trunk and pelvis
3. BE amputation	Elbow flexors, extensors and forearm pronators and supinators	Trunk mobilization
4. Hip disarticulation	Pelvic elevators and rotators	Excessive mobility of the upper and the lower trunk
5. AK amputation	• Hip flexors, extensors and adductors • Shoulder girdle muscles	Trunk and pelvis
6. BK amputation	Knee–flexors and extensors	Hip joint
7. Syme's amputation	Hip flexors, extensors and adductors knee flexors and extensors	Hip and knee

Restore free mobility to the upper and lower trunks and the pelvis.

Do's and don'ts for the amputee

(A) ***During the first visit of the patient***

- Long explanatory and encouraging counselling
- Critical assessment
- Preoperative guidance and training

(B) ***Early postoperative phase***

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- Long session of counselling
- Preoperative training
- Measures to control oedema and pain
- Prevention of contractures:
  - Soft mattress bed is an invitation for developing hip flexion contracture, so also long periods of sitting. Even 5–10 degrees of FFD can result in difficulties in standing balance along with a limping gait.
  - Regular monitoring of the stump to ensure adequacy of circulation and healing of the surgical wound.
  - Guide and supervise to ensure strong and sustained isometrics to the functional muscle group of both upper and lower limbs required for ambulation and other functional activities of daily routine (ADRs).
  - Initiate weight bearing on the stump on a soft mattress by alternate weight transfer in knee-standing postures.
  - Sessions of improving free and easy mobility to the upper and lower trunk and the pelvis.
  - Extensively educate the patient on bandaging and ideal posture.
  - Give patient the responsibility of early and sound recovery by emphasizing and insisting on easy but beneficial modes of self-performance.

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(C) ***Late postoperative phase***

- Increase the vigourosity of exercises.
- Longer sessions of progressive ambulatory activities, e.g., stairs, slopes.
- Guidance to self-control whatever deviations present in the gait.
- Correct application and maintenance of the prosthesis.
- Sensory re-education towards the feel of the original normal limbs.
- Functional training towards the requirements of the job or work of daily routine.
- Alterations if required in the house or at the working place.
- Additional efforts to restore pre-amputation lifestyle.

Prosthesis

Prosthesis is a Greek word meaning 'addition', i.e., prosthesis is the substitution of a missing body part by artificially fabricated replacement to perform the basic functional task of the lost or missing part.

Classification of prosthesis

Prosthesis can be of the following types:

- **Endoprosthesis:** Replacing the missing body part inside the body

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by an artificially fabricated similar prosthesis, e.g., joint replacement

- **Exoprosthesis:** Replacing the externally missing part of the body to perform its functional tasks, e.g., prosthesis designed for the missing external segment of the upper and lower limbs.

The materials used in the fabrication of prosthesis include the following:

Metal: Steel and other alloys are used for the hip and knee mechanics. Duralumin is used for the outer shell and the socket.

Leather: Soft leather is used for the suspension straps while hardened leather (block leather) is used for the socket and thigh corset.

Plastics: Thermoplastic materials like polypropylene are used for the inner lining of the socket.

Plastic form is also used to support the distal tissues of the stump and the cosmetic covering of the prosthesis.

Wood: It is usually preferred as a socket material and the prosthetic feet, especially in tropical climates.

Stages in the application of prosthesis

During the early immediate postoperative phase, the patient is provided with a temporary prosthesis. Later on, it is replaced by a final prosthesis.

Temporary prosthesis

A lightweight, mechanically simple temporary prosthesis (rocker pylon) is given to assess the potentials of the patient and to encourage early standing (see Fig. 25.3). It can be fitted following stitch removal within 2 weeks. The patient is given training in balancing and standing in the parallel bars.

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Final prosthesis

A final prosthesis is prescribed after critically assessing the performance of the patient with the temporary prosthesis.

Basic features of a prosthesis (fig. 25-7)

1. *Socket:* It provides weight bearing and receptive areas for the stump.

2. *Suspension:* It holds the prosthesis to the stump.

3. *Joints:* The joints which are amputated are replaced by artificial mechanical joints.

4. *Base:* It provides contact with the floor.

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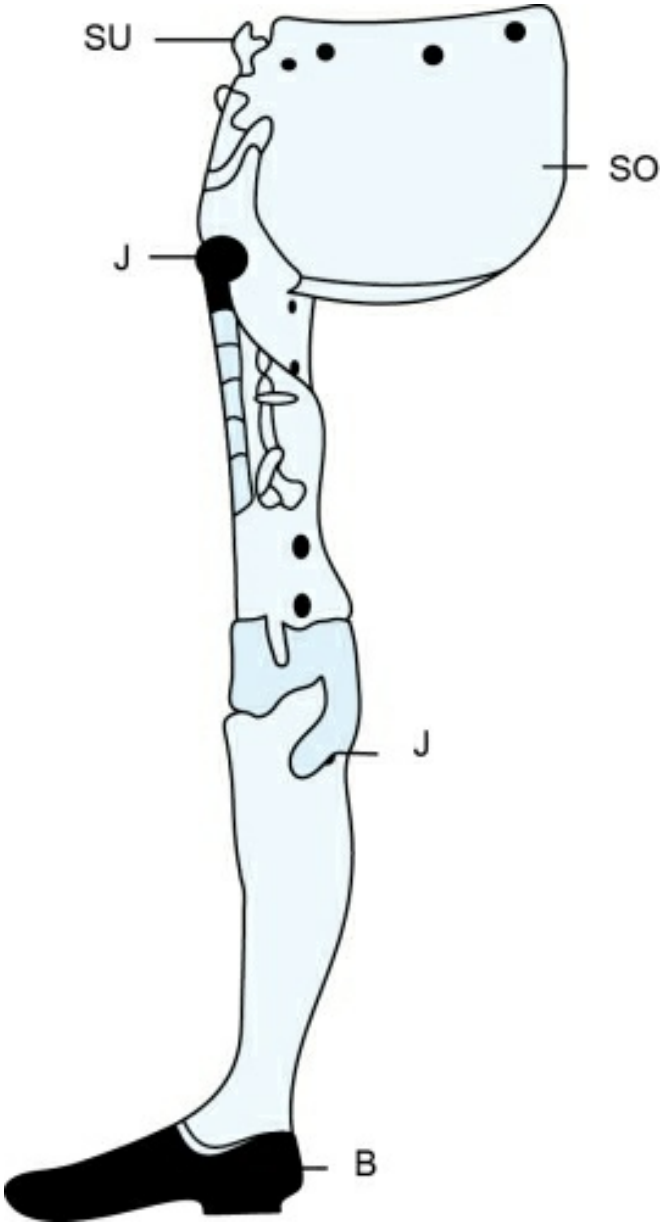

FIG. 25-7 Hip disarticulation prosthesis and its basic features. SO, socket; SU, suspension; J, joint; B, base.

Methods of fabrication of prosthesis

1. Conventional or exoskeletal prosthesis: The strong outside shell supports the body weight of the patient.

2. Modular assembly prosthesis (MAP) or endoskeletal prosthesis:

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Here the patient's weight is supported by a metal tube with soft cosmetic covering. The present trend is to provide a lightweight endoskeletal prosthesis with one-piece cosmetic covering.

The mechanical joints are constructed according to the functional demands of the amputated joints, giving the necessary mobility as well as stability. Locking mechanism can be automatic, semi-automatic or manually operated. The joint can be free, with a restricted arc of motion or it can be one with constant friction.

Prescription of the prosthesis

The type of prosthesis to be prescribed depends on various factors like:

1. Age of the patient

2. General physique of the patient

3. Length of the stump

4. Status of circulation to the stump, e.g., a suction socket should not be prescribed for a patient with insufficient limb circulation

5. Strength, ROM, stability and mobility of the related body segments

6. Requirements of job and daily living

Prosthesis for lower limbs amputations

Depending upon the level of amputation, there are seven types of prosthetic designs for lower extremity amputations:

1. Hemipelvectomy amputation

2. Hip disarticulation

3. Above-knee amputation

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4. Through-knee amputation

5. Below-knee amputation

6. Syme's amputation

7. Partial foot amputation

Designs of fabrications vary with level of amputation.

Hemipelvectomy

In this operation, half of the pelvis and complete lower limb is removed.

Hip disarticulation (fig. 25-7)

In this, the pelvis is intact but the whole of the lower limb is removed from the acetabulum.

Prosthetic design (components)

- *Socket*: A totally embracing socket is given which encloses both the iliac crests. In case of hemipelvectomy, the weight-bearing area is the ischial tuberosity and the buttock of the other side, while for hip disarticulation, the weight-bearing area is the ischium and the buttock of the amputated side.

- *Suspension*: Through the total tissue contact with locking over the iliac crests. Additional shoulder suspension may be necessary.

Joints

Artificial joints of the prosthesis could be

1. Manually operated

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2. Semi-automatic

3. Automatic

Hip mechanism: It could be either of the following:

1. Standard hip joint which locks automatically in extension.

2. Canadian tilting mechanism which is fitted anteriorly on the socket. It locks anteriorly on the socket. It also locks automatically when the patient stands. At the same time, it allows 20 degrees of hip flexion during the swing phase of the gait.

Knee: The knee joint is constructed in slight hyperextension to offer stability during the stance phase: This allows the ground reaction force to pass anterior to the knee joint. Knee lock could be hand operated, semi-automatic or with constant friction device.

Feet: Ideally SACH (solid ankle cushion heel) foot is given to offer maximum stability during floor contact (Fig. 25-8).

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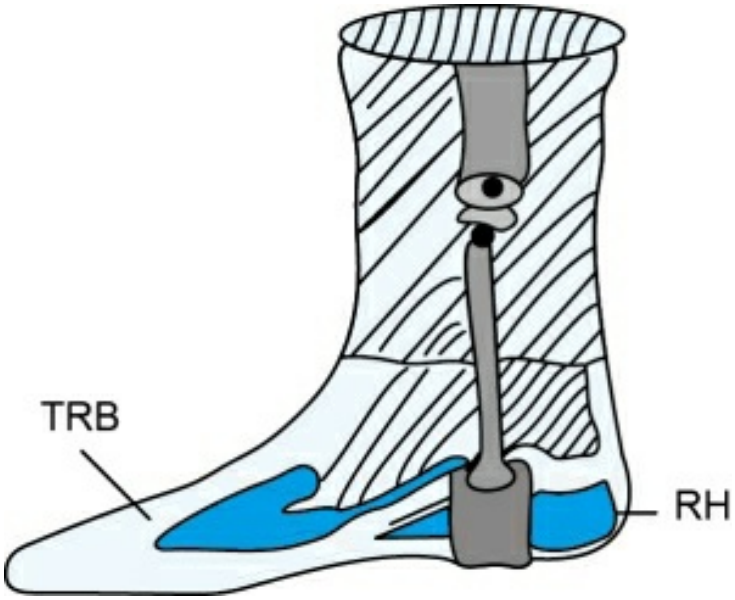

FIG. 25-8 Solid ankle cushion heel (SACH) foot. TRB, toe (rubber) bumper; RH, rubber heel wedge.

Above-knee amputation

Prosthetic designs

Socket: Quadrilateral H-type socket, in which most of the body weight is transmitted through the ischial seat and the posterior brim of the socket.

Suspension: Suspension with double swivel pelvic band with multiaxial joint provides all the basic movements at the hip. However, rigid pelvic band allowing only flexion and extension at the hip is preferred in cases where the muscle control and stability of the joint are deficient (Fig. 25-9).

Suction socket or a modular prosthesis: Suction socket with valve, which requires a cylindrical stump that fits snugly and has two-way valves is ideal. It has a mechanism for the maintenance of a negative pressure which holds the prosthesis in place with total stabilization during performance of both static and dynamic ambulatory activities (Fig. 25-9B), modular prosthesis (Fig. 25-9C).

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Suction sockets have the following advantages:

- Greater feel of a close contact promoting the sensation of a most stable normal limb.
- There are less chances of infection.
- Stump socks are not necessary.

However,

- Nonsuction sockets provide comfortable fit.
- No difficulty in changing the stump circumduction.
- There is lesser discomfort of perspiration.

Knee mechanism: Hand-operated or semi-automatic locking mechanism along with constant friction device or knee joint with free mechanism at swing can be given.

Feet: Uniaxial or multiaxial SACH foot is preferred. It stimulates plantar flexion through compression of rubber heel. Uniaxial foot permits both dorsiflexion and plantar flexion. The biaxial foot also allows eversion and inversion. The foot made of wood moulded with plastic material is incorporated with rubber bumpers to provide necessary movements.

- **Note:** Suction socket is never prescribed for amputees with circulatory disturbances.
- It is ideal for young adults.

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■ Conventional type of prosthesis is safe and suitable for weak and elderly patients, labourers and those requiring long standing.

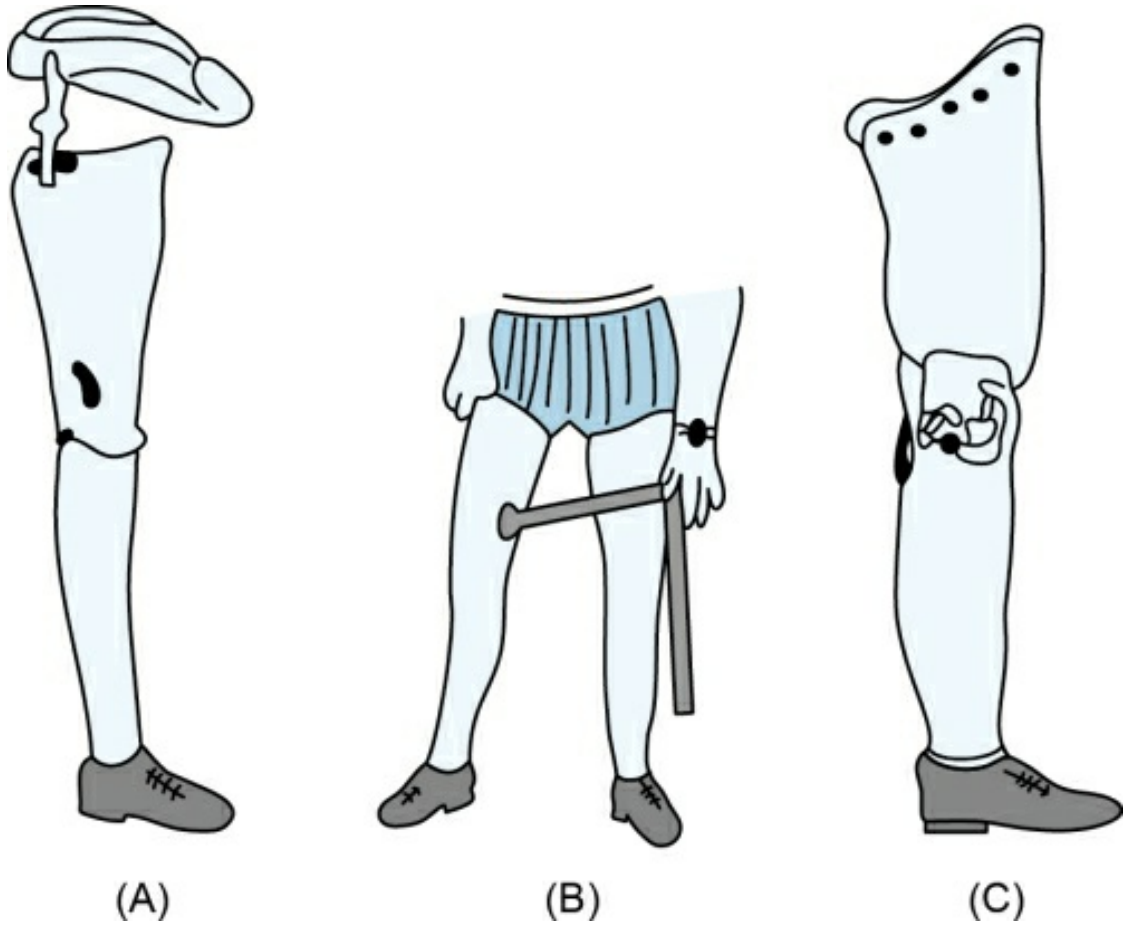

FIG. 25-9 Above-knee amputation prostheses. **(A)** With pelvic band. **(B)** With suction socket. **(C)** With modular assembly.

Through-knee amputation (fig. 25-10)

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FIG. 25-10 Conventional prosthesis for below-knee and through-knee amputations.

Prosthetic design

Socket: A self-suspending thigh corset with ischial seating area made of blocked leather or metal or a total contact of plastic material is used. It could be made a rigid contact from the plastic material.

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Suspension: It may be a rigid pelvic band, shoulder suspension or a waist band.

Knee: Uniaxial knee joint with automatic or manual locking ring.

Feet: Either uniaxial or a SACH foot.

Through-knee and above-knee amputees have to depend upon prosthetic knee joints for mobility as well as for stability. It takes them a longer time to get adjusted to it. Younger patients learn to manage independent ambulation early while older patients need to lock knee joint and a walking aid.

Below-knee amputation

Two types of prosthesis are used: (i) conventional prosthesis with thigh corset (Fig. 25-10), (ii) PTB prosthesis (Fig. 25-11).

(i) *Conventional prosthesis with thigh corset:* It is preferred in patients with:

(a) An unstable knee joint

(b) Flexion deformity of more than 25 degrees

(c) Very short stump

(d) Anaesthetic stump

(e) Patellar malformation

(f) Those who have to perform heavy duties

Thigh corset: It is made up of blocked leather with steel uprights and front fastening.

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Socket: It is a proximal weight-bearing socket made of metal, wood or moulded polyester resin. It extends 3 cm proximal to the lower pole of patella.

Suspension: Rigid pelvic band, shoulder strap or waist belt suspension may be used.

Knee joint: Uniaxial knee joint allowing free movements.

Feet: Uniaxial foot.

(ii) *PTB prosthesis* (Fig. 25-11): The PTB prosthesis is ideal and handy for patients with a long stump. It offers normal gait and early rehabilitation.

Socket: Soft inner socket with a hard covering is set in slight flexion at the knee to ensure correct weight bearing. Major weight-bearing area is on the patellar tendon emphasized by the counterforce of the upper part of the posterior wall.

Weight-bearing areas: Patellar tendon area, medial flare of the tibia and tibial condyle. The lateral flare of the tibia to a lesser extent and posterior muscle bulk (Fig. 25-12).

Pressure-sensitive areas: The proximal end of the tibia, the crest of tibia and tibial tubercle, head of fibula and medial and lateral insertion of hamstrings (Fig. 25-12).

Suspension: Elastic stocking suspension and supracondylar cuff.

Feet: Either uniaxial, multiaxial or SACH can be used.

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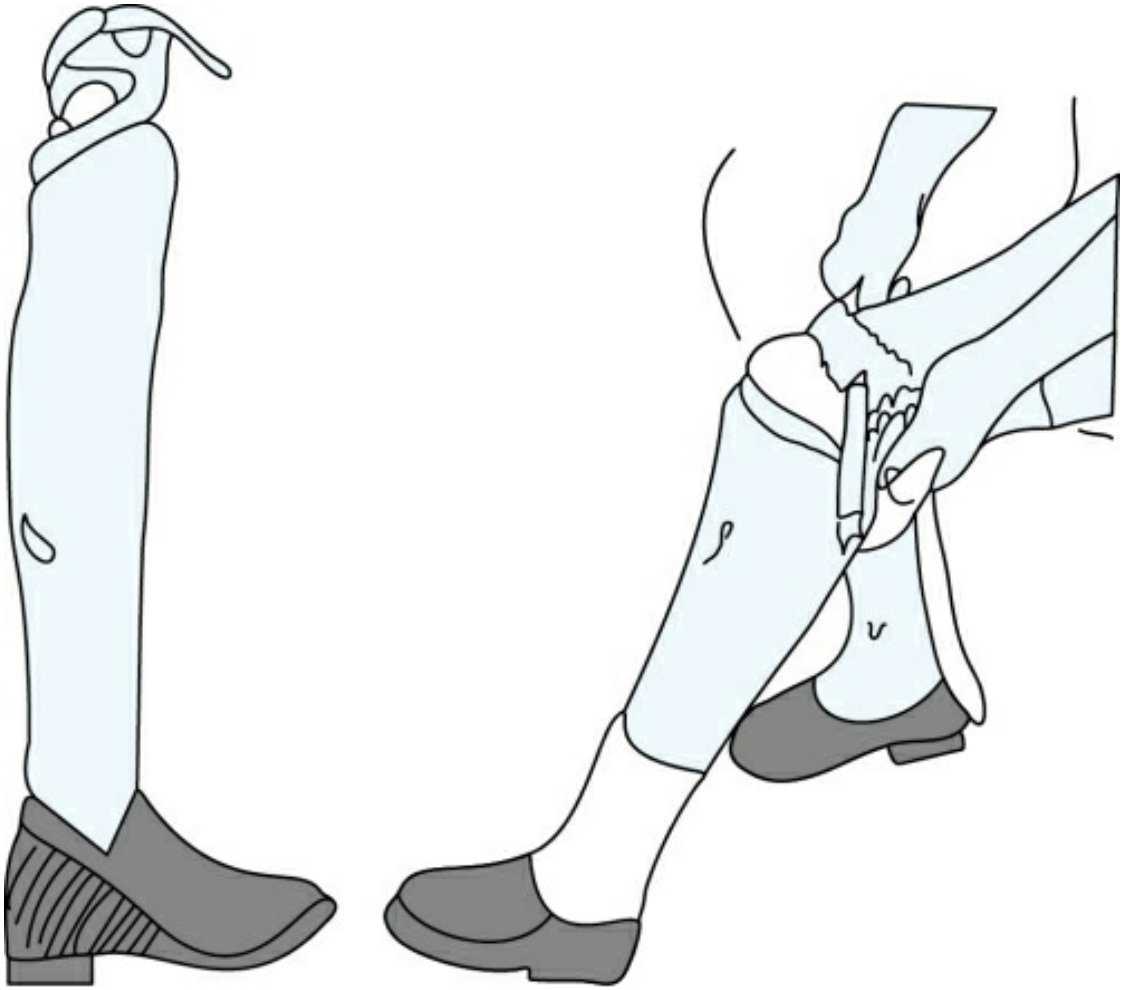

FIG. 25-11 Patellar tendon bearing prosthesis. **(A)** Lateral view. **(B)** Application of PTB prosthesis.

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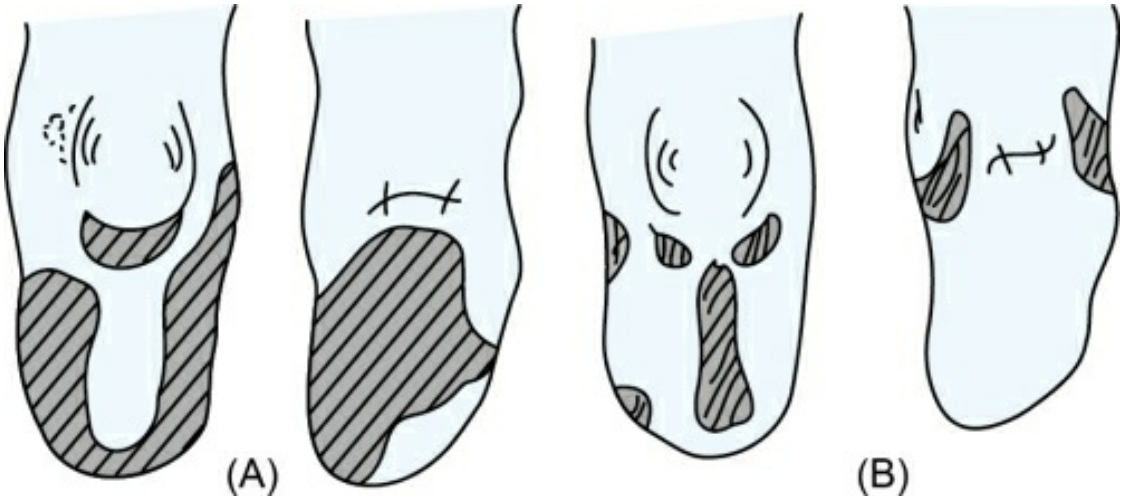

FIG. 25-12 Critical areas on the anterior and posterior aspects of below-knee stump. **(A)** Pressure-tolerant areas or weight-bearing areas. **(B)** Pressure-sensitive areas.

Almost all patients can be made ambulatory with a normal or near-normal gait. Younger patients can manage all the activities including running and sports without any aid (Brouwer et al., 1989).

Syme's amputation (see fig. 25-3)

(i) Plastic Syme prosthesis: A hard plastic outer socket is lined by a pelite liner with medial or posterior access panel. The foot could be uniaxial or SACH.

(ii) Three-strip Syme posterior steel socket is fully articulated to the foot. The socket is anteriorly connected by two side steels and an inverted Y-shaped front steel part. The socket is made of leather with an access opening posteriorly.

(iii) Enclosed metal Syme: There is a leather liner with a posterior flap opening fitting inside the metal socket. The uniaxial foot is used.

(iv) Tongue and bolt Syme: A leather socket with front open and two side steels connect the socket to the foot piece.

These patients need no support and can manage all activities freely,

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including sports.

Partial foot amputation

1. A simple shoe filler made of leather, covered with ortholene, is fitted in the shoe.

2. A short leather ankle corset is attached to the wooden foot worn inside the shoe. The design of the prosthesis depends upon the individual stump and thus several designs can be fabricated.

Patients achieve total freedom of ambulation and all the activities.

Prosthesis for bilateral amputations

Bilateral amputees pose problems in balancing and equilibrium because of the total loss of proprioceptive feedback from the walking surface. They invariably need temporary short prosthesis which brings down the centre of gravity to ease the learning process.

The presence of a natural knee joint is very important and therefore, bilateral below-knee amputees have good potentials for ambulation.

Prosthetic rehabilitation is possible in patients where there is at least one-knee joint and the other hip is free from flexion contracture. In bilateral above-knee amputees with long stump or through-knee amputations without hip flexion deformity, indoor walking with plastazote stump covers, or short crutches is possible (Fig. 25-13). For an elderly obese patient, wheelchair provides an ideal means of mobility.

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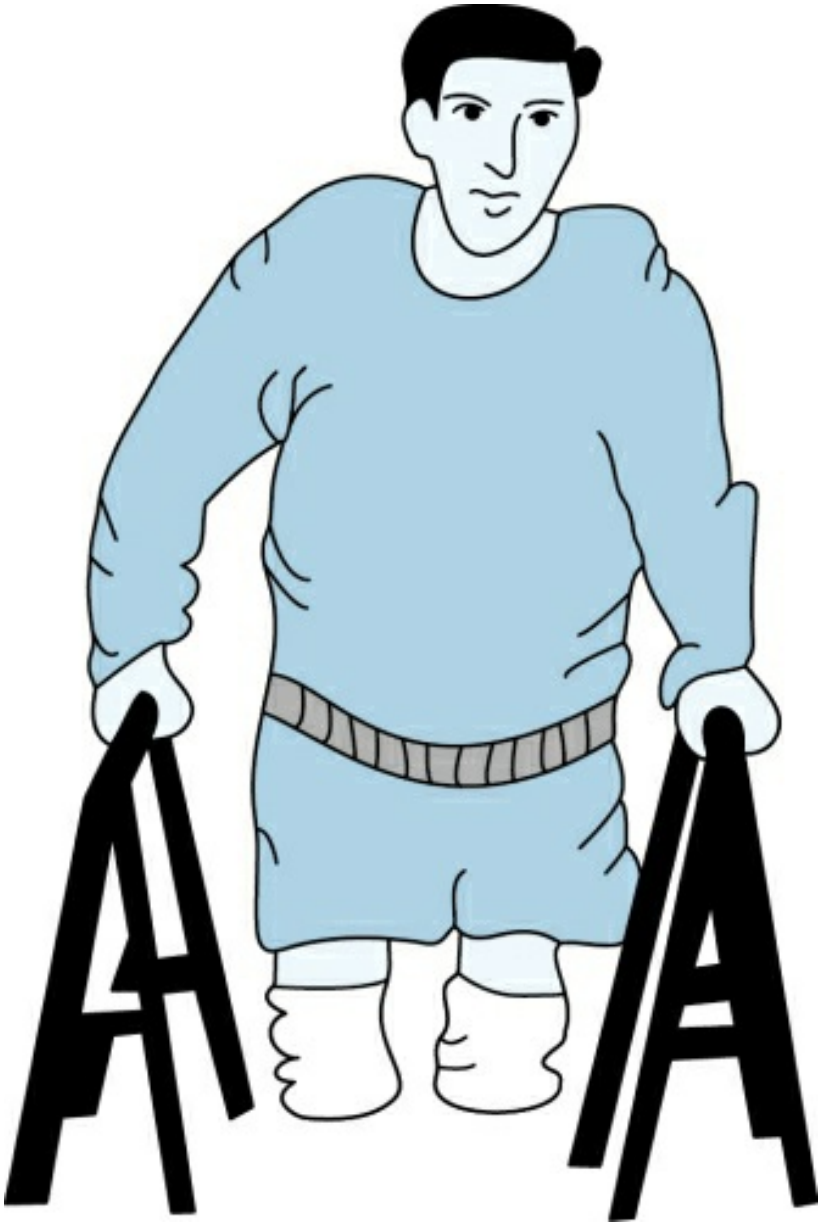

FIG. 25-13 Bilateral through- or above-knee amputee ambulation with plastazote stump covers and short arm crutches.

The length of the short prosthesis is increased at the second stage. If patient attains proficiency, the final prosthesis can be given in the third stage. The type of the final prosthesis depends upon the patient's ability.

Considerable time and efforts are needed to train bilateral amputees to check and adjust the prosthetic alignment in balancing, standing, walking, transfers and stair climbing.

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The physiotherapeutic programme, besides ROM strengthening and balancing, should be concentrated on achieving maximum trunk and pelvic mobility for easy postural adaptations for balance. One knee is kept locked during all the activities and at least double cane support is needed for stable balance.

Prosthesis for bilateral hip disarticulation

It is rare and difficult to manage. Physical independence is difficult to achieve, particularly stability in sitting balance and transfer. A special sitting 'shell' is necessary to learn balance (Fig. 25-14).

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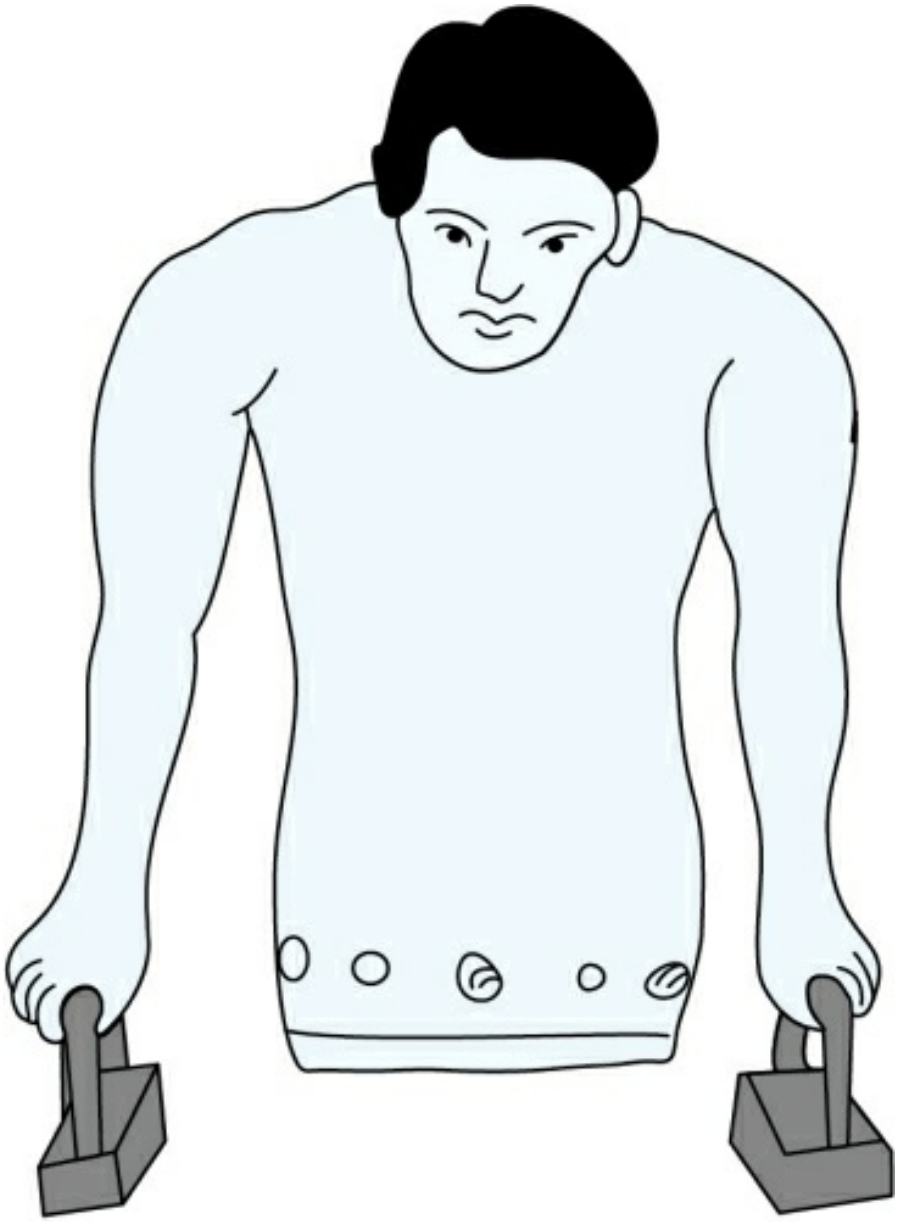

FIG. 25-14 Bilateral hip disarticulation. Ambulation with special 'sitting shell' and push-up blocks.

In a patient with very strong arms and trunk muscles, good balance and good pelvic mobility and lumbar mobility, limited ambulation may not be impossible with prosthesis and bilateral axillary crutches or push-up blocks. But the patient needs help for wearing the prosthesis and also for assuming standing as well as sitting positions from standing. He also cannot manage on uneven ground, slopes and stairs.

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A fibre glass total chest contact jacket prosthesis consisting of anterior and posterior shells was reported by Cosla et al. (1965). This provides the necessary stability for wheelchair ambulation as well as floor ambulation using small hand crutches.

Bilateral below-knee amputees, through-knee amputees or combination of above-knee and below-knee amputees can be given prosthesis in stages, starting with temporary simple prosthesis.

Prosthesis for upper limbs amputations

The ratio of upper to lower limb amputations is approximately 1:24.

Upper limb amputation may be:

1. Acquired

2. Congenital

1. *Acquired:* Due to trauma or diseases like tumour, leprosy, peripheral vascular diseases like Buerger or Raynaud disease and thrombosis or embolism.

2. *Congenital:* There may be congenital absence of part of the limb or congenital deformity. These conditions need a highly individualized approach and long efforts, as the problems are complicated and specific to each patient. The basic aims of treatment are improvement of joint mobility, strength, balance and coordination, control of oedema and the maintenance of neurophysiological movements.

In upper extremity amputees, immediate (within 48 h) postsurgical fitting of a temporary prosthesis is highly successful. Plaster of Paris or thermoplastic materials are used for BE amputees and a learner socket with sockets and split hook for the AE amputee.

There are six types of prosthetic designs for upper extremity amputees depending upon the level of amputation:

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1. Forequarter amputation

2. Shoulder disarticulation

3. AE amputation

4. BE amputation

5. Wrist disarticulation

6. Mechanical terminal devices

1. *Forequarter amputation:* The whole arm is removed along with the clavicle and scapula. A plastazote cap, padded with foam and retaining straps, may be provided. Only a sleeve-fitter cosmetic prosthesis can be supplied.

2. *Shoulder disarticulation:* It incorporates an extended shoulder cap to hold the prosthesis. The elbow joint of the prosthesis can be flexed by strong protraction of the shoulder girdle which puts tension on the flexion cord. Hand piece can be purely cosmetic or the split hook type (Fig. 25-15).

3. *AE amputation:* The prosthesis is the same as for shoulder disarticulation. In this, flexion of the elbow joint, attained by the combined action of scapular protraction and arm flexion is comparatively stronger. Automatic functional locking can be achieved by reverse movement of combined depression and extension of the arm.

4. *BE amputation* (Fig. 25-16): (a) A cup socket, harnessed with an operational cord, can be given to activate the

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terminal device and (b) the terminal device is operated by a loop harness attached to a self-suspending supracondylar socket.

5. *Wrist disarticulation:* For wrist disarticulation or long BE stump, split socket forearm with wrist rotation unit can be given. A locking device can be provided for pronation and supination (Fig. 25-17).

6. *Terminal devices*

(a) Mechanical thumb abduction for grasp can be attained by tension on the operational cord.

(b) Mechanical hand allowing grippy flexion of the index and middle fingers with the thumb are available.

(c) Split hook: A popular terminal device with one fixed and the other movable jaw operated by power of the shoulder girdle muscles is used as a strong working hand.

(d) Battery-operated myoelectric device for grip (Fig. 25-18): Other terminal devices for the specific tasks are also available or can be fabricated.

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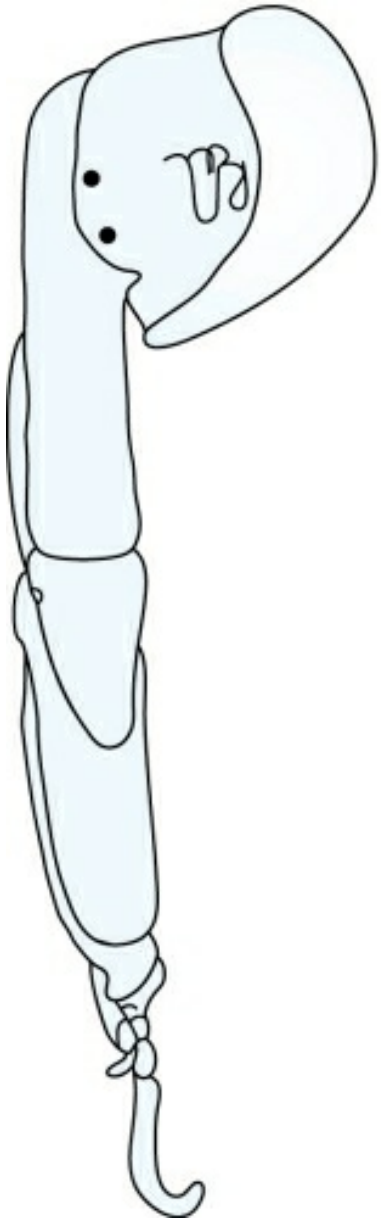

FIG. 25-15 Shoulder disarticulation prosthesis.

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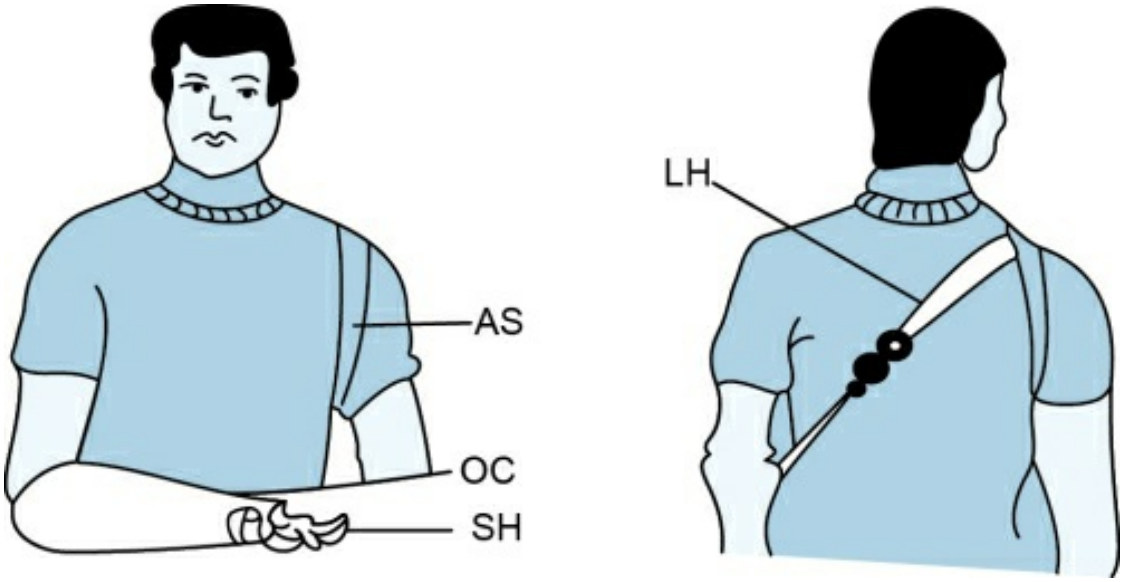

FIG. 25-16 Below-elbow prosthesis with loop harness and split hook terminal device. AS, axillary strap; OC, operational cord; LH, loop harness; SH: split hook.

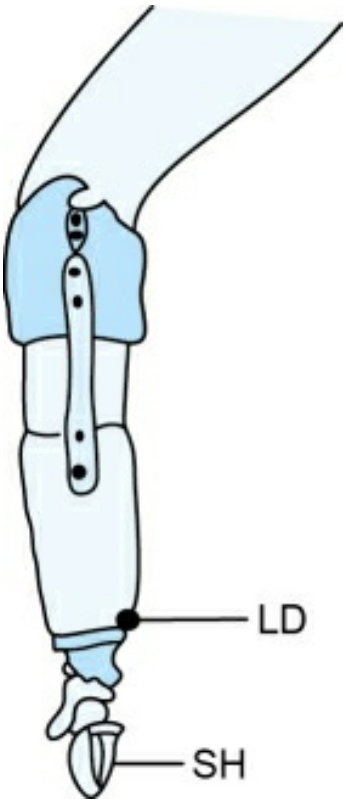

FIG. 25-17 Wrist disarticulation or long below-elbow stump: split socket

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forearm prosthesis. LD, Wrist rotation unit with locking device; SH, split hook.

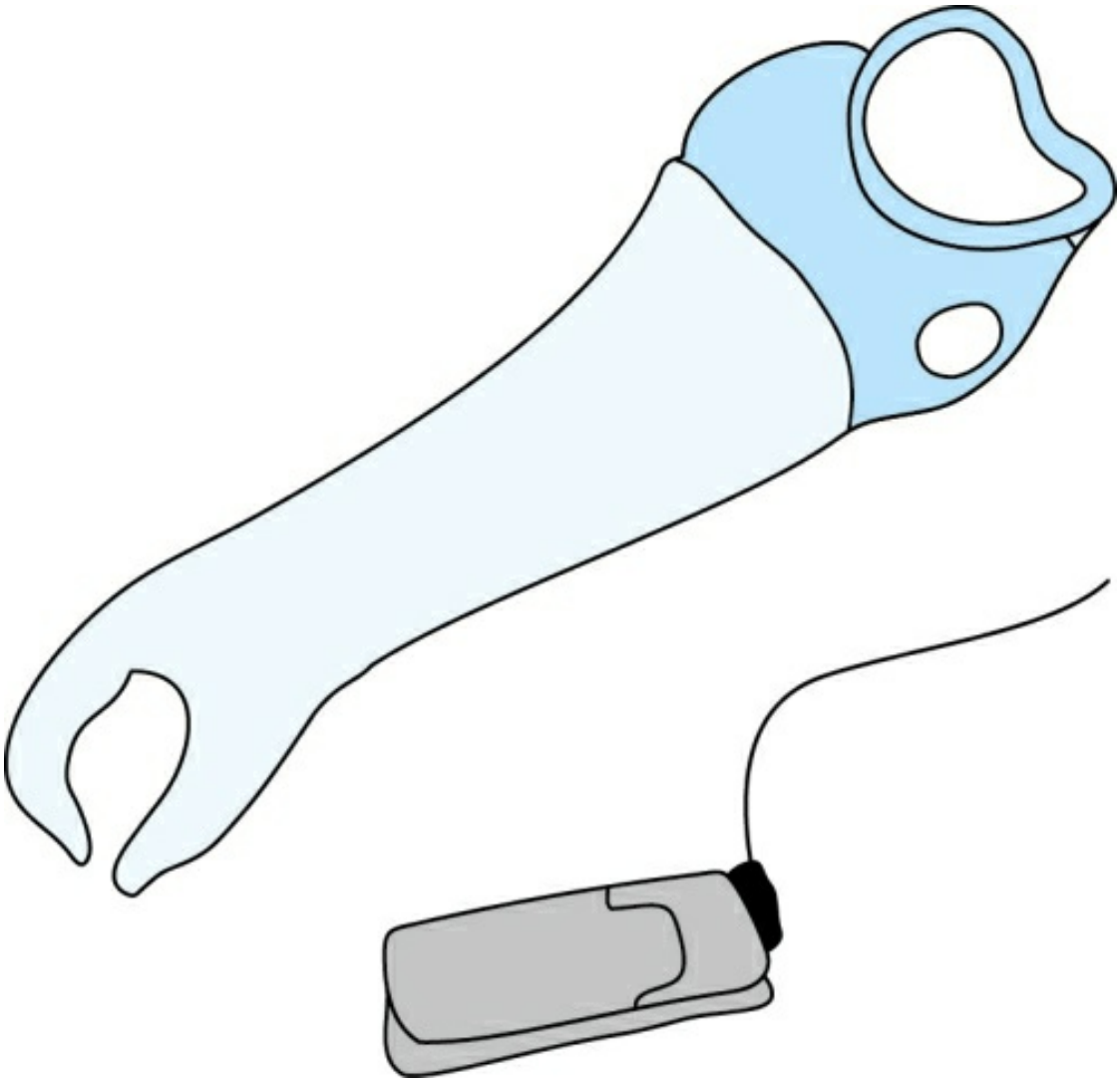

FIG. 25-18 Battery-operated cosmetic glove (myoelectric device) for three-point grip and release action on activation of flexor and extensor group of muscles, respectively.

Upper and lower limb combination

1. *One upper and one lower limb:* The lower limb prosthesis is fitted first, while exercise and other programme of management are continued.

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Upper-limb prosthesis is fitted at a later date after regaining proficiency in ambulation.

2. *One upper and bilateral lower limbs:* Here the upper limb prosthesis is fitted first and the lower limbs prosthesis is fitted subsequently.

Congenital absence and deformities

The majority of these deficiencies are present in the upper limbs. The ratio of upper limb to lower limb anomalies is approximately 5:1. A child can be born with total absence of one to all limbs.

The commonest upper limb deficiency is absence of hand or the remnants of forearm (hemimelia). As soon as the child starts sitting (6 months age), he is fitted with a passive arm to get adapted.

At the age of 2 years, a body-powered working prosthesis diminutive model of a split hook type could be given and the child taught to use it with play activities. At school-going age, it may be replaced by an externally-powered prosthesis.

Myoelectric prosthesis

Effective hand function has been reported by myoelectrically controlled prosthesis in adults as well as in children. The prosthesis has a self-suspending socket with pick up electrodes placed over the flexors and extensors for the movements of flexion and extension, respectively. These electrodes pick up the myopotentials generated by the contractions in the respective muscles. The electrical potentials are amplified by microcircuitry. The motion power is derived from compact 6 volt batteries. Thought and voluntary effort producing flexion contractions will switch on flexion or grasping motion of pinch grip at the hand.

Reversing the process to the extensor group initiates extension or the release of grasp. The main advantage is the combination of function and cosmesis.

In the lower extremity, the prosthesis is prescribed as per the extent of the deficiency. The time of fitting a prosthesis could be anywhere between 6 and 8 months. At this age, the child attempts to pull up to

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standing; till that time, physiotherapeutic measures as described in the preprosthetic stage should be initiated. Children pick up very quickly provided proper education is given to the parents.

Limb deficiencies that can be compensated by a prosthesis can be easily managed by training.

Application and checking of the prosthesis

The prosthesis should be thoroughly checked for smoothness of contact areas, joint alignments and character of movements of the prosthetic joints in relation to the needs of the patient.

Points to be checked before and after fitting the prosthesis – before proceeding with functional use and ambulatory training – are presented in Box 25-1.

Box 25-1

Important Points to be Checked before and While Applying the Prosthesis

- Check the alignment of the joint and its ROM.
- Socks should be pulled up and fastened firmly.
- The prosthesis should be applied in the functional position, e.g.,
- In sitting for the upper limb
- In standing for the lower limb, etc.
- Check firm heel contact with the ground in standing with equal weight on both the limbs. Also check the anatomical alignment of both the limbs.
- Check for pain or discomfort on body weight transfer on the prosthetic limb or standing on the prosthetic leg alone.
- Ensure the position of the axis of weight bearing.

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- Firm fitting of the socket, corset, pelvic band over the anterior superior iliac spine (ASIS).
- Check position and functions of the prosthetic joints.
- Check the length of the prosthesis with balanced standing by the position of the ASIS. Confirm that they are in a perfect horizontal line.

The sock is pulled well on the stump and secured properly. The prosthesis is applied and checked in the functional position. The patient standing in parallel bars with the feet two inches apart is the ideal position for checking the lower limb prosthesis. The upper extremity prosthesis is checked with the patient in sitting position. Anatomical alignment of the prosthetic joints is checked in relation to the normal limb joints. Various levels of the body are checked anteriorly, posteriorly and from the sides, e.g., shoulder, pelvis, knee joints and feet with equal body weight borne on both the legs. Any discomfort on the pressure areas is noted. Proper weight transfer on weight-bearing areas should be ascertained. Axis of weight bearing and the axis of the prosthetic joints are checked the former in standing on the prosthetic leg alone and the latter by voluntary movements of the limb with prosthesis. Total alignment of all the components of the prosthesis in relation to the stump and the whole body is carefully done in functional positions as well as by initiating and assisting functional activities.

Socket: Overall fitting of the socket is to be checked. Weight-bearing areas, e.g., upper brim of the ischial seat, should not be biting into the flesh. Weight bearing should not cause discomfort on the terminal end of the stump.

Corset: It should be close fitting with the thigh. Weight bearing is through the ischial seat area or inguinal region. It should provide proper support without discomfort on bearing weight.

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Suspension: It may be in the form of a rigid pelvic band, Silesian belt, shoulder suspension or waistband with down straps. If there is proper fitting of the socket, the role of suspension is just to provide additional stability.

Prosthetic joints: Prosthetic joints should be thoroughly checked for their axes, arcs and movements with and without prosthesis.

Base: Rocking mechanism SACH uniaxial or biaxial foot of the brace should be checked properly, both with and without prosthesis.

Length: Accurate check of the length is necessary for the lower extremity prosthesis. It is done by using the shortening blocks and observing steady standing posture.

Re-education with prosthesis

Once the fitting of the prosthesis is found satisfactory, the process of training and re-education of the amputee begins for functional use of the prosthesis. It includes:

1. Correct method of application and removal of the prosthesis.

2. Early detection of any complications arising due to prosthesis.

3. Functions of the various components of the prosthesis and overall limitations on the activities of the prosthetic limb.

4. Gait training in lower limb amputees.

5. Functional training in the use of the upper extremity prosthesis.

6. Guidance on proper maintenance of the prosthesis.

Ambulation and gait training forms the major part of rehabilitation programme for lower limb amputees. The main problem in gait training is the difficulty in maintaining balance and equilibrium. Total lack of proprioception from the floor is the root cause.

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It is, therefore, important to initiate standing and gait training at the earliest, with adequate visual compensation and pre-ambulatory training (Figs 25-19 and 25-20).

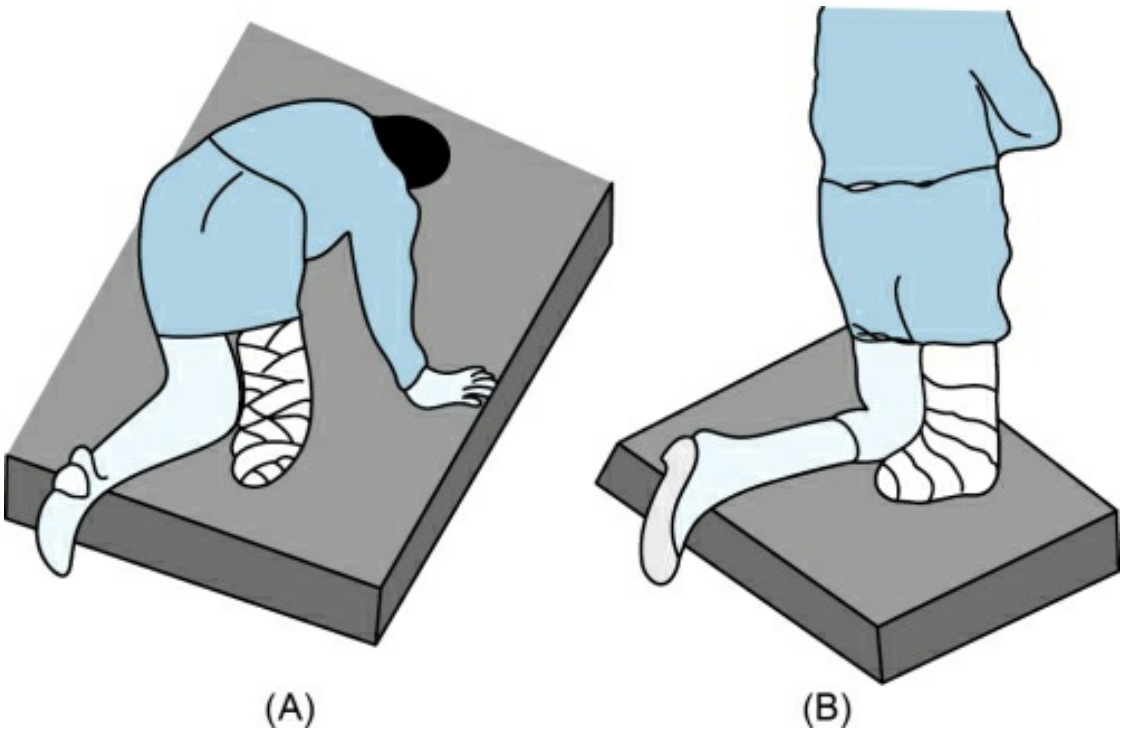

FIG. 25-19 **(A and B)** Below-knee amputee practising four-point and two-point kneeling.

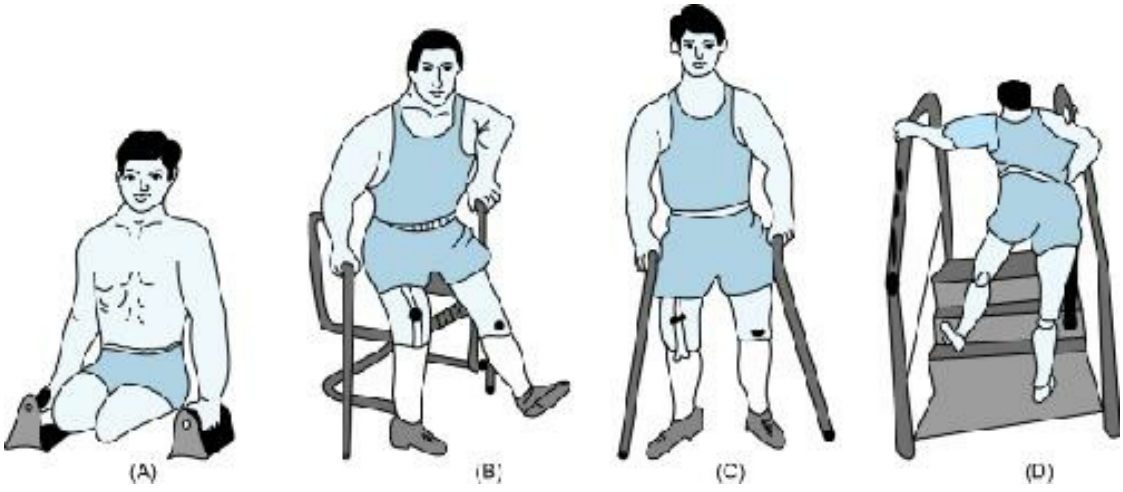

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FIG. 25-20 Bilateral above-knee amputee. **(A)** Preambulatory push-ups. **(B)** rising from chair by locking left knee. **(C)** Walking with two canes. **(D)** Climbing stairs with one cane and holding stair railing on the other side.

Gait training

It is initiated, by careful monitoring of the patient, in the gradually progressive stages outlined as follows.

Training in Parallel Bars

1. Standing balance with equal weight on both legs.

2. Correct method of weight transfers on an individual leg.

3. Weight transfers on both legs alternately emphasizing single-leg standing on the prosthetic leg.

4. PNF techniques of resistive gait, rhythmic stabilization and approximation are to be emphasized.

5. Normal coordinated stepping in parallel bars with bilateral hand support to be initiated as early as possible. It needs careful training in all the aspects of normal gait.

6. Progress to single hand support.

7. Raising to standing from sitting and sitting from standing.

8. Sidewalks and turning.

The various ambulatory activities like sitting, standing, negotiating slopes and stairs and getting up from the floor should be taught. While guiding these activities, basically, the patient should be trained to maintain balance and stability by the maximum use of the unaffected or strong parts of the body and the sound limb (for details, readers are recommended to refer to Engstorm Van de ven).

Once the patient is proficient in parallel bars, he is made to walk on the footmarks on the floor in front of a postural mirror. It provides

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enough scope for self-corrections. This encourages the patient to watch and correct the pattern of gait himself.

Frequent checks of the skin, especially the pressure areas, and precise analysis of the gait deviations are necessary.

Besides using PNF techniques to attain efficiency in ambulation, considerable time should be spent on balancing on the affected leg alone. This offers stability and prevents limp. One should remember that proficiency in the pattern of gait must not be attempted at the cost of the three 'Ss', i.e,. security, stability and safety of ambulation.

Caution

1. Undue haste to minimize the walking aid should never be attempted. This may lead to a permanent lack of confidence or a habitual limb. It may even lead to a patient refusing to walk.

2. The amount of energy consumption during walking with different levels of amputation should be considered while planning the programme of ambulation. The percentages of excessive energy consumption are as follows:

Unilateral below-knee amputee: up to 9%

Unilateral above-knee amputee: up to 49%

Bilateral above-knee amputee: up to 80%

Gait deviations in lower limb amputees: The deviations from the normal pattern of gait could either be because of the musculoskeletal deficiencies in the body and the concerned limb or due to defect in the prosthesis. It is, therefore, important for the physiotherapist to identify the cause and rectify it. Gait deviations are usually minimal, if the patient has had proper education during the preprosthetic stage.

Common gait deviations and their possible causative factors are depicted in Tables 25.2 and 25.3.

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Table 25-2

Gait Deviations with the PTB Prosthesis and the Possible Causes

Deviation	Amputation Cause	Prosthetic Cause
During stance		
Excessive knee flexion	1. Flexion deformity at hip/knee 2. Pain	1. Excessive dorsiflexion 2. Ill-fitting socket 3. Faulty cuff suspension 4. Stiff plantar flexion bumper
Insufficient flexion or hyperextension	1. Weak vastus medialis 2. Unstable knee 3. Stump discomfort 4. Patient habituated to corset prosthesis	1. Excessive foot plantar flexion 2. Hard plantar flexion bumper 3. Incorrectly aligned socket
Trunk lateral bending	1. Painful stump 2. Lack of balance 3. Weakness of hip abductors	1. Short prosthesis 2. Socket in adduction 3. Too lateral foot setting
Foot rotation	1. Pain 2. Unstable knee joint 3. Weak hip muscles	1. Hard plantar flexion 2. Ill-fitting socket 3. Poor suspension
During swing Delayed knee flexion	1. Limitation of pelvic and hip movements 2. Stiff knee after having used AK/BK prosthesis	1. Inadequate suspension

Note: There is a general tendency of excessive dorsiflexion during the heel strike phase in all lower limb amputees as a safety measure to quickly transfer and balance on the prosthetic limb.

Table 25-3

Gait Deviations and Possible Causes with AK and Through-Knee Prosthesis

Deviation	Amputation Cause	Prosthetic Cause
At stance 1. Foot rotation	1. Weakness of hip extensors and medial rotators	1. Loose socket 2. Incorrect prosthetic alignment (too much toe out)
2. Lumbar lordosis	1. Hip flexion contracture 2. Weak hip extensors 3. Weak abdominals 4. Attempts to bring centre of gravity forward	1. Insufficient flexion in the socket alignment 2. Discomfort on ischial-bearing area 3. High heel on prosthetic shoe
3. Drop off – body moving down with weight bearing on prosthetic	1. Incorrect shoe	1. Too soft dorsiflexion bumper in prosthetic foot

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foot		
4. Foot slap	1. Habit 2. Incorrect shoe	1. Too soft plantar flexion bumper
	To prosthetic side	
5. Lateral or side bending	1. Stump with abduction contracture 2. Short stump 3. Painful stump	1. Short lateral socket wall, insufficient support to femur 2. Too short prosthesis 3. Abducted socket 4. Hurting medial brim of the socket
	To normal side	
	1. Weak abductors on the amputated side	1. Top long socket 2. Incorrect alignment of prosthesis socket too abducted
Short stance phase on amputed side	1. Lack of balance on weight bearing	1. Ill-fitting socket causing discomfort
Uneven arm swing	2. Lack of confidence	
Uneven timing	3. Weak trunk or leg 4. Habit 5. Hurting at ischial seat	
During swing		
1. Circumduction	1. Abduction contracture 2. Weak abductors	1. Too long prosthesis 2. Inadequate suspension
2. Vaulting (heel raise on normal leg)	1. Fear of toe catching on prosthetic side 2. Very short stump 3. Poor muscle control of hip flexors (hip hiking)	
3. Medial or lateral whip	1. Habit due to stump discomfort	1. Internal or external rotation at the prosthetic knee alignment 2. Too tight or too loose socket 3. Excessive valgus or varus in prosthesis at knee level
	General pattern	
1. Abduction of prosthetic leg (wide base gait)	1. Abduction contracture 2. Abductor roll	1. Long prosthesis 2. High medial brim of socket 3. Insufficient support at the lateral wall of the socket 4. Rigid pelvic band 5. Adducted socket
	Long step of prosthetic leg	
2. Uneven step length		
	1. Weakness of hip extensors 2. Hip flexion contracture 3. Lack of confidence 4. Early habit	1. Flexion contracture at hip not accommodated in the prosthesis 2. Too long prosthesis
	Short step of prosthetic leg	

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	1. Lack of confidence 2. Pain	1. Ill-fitting socket causing discomfort 2. Too flexed socket
3. Forward trunk flexion	1. Weak hip extension 2. Hip flexion contracture 3. Poor general posture 4. Spinal kyphosis 5. Habit due to looking constantly down at feet 6. Poor eyesight	1. Insufficient flexion built in the socket 2. Socket discomfort

Instant prosthesis

In 1963, Dr Weiss revolutionized the management of AK and BK amputation by introducing instant prosthesis followed by immediate postoperative ambulation. The various stages of instant prosthesis are as follows:

1. Functional amputation stump was constructed and shaped by anchoring the muscles that cross two joints, by tension myoplasty procedure, with the limb in neutral position.

2. The stump is covered with contoured surgical dressing over which a sterile stump sock is applied.

3. A plaster cast is then applied over the sock with even pressure. This is known as *rigid dressing*.

4. A coupling device with steel straps is incorporated over this cast by POP bandages.

5. Premeasured walking pylon with SACH foot is attached to this coupler. The cast may get loosened and may have to be reapplied by the end of a week.

6. After 3 weeks, the cast is split and measurements are taken for the final prosthesis.

7. The splint cast is taped back and continued to be used till the

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prosthesis is ready.

Standing and partial weight bearing (about 8–9 kg) can be instituted as early as the next day of surgery. Full weight bearing is permitted by 6 weeks when the tissues are healed well and are ready to take the body weight.

Advantages of instant prosthesis

1. Initiation of standing and partial weight-bearing ambulation from the next day of surgery minimizes the following problems:

(a) Stump oedema

(b) The complications of prolonged prosthetic period

(c) Unstable nonweight–bearing crutch walking

(d) Contracture and deformities

(e) Regime of strengthening and ROM exercise is minimized

(f) Rigid cast socket coupled with pylon promotes conditioning of the stump

(g) Prevents or provides relief in the phantom limb sensation

(h) The patient is discharged early with either a temporary or a permanent prosthesis; the patient quickly picks up a stable and good pattern of gait.

2. The most important advantage of the surgical procedure is that it reduces the neurologic silence below the level of amputation. The

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significant part of the feed-in mechanism is preserved which quickly establishes communication with the proximal parts. Re-establishing proprioception and feedback by contact with the floor, substantiated with visual and auditory feedback, alerts the appropriate muscles for normal synchronized actions. It re-establishes the signalling system. It promotes stabilization, weight transfer and early ambulation.

Although this procedure was not reported to be successful by many centres in the UK due to problems of poor vascularity and healing, Stovlov et al. (1971) thought it to be ideal in patients without vascular disease.

Re-education of the upper extremity amputee

The basic responsibility of the physiotherapist in the re-education of an upper extremity amputee is to train the patient for functional activities.

The training aspect has the following objectives:

1. To increase the mobility of the related adjacent body parts so that some compensation can be achieved for the absence of the true limb.

2. To strengthen the muscles directly involved in activating the prosthesis.

3. To increase the endurance of these muscle groups to sustain the motion of the prosthetic joint whenever necessary.

4. To prevent soft tissue contractures in certain muscle groups like shoulder adductors, and rotators and elbow flexors.

Standard basic areas

Ae amputee

Mobility should be concentrated to scapulohumeral and scapulothoracic motions along with the neck and trunk.

Powerful arm flexion is needed for producing strong flexion at the

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prosthetic elbow while extension is needed for controlling the locking mechanism of the prosthetic elbow joint.

Be amputee

For forearm and wrist amputees, the mobility of the shoulder girdle, shoulder joint and elbow needs to be improved but more emphasis should be placed on the forearm. Although prosthesis cannot perform pronation and supination, it can have a device to lock the forearm in the necessary functional position.

Strengthening and endurance exercises should be planned for the shoulder complex, elbow as well as forearm. All these play a key role in the prosthesis.

Training of the prosthesis controls: Four basic body controls are necessary to operate the upper extremity prosthesis (Aylesworth, 1952).

1. In the beginning, the patient is trained to perform one basic movement, e.g., true shoulder flexion without the movement occurring at the shoulder girdle (arm flexion control motion). This is the major control for the AE amputee. When proficiency is attained in performing one basic body motion, then coordination of the individual motions can be taught for the operation of prosthesis. Manually operated accessories like wrist flexion unit are not operated by a control system and can be taught to be prepositioned or fixed (Fletcher, 1954).

2. BE single control system: Patients with forearm amputation or wrist disarticulation use BE single control system to operate the prosthesis. For example, the patient is first trained to flex the elbow to 90 degrees and then flex the shoulder till the terminal device becomes operational (Taylor, 1955).

3. AE dual control system: Patients with AE or through-elbow amputation use the dual control system. Here, the arm flexion control motion is used to teach the following two prosthetic operations:

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(a) With the prosthetic elbow unlocked, flexion at the shoulder produces flexion at the elbow of the prosthesis.

(b) With prosthetic elbow locked, flexion at the shoulder operates the terminal device. To begin with, combined operation of the elbow flexion by flexing the shoulder and locking the elbow by protraction of the shoulder is taught. When this is achieved, the amputee is trained to operate the terminal device.

4. AE triple control system: The standard AE amputee is trained by a triple control system. The amputee is first trained to control elbow flexion and elbow lock as mentioned in the dual control system. Elbow flexion is produced by the arm flexion control motion, locking of the elbow is achieved by arm extension control motion. Operation of the terminal device is achieved by controlled shrugging motion on the normal side. Practice makes it possible to coordinate all these movements together.

Besides these, guidance is also necessary to use this prosthetic hand for various other activities of daily life.

Complications

1. *Phantom pain*: It is a common complication where the patient feels persistent pain in the nonexistent, already amputated part of the limb. It is due to persistence of nerve impulses caused by local anoxia, neuroma or atherosclerosis. The most important mode of treatment is reassurance. In addition, do the following:

(a) Percussion – light rhythmic hammering with a small hammer starting proximally working up to the painful area till it is numb.

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(b) Ultrasonics, thermal modalities and transcutaneous electric nerve stimulation (TENS) may be used. A low frequency TENS has been reported to be not only effective in reducing the phantom pain but also in healing (Finsen et al., 1987). Preoperative (72 h before amputation) lumbar epidural blockade has also been found to be effective in eliminating the phantom pain (Bach et al., 1987).

(c) Ice packs

(d) Brushing with a battery-operated rotating brush

(e) Exercises (general)

(f) Local injection of hydrocortisone

(g) Exploration and removal of neuroma

(h) Psychological counselling

2. *Painful adhesive scar formation:* An adherent painful scar over the surgical incision hinders the fitting of the prosthesis. Mobilization of a painful scar should begin as early as possible, before it gets organized as adherent. Ultrasonic and deep friction massages are helpful in the mobilization of a scar.

3. *New bone formation at the amputation sites:* In electrical burn amputees, new bone formation has been reported 5 weeks after amputation. It may require revision of amputation and refabrication of the prosthesis. The stump should, therefore, be watched closely for any signs and symptoms of new bone formation like excessive tenderness, warmth and swelling (Helm & Walker, 1987). If such symptoms are observed, the fitting of the final prosthesis should be

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delayed.

4. *Flexion deformity:* The presence of a flexion deformity complicates the process of prosthetic fitting and ambulation. However, the prosthesis may be modified to accommodate the deformity and provide ideal weight-bearing alignment. Alexander and Herbison (1965) reported successful ambulation in a patient with right above-knee and left below-knee amputation with bilateral hip flexion contractures of 60 degrees and left knee flexion contracture of 90 degrees.

5. Haematoma: Delays wound healing and becomes a site of infection.

6. Infection: Especially in diabetics and in peripheral vascular disease.

7. Necrosis of the skin flaps due to press on the distal part of a stump leading to ischaemia

8. Neuromas at the end of the cutaneous nerve.

Latest advancement in upper extremity prosthesis: Bionic arm (thought-operated prosthesis)

A new prosthesis had been developed by the Centre for Artificial Limbs at the Rehabilitation Institute of Chicago by Dr Todd Kuiken, Director of Neuro-engineering.

It is an advancement over the conventional prosthetic arm which has flexion and extension of the arm. This device is capable of 22 discrete movements including:

- Rotation of the upper arm
- Bending elbow
- Closing and opening the fist

It works on the principle of muscle reinnervation through nerve

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grafting.

The greatest advantage of this bionic arm is that it is *thought operated*, the activities are not controlled mechanically, but are controlled by the brain like we do normally (e.g., if a patient thinks of closing the fist, the electrical signals are sent through the surgically rerouted nerves resulting in smooth closing of the fist). The shoulder nerves, which used to go to the arm are rerouted and grafted to the pectoral muscles. The grafts receive thought-generated impulses, and the muscle activity is picked up by the electrodes which relay the signals to the arm's computer, which then causes motors to move the elbow and hand mimicking a normal arm.

The initial trials of thought-operated devices have been a 100% success.

Latest advances in prosthetic hand

The world's first bionic hand with a return of the sensation of feeling and touch has been designed and reported by Selvestero Miceria in February 2013.

It can identify:

- The shape of the object held
- Consistency of various objects being touched
- Strength of the grasp

It works on the principle of reactivation and restores reduced sensitivity in the median and ulnar nerves due to disuse.

Report by british surgical team which reported electronic devices known as *acti-gait*

The electronic device, Acti-Gait, implanted in the upper thigh, sends radio signals to the calf and foot muscles. A tiny computer on the waist sends radio signals via external antenna to a stimulator which fires an electrical current to the calf muscle fitted with electrodes. The

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circuit is completed by a small switch in the user's shoe, which makes sure that the foot does not hit the ground hard.

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CHAPTER 26

Lesions of the brachial plexus

OUTLINE

- Brachial plexus
- Erb palsy
- Klumpke paralysis
- Brachial neuritis
- Radiation-induced brachial plexus lesion

Brachial plexus

Brachial plexus, a major source of motor and sensory supply to the shoulder girdle, the upper trunk and the whole of the upper extremity, is composed of a highly complex neuronal organization.

Anatomy and composition of brachial plexus (fig. 26-1)

1. Five nerve roots: Basically, it is composed of five nerve roots formed by the anterior rami of C5 to T1, situated between the scalenus anterior and the medius.

2. Formation of nerve trunks: Integration of these five nerve roots (C5 to T1) forms three distinct nerve trunks from the lateral border of the scaleni as follows:

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(a) The *upper trunk* is formed by the anterior rami of the C5 and C6 nerve roots.

(b) The *middle trunk* is formed by a single C7 nerve root.

(c) The *lower trunk* is formed by the C8 and T1 nerve roots.

(d) Each of the three major trunks thus formed divides into anterior and posterior divisions.

3. Formation of three cords: Integration of the divisions of these three nerve trunks results in the formation of three cords: the medial cord, the lateral cord and the posterior cord. It takes place as follows:

(a) The anterior division of the lower trunk forms the *medial cord*

(b) The anterior division of the upper and middle trunk forms the *lateral cord*

(c) The posterior divisions of all the three (i.e., upper, middle and lower) trunks integrate to form the *posterior cord*

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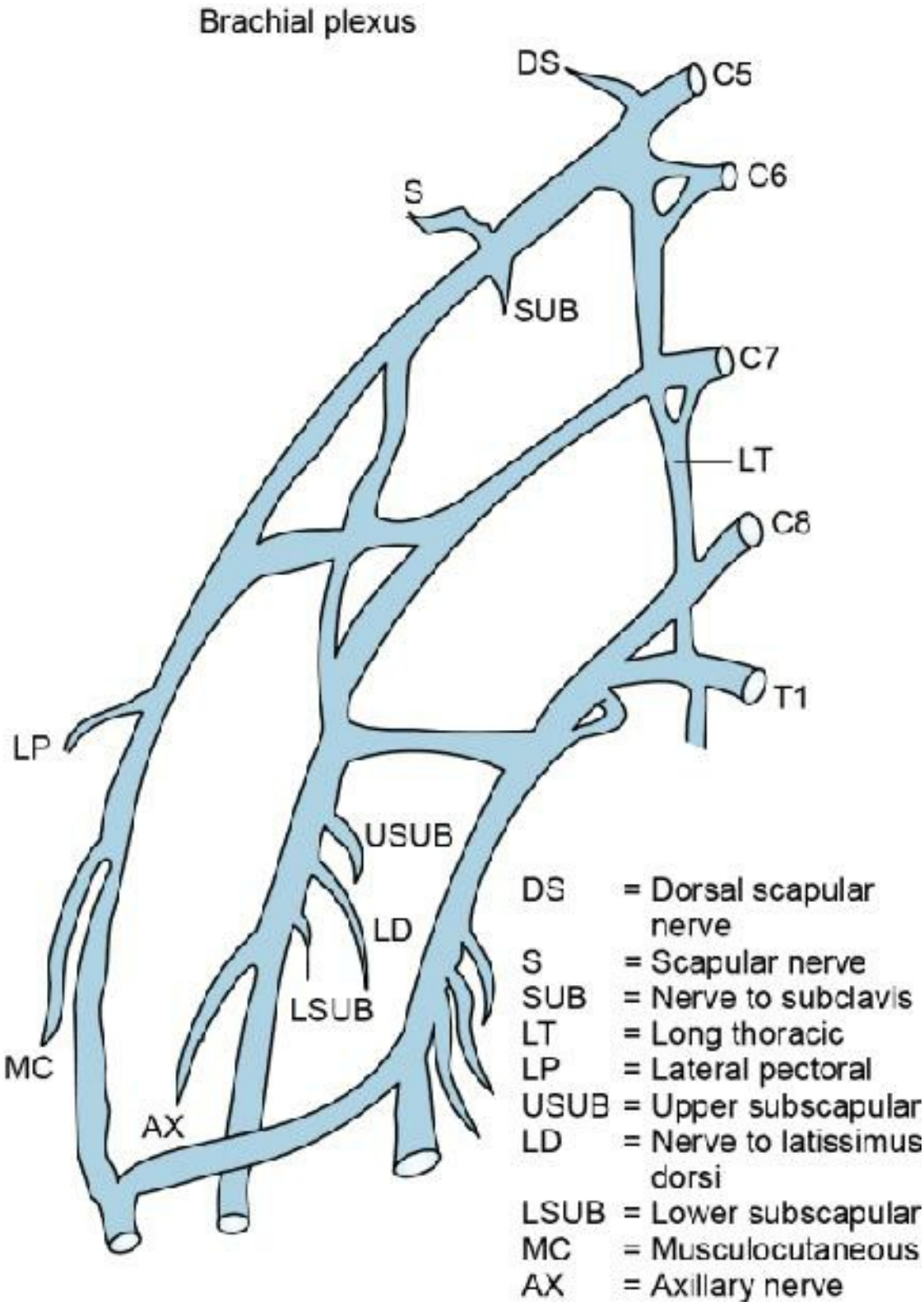

FIG. 26-1 Brachial plexus. DS, dorsal scapular nerve; S, scapular nerve; SUB, nerve to subclavius; LT, long thoracic; LP, lateral pectoral; USUB, upper subscapular; LD, nerve to latissimus dorsi; LSUB, lower subscapular;

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MC, musculocutaneous; AX, axillary nerve.

These three cords join, leading to the formation of terminal branches, as follows:

- The branches of the lateral cord: Lateral head of pectoral nerve, musculocutaneous nerve and lateral head of median nerve.
- Branches of the posterior cord: Axillary, upper and lower subscapular, thoracodorsal and radial nerves.
- Branches of the medial cord: Medial pectoral, medial brachial cutaneous, medial antebrachial cutaneous, ulnar and medial head of the median nerve.

The following nerves are given off at the root level:

- The dorsal scapular nerve from the C5 nerve root supplies the rhomboids.
- The long thoracic nerve from the C5 to C7 nerve roots supplies only the serratus anterior.
- The axillary nerve originating from the posterior cord supplies the deltoid and the teres minor.
- The musculocutaneous nerve from the C5 to C7 nerve roots supplies brachialis, biceps and coracobrachialis.

Types

Fig. 26-2 depicts types of brachial splexus lesions.

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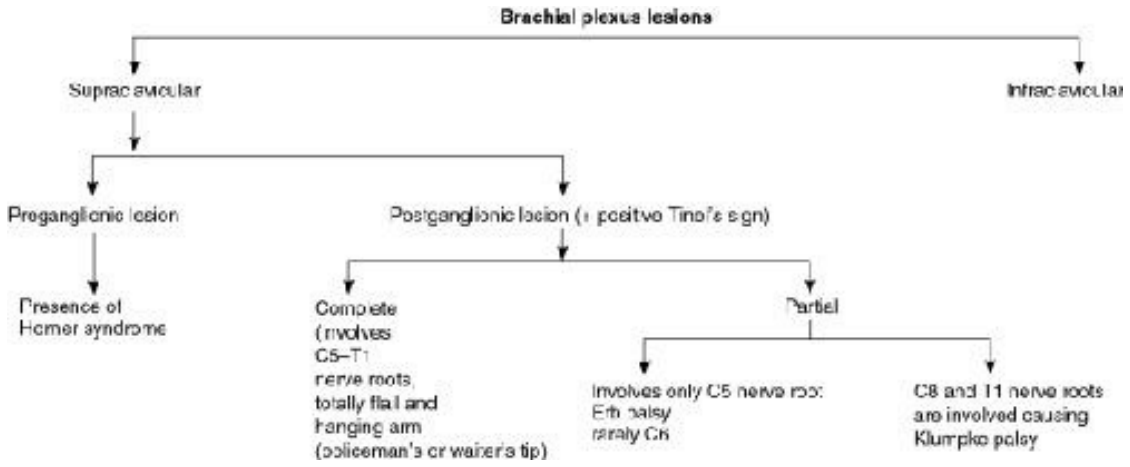

FIG. 26-2 Types of brachial plexus lesions.

Lesions of the brachial plexus: Causative factors

Traumatic causes

- Birth injury (most common).
- Shoulder dislocation, penetrating injuries (gunshot), scapular or humeral fractures.
- Bike injury (common in adults as a result of violent fall on the depressed shoulder with neck in lateral flexion).

Nontraumatic causes

- Anatomical abnormalities like cervical rib, thoracic outlet syndrome.
- Following surgery of the tumour, cervical rib or heart.
- Compressive lesions like crutch palsy or malpositioning of the arm during anaesthesia or during the unconscious state.
- Fibrosis following radiation-induced plexopathy or following brachial neuritis.

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Remember

- The roots and trunks of the brachial plexus are supraclavicular.
- The cords and nerves of the brachial plexus are infraclavicular and follow the pattern of the related nerve either alone or in various combinations.
- The supraclavicular lesions of the brachial plexus are common and may occur in five different root combinations: (C5–C6), (C5–C7), (C8–T1) or (C5–T1) of these five combinations.

Lesion of the upper trunk

- The upper trunk lesion at the C5–C6 nerve roots is most common (e.g., birth injury and bike injury)
- When the injury is complete, the nerve roots at C5–C6 levels are completely avulsed from the spinal cord with totally flail and hanging arm (policeman or waiter's tip).

Lesions of the middle trunk

These mainly involve the C7 nerve root, but rarely in isolation; they mostly occur in combination with either upper or lower trunks.

Lesions of the lower trunk

These lesions involve the C8 and T1 nerve roots; although rare, when present, they result in 'Klumpke palsy' or 'thoracic outlet syndrome', following sternotomy.

Types of supraclavicular lesions

Principally, the lesions of the brachial plexus are of two types:

1. **Preganglionic lesion:** Where the nerve root is avulsed out of the

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spinal cord. This type has a poor prognosis.

2. **Postganglionic lesion:** These are of two types:

(a) Lesion in continuity – The nerve root and its sheath are intact and hence recovery is spontaneous.

(b) Lesion with discontinuity – In this type, the nerve root is intact but there is rupture in the nerve sheath; the lesion could be complete or partial. In complete lesion, there is an involvement of all five roots (C5–T1). Partial lesions may involve either upper trunk (C5–C7) or lower trunk (C8–T1).

Identification of the exact site of the lesion is important from the point of view of management.

Immediate surgical repair may be necessary in upper trunk postganglionic lesions.

To determine the site of the lesion and its extent, various investigations are available besides a thorough clinical examination of the patient.

Preganglionic lesion (fig. 26-3a)

History: There is usually a history of a high speed head-on collision accident. The head is forced away from the shoulder. Severe injury occurs, causing unconsciousness, fractures and associated head injury.

Signs

1. Horner's sign: There is damage to the sympathetic nerve

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supply to the eye as it merges at the T1 root. Ptosis with constriction of the pupil will be present. Deficit of facial sweating can be noticed on the affected side.

2. Positive sensory action potentials (SAP).

3. Meningocoele may be seen in a myelogram.

4. A typical crushing or sharp constant pain even at rest.

5. Usually, there is high cervical scoliosis.

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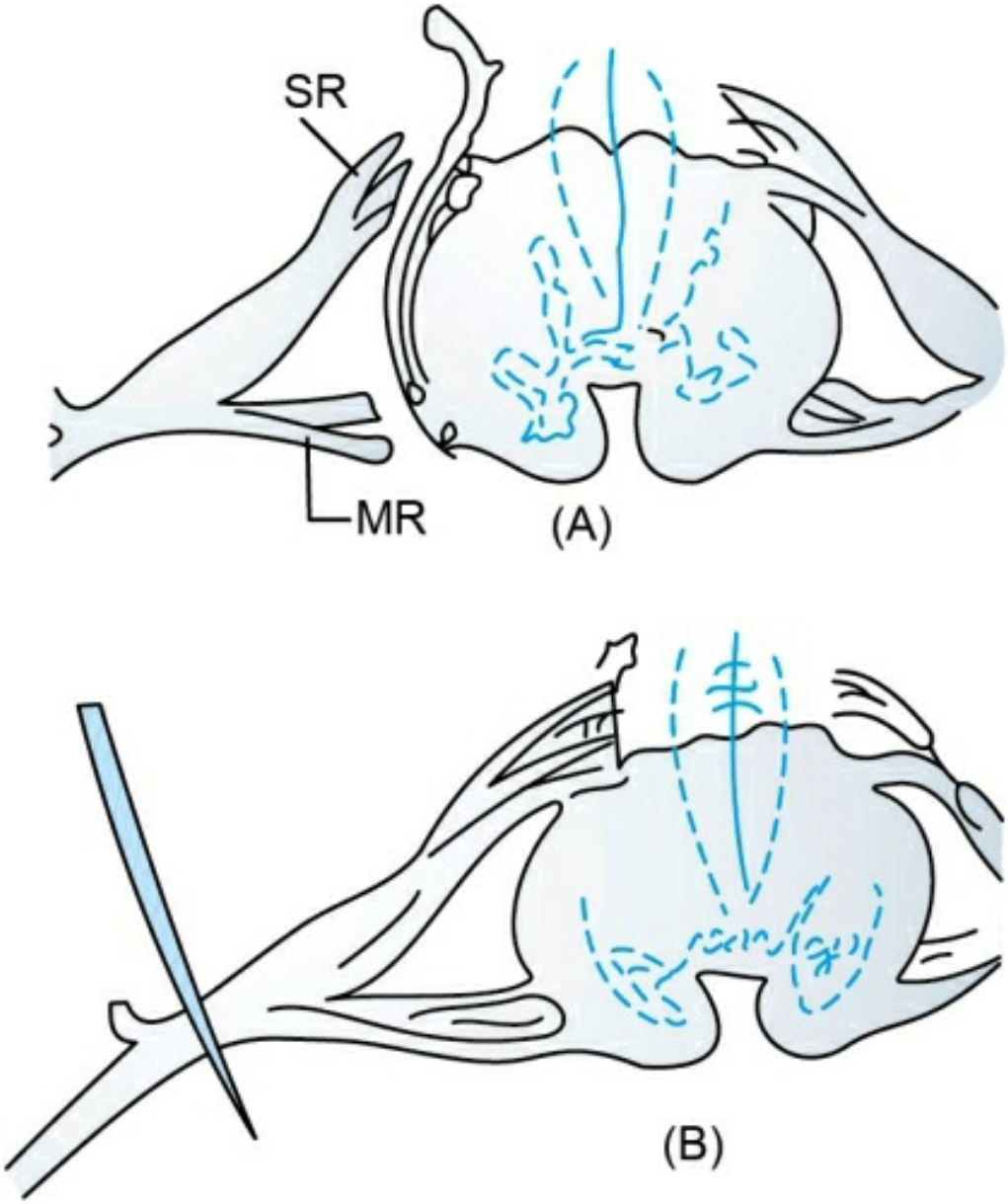

FIG. 26-3 Pre- and postganglionic lesions. **(A)** Preganglionic lesion: motor and sensory nerve roots (MR and SR) avulsed from the spinal cord. **(B)** Postganglionic lesion: root intact, nerve sheath either intact or ruptured.

Caution

As there are chances of plexus injury going unnoticed because of unconsciousness, careful examination at an early stage is important.

Postganglionic lesion (fig. 26-3b)

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History: Usually there is a history of slow-speed trauma, a person being thrown on the ground due to sudden halt of a motorbike. Associated injuries or loss of consciousness are rarely seen.

Signs

1. No Horner's sign.
2. Absence of SAP.
3. No pain.
4. A positive Tinel's sign (Copeland & Landi, 1979) or neuroma sign may be present. While tapping along the course of the nerve from distal to proximal, a referred *tingling* is felt in the distribution of that nerve. There may be two Tinel sites, one at the level of the lesion and the other at the point of regeneration. Stronger distal signs than the proximal ones indicate axonal regrowth and the possibility of a clinical recovery.

Tapping over the plexus above the clavicle produces tingling in the anaesthetic arm or hand. This indicates distal rupture (postganglionic) indicating the availability of proximal axons for grafting.

Examination of the passive range of motion

The passive range of motion (ROM) of all the joints of the upper limb should be done to assess any sign of soft tissue tightness. Soft tissue contractures may be present in patients with severe lesions and flail arms. Common sites of contractures are as follows:

1. Shoulder elevation, abduction and external rotation
2. Elbow extension and supination

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3. Wrist palmar flexion and extension

4. Metacarpophalangeal joints flexion

5. Interphalangeal joints extension

In addition, reduction of the thumb web space, shortening of the long flexor tendons with loss of full extension of digits and wrist in extension may be present. Any sign of tightness, which precedes the contracture, must be carefully examined to avoid contractures. Also examine for subluxation of the shoulder joint. Proper guidance to fully stretch these movements to the full ROM is necessary. Shoulder needs more emphasis on abduction and external rotation as brachial plexus cannot be exposed for surgical intervention without full external rotation at the shoulder joint.

Examination of sensibility

Sensibility evaluation for light touch, pinprick and proprioception is documented on the body chart. It can provide definite guidance in the diagnosis of the lesion.

Evaluation of vascular status

It can be done by palpation of pulses (either radial or carotid). If necessary, angiography can provide further information.

Vasomotor changes like dry and cold skin, or the presence of oedema indicates significant nerve injury.

Manual muscle testing

Manual muscle testing (MMT), though time consuming, still remains the most vital part of the evaluation. MMT as applied to plexus injury, however, needs a thorough knowledge of the anatomical interrelationship of various muscle groups, their innervation and action. Common trick movements, e.g., winging of the scapula with the lesion of the spinal accessory nerve, should be looked for. This muscle is innervated by the C5, C6 and C7 branches which come off immediately after the nerve roots exit from the intervertebral

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foramina. Injury to them could be because of root avulsion.

If the serratus anterior is intact, and the supraspinatus and infraspinatus are paralysed, the lesion could be infraganglionic in the region of Erb's point where the C5–C6 join to form the upper trunk.

If the serratus anterior is intact with paralysis of the deltoid and the biceps, the lesion could be more distal in the terminal branches of the plexus.

Radiological examination

Radiological examination is done basically to rule out fractures. Fractures of the transverse process may result in avulsion of the corresponding nerve root, because of the attachment of the deep cervical fascia between the cervical nerve roots and the vertebral transverse processes (Sunderland, 1978). Widely displaced fracture of the clavicle or scapula can produce traction injury.

MRI: An MRI may show root avulsions or discontinuity in the nerves/cords of the brachial plexus.

MR neurogram: A relatively newer investigation, MR neurogram, may also show discontinuity or absence of the neural tissue of the brachial plexus.

Electrodiagnostic tests

As the electrical changes are parallel to the pathophysiology of denervation or to the loss of axonal continuity, they provide significant information:

1. To confirm denervation

2. To diagnose the nature of lesion, whether it is preganglionic (avulsion) or postganglionic

Electromyography

The following investigations should be conducted 4 weeks after injury:

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1. Electromyography (EMG) of the limb and the shoulder girdle muscles

2. Motor and sensory nerve conduction velocity

3. Somatosensory evoked potentials and the 'F' responses

EMG: The muscle which is innervated normally does not exhibit spontaneous electrical activity at rest. Therefore, the presence of small fibrillation potentials or large potentials called sharp positive waves at rest, when the muscle is examined with needle electrode, indicate Wallerian degeneration.

The absence of fibrillation potentials or sharp positive waves at rest indicate postganglionic lesion (Leffert, 1988).

The presence of polyphasic units indicates regeneration. This is important as electrical evidence precedes clinical evidence by many weeks.

Electrical silence both at rest and at attempted activity indicates interference with the conduction of the nerve impulses.

Electrical silence at rest but normal action potentials with complete interference patterns on voluntary activity indicates an intact conduction.

Investigations of SAP

When there is avulsion of the root, the process of Wallerian degeneration occurs in the motor nerves. However, the axons in the same spinal nerves will not degenerate, unless there is an infraganglionic rupture in addition to the supraganglionic avulsion. The detection of either reduced or normal amplitude SAP, with the absence of motor conduction, in a flail and anaesthetic limb is a bad prognostic sign. It indicates that the nerve is in continuity with its cell body, with the lesion being present proximal to the dorsal root ganglion (preganglionic). This in turn indicates avulsion of the root. A negative reading implies a lesion distal to the dorsal root ganglion with an intact root (postganglionic).

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Somatosensory evoked potentials

Zalis et al. (1970) and Jones et al. (1981) reported on the electrophysiological diagnosis of traction lesions of the brachial plexus by sensory nerve action potentials and somatosensory evoked potentials. They provide information about the different pathways and the condition of the intraspinal root. If the afferent pathways are intact, the evoked potentials may be recorded from the scalp electrodes over the contralateral hemisphere of the brain on stimulation of the median and/or ulnar nerves at the wrist and elbow. If the root is avulsed, the evoked potential will not be obtainable because of the lack of central connection, even though the sensory peripheral nerve conduction may be normal. The exposed parts of the brachial plexus are stimulated directly during surgery. Intraoperative use of this technique is valuable to verify the central connections of the nerve root for grafting to a distal part of the plexus.

Nerve conduction velocity

A normal nerve conduction velocity indicates intact conductivity. When it is not measurable, it indicates the severance of nerve fibres with Wallerian degeneration. Both the techniques of motor and sensory nerve conduction velocities should be done to distinguish root avulsion from the distal rupture.

Percutaneous electrical stimulation

Abnormality in conduction can be verified by plotting strength–duration curves by percutaneous electrical stimulation.

Factors like sharp curve, long chronaxie, low rheobase and the absence of contraction with repetitive stimuli (strength interval curve) can indicate abnormality of impulse conduction, i.e., PRD, CRD or even A & D or complete denervation.

Myelogram

Myelography with radiopaque dye will show ‘meningocoele’ in the presence of avulsion. But this test is by no means infallible and hence not conclusive.

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CT scan and magnetic resonance imaging

CT scan is a method of radiological imaging that has developed over the last decade. It gives a cross-sectional display of the anatomy and pathology. Magnetic resonance imaging (MRI) is the latest of the imaging modalities. It makes use of the magnetic properties of atomic nuclei. It has two main advantages over CT scanning. The technique is safer and it delineates soft tissue structures better.

Physiotherapeutic management

Physiotherapeutic management is offered only in conservatively managed patients.

Treatment

The treatment is divided into three stages:

1. Early stage

2. Intermediate stage

3. Late stage

1. *Early stage*: The following measures are necessary.

   (a) Measures to control pain and oedema.

   (b) Measures to prevent complications due to anaesthesia in the limb.

   (c) Maintenance of full mobility of the soft tissues and the joints, keeping in view the susceptible areas of contractures and deformities.

   (d) Splinting: Cosmetically acceptable functional flail arm splint (FAS) has been reported by Framton (1984) for

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patients with total brachial plexus lesion. It allows shoulder abduction, prevents glenohumeral subluxation and also allows five different positions of elbow with locking system. It provides a platform on the flexor aspect of the forearm on which standard artificial limb appliances like split hook or universal holder can be fitted. This functional prosthesis can be operated through a cable to a shoulder strap secured to the opposite normal shoulder like a standard artificial limb.

Partial lesion can be fitted with splints with the necessary modifications to protect weaker areas and to facilitate the functional activity. Modifications like providing elbow lock or elbow lock with wrist drop appliance are useful.

Caution

It is important to keep in mind the sensory loss while adopting every therapeutic measure.

1. Applying TENS is the best way to control sharp bouts of pain but the intensity as well as the duration should be carefully operated as afferent input is poor.

2. Passive ROM exercises can overstretch the soft tissues and joints, in the presence of sensory loss and therefore, they should be properly regulated.

3. Splint: It should be checked repeatedly for any local pressure areas.

2. *Intermediate stage*: After 3 weeks, the extent of the lesion should be reassessed to establish the prognosis.

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Re-education: If evidence of reinnervation is present, exercises to re-educate movements should be initiated.

(a) Weaker movements are repeated with self-resistive techniques by the patients themselves.

(b) Proprioceptive neuromuscular facilitation (PNF) technique can be used to strengthen the simultaneous action of various muscle groups in functional diagonal patterns.

(c) Possible functional activities by the involved upper extremity should be encouraged either by a physiotherapist or by self-assistance only after guidance, education and supervision by a physiotherapist.

(d) Percutaneous electrical stimulation of the functionally important muscle groups synchronized with patient's voluntary efforts can be helpful in re-educating accurate muscle action. As the success of motor re-education largely depends upon sensory re-education, concentrated efforts aided by visual and auditory feedback are most important.

(e) Stimulating technique like icing and brushing (Rood, 1956) can be effective at this stage.

(f) If the pain persists, intensity and duration of transcutaneous electric nerve stimulation (TENS) can be increased to a suitable level.

(g) Splints may need modifications like making it short, increasing its dynamicity or resistance.

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3. *Late stage*: By 2 years, most of the recovery would have taken place. Therefore, reassessment is necessary. Response to the treatment is assessed by electrodiagnostic tests. If the recovery is stagnant, it may be necessary to plan for the possible reconstructive surgery.

Surgery

Exploration of the brachial plexus, suture or nerve graft may be done using an operating microscope. However, in root avulsion injuries, it is worthless.

In residual paralysis, reconstructive surgical procedures may be undertaken depending upon the extent of involvement of the trunk/roots to improve shoulder functions, especially abduction. If the lower trunk is spared, the hand function may be retained. In such cases, shoulder function can be improved by arthrodesis of the shoulder or by tendon/muscle transfers (refer to Fig. 28-2). Trapezius transfer to the neck of humerus can provide a useful range of abduction (Fig. 26-4).

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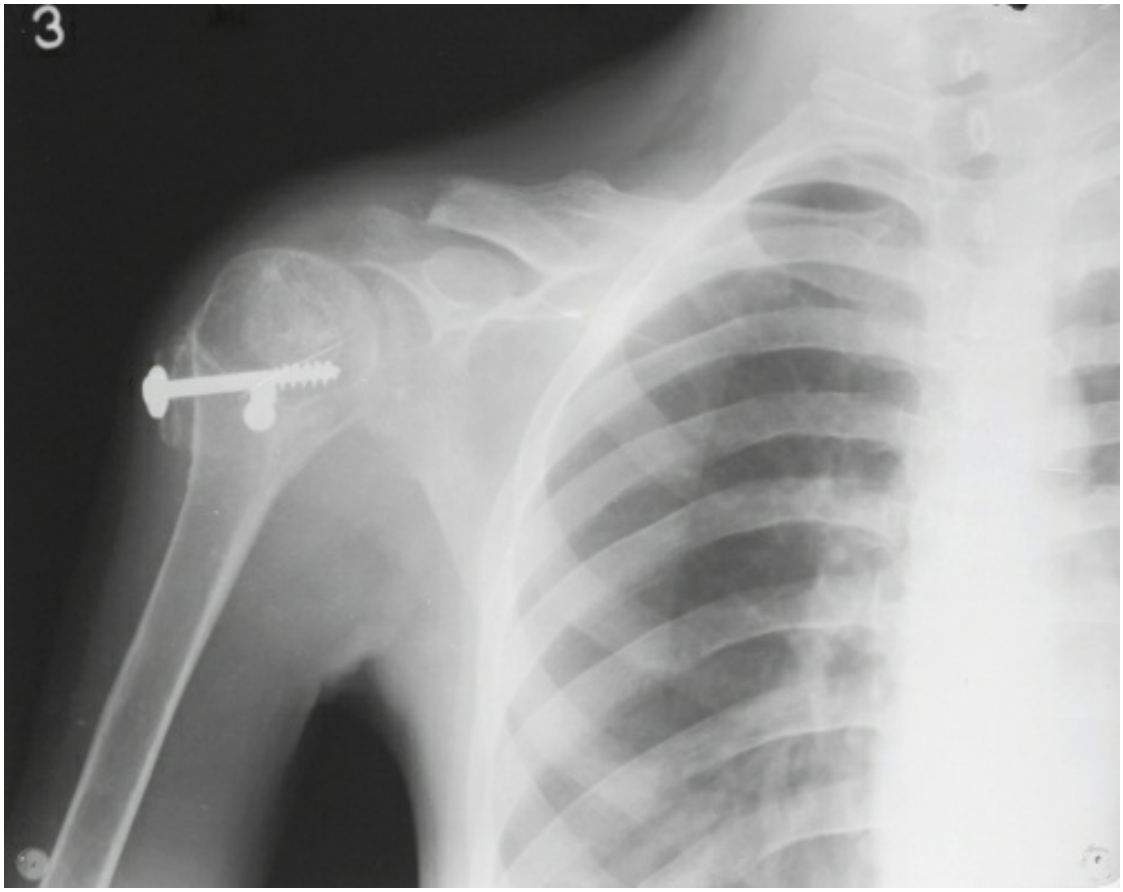

FIG. 26-4 Trapezius transfer for right shoulder. Note that the acromion process has been relocated at the neck of humerus and fixed with two screws. The acromion process carries the insertion of trapezius muscle which helps in abdomen of shoulder.

The elbow function can be improved by transferring latissimus dorsi or pectoralis major to biceps, or by Steindler's flexorplasty (refer to Fig. 28-3).

Wrist and finger extension may be achieved by the following muscle transplants:

1. Transfers of flexor carpi ulnaris to extensor digitorum and extensor pollicis longus or flexor digitorum superficialis to extensor digitorum and extensor pollicis longus.

2. Palmaris longus to abductor pollicis longus.

3. Pronator teres to extensor carpi radialis brevis.

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Physiotherapy following surgery

For the success of the surgical procedures of tendon/muscle transfers, careful preoperative assessment and training with well-planned re-educative measures are important.

The following play an important role in the re-education of the transplanted muscle:

1. Appropriate splint to stabilize the transplanted muscle and to facilitate its re-education

2. Electrical stimulation

3. Biofeedback techniques

4. Self-assisted and guided functional movements

5. Relaxed passive movements, active assisted movements, progressed to resisted exercises. It provides the necessary strength and endurance to the transplanted muscle

6. Extensive education on self-controlled exercises is most important

ERB palsy

It is the lesion of the 5th cervical root. It occurs as a result of birth injury due to traction between the child's head and shoulder. The principal strain falls on the upper root (C5) of the brachial plexus. Often the force may be excessive enough to involve the root below (C6) (Fig. 26-1).

Injury to the 5th cervical root alone results in weakness or the loss of:

1. Shoulder: abduction and external rotation

2. Elbow: flexion

3. Forearm: supination

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This occurs due to the involvement of deltoid, rhomboids, supraspinatus, infraspinatus and teres minor at the shoulder complex; biceps and brachialis at the elbow and supinators at the forearm.

Involvement of the 6th cervical root results in the loss of wrist extension (radial side) due to the involvement of extensor carpi radialis longus and brevis.

The involvement of these muscle groups results in the typical posture of 'waiter's or policeman's tip' position to the involved limb. The arm loosely hangs by the side of the trunk internally rotated with elbow in extension.

Anaesthesia may be present over the outer border of the arm and forearm, on both anterior as well as posterior aspects. When the 6th nerve root is involved, anaesthesia extends medially and also involves the thumb.

Treatment

Conservative – splints and physiotherapy

- To avoid soft tissue contracture, abduction splint (aeroplane splint) may be given (Fig. 26-5). This maintains the shoulder in abduction and external rotation, elbow in 90 degrees flexion, forearm in supination and wrist in a few degrees of extension.

- However, this splint is too cumbersome for a child during sleep and therefore the mother is taught to keep the child's arm in this position by using small sand bags.

- Passive full range movements to prevent contractures are taught to the mother.

- The involved muscles are activated by assisted active movements using sensory stimulus. Bilaterally

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symmetrical PNF patterns may be included to achieve irradiation from the normal contralateral limb or from the surviving strong muscles of the affected limb.

- In later life, a similar condition may occur as a result of violent injury to the brachial plexus. The clinical picture depends upon the degree of involvement of the brachial plexus. The plan of treatment is similar to that of the Erb palsy. However, as the patient is able to follow the instructions, the therapeutic procedures can be more precise like:

- Involved individual muscles groups can be exercised and re-educated.

- Electrical stimulation can be used as an adjunct.

- Trick movement for functional achievements can be taught effectively (e.g., substitution by the long head of biceps brachii and brachioradialis with flexors to achieve shoulder abduction and elbow flexion, respectively).

- Conservative treatment is successful only in children with mild involvement or in adults with incomplete severance of the nerve roots.

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FIG. 26-5 Aeroplane splint.

Surgery

Most cases may recover spontaneously without treatment.

In some cases, exploration and repair of the injured nerve roots may be undertaken. The results, however, are unpredictable.

Tendon/muscle transfers around the shoulder may rarely be indicated to improve the abductor or external rotation of the arm.

If fixed deformities have developed, surgical release of the contracted soft tissues or osteotomy to correct the rotational deformity of the arm or forearm may be indicated.

Physiotherapy follows the same routine as described for nerve repair, tendon transfers, release of the contracted soft tissues and osteotomy under the respective headings.

Klumpke paralysis

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The traction between the arm and trunk exerts pull on the 8th cervical and first thoracic roots (C8 and T1) (Fig. 26-1). It may occur as a complication of a shoulder injury or due to sudden fall of the body weight on the arm, e.g., a person grasping some support during fall from a height, suddenly taking body weight on the arm leading to severe traction between the arm and the trunk.

Injury to the 8th cervical root results in loss of grip or grasp because of paresis or paralysis of the wrist and finger flexors.

Involvement of the first thoracic root results in paralysis of intrinsic muscles of the hand weakening the grip. Anaesthesia due to the involvement of the first thoracic root is present over the back and the front of the inner (medial) side of the forearm. Anaesthesia due to the lesion of the 8th cervical root presents as a long strip from the arm, lies medial to the area of the first thoracic in the forearm and extends to the little finger.

A combined lesion of C8 and Tl roots results in a functionally useless flaccid hand. A deformity of claw hand eventually develops with the thumb lying in the same plane as that of the fingers. The hand presents the picture of a combined median and ulnar nerve lesion (Fig. 26-6).

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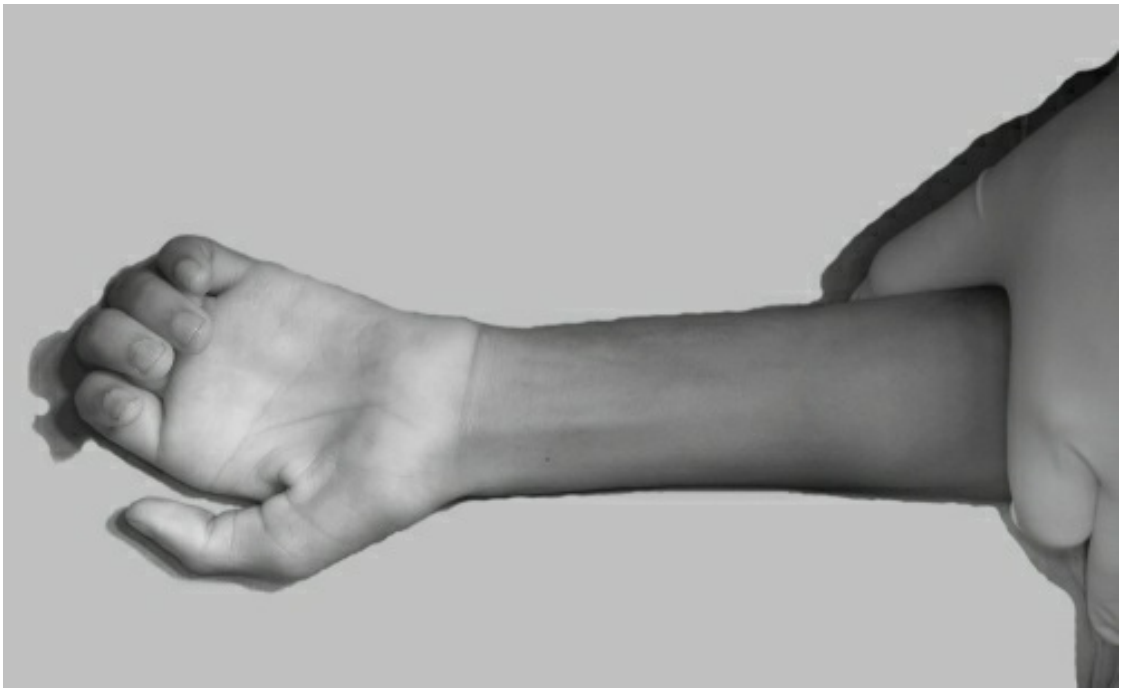

FIG. 26-6 Klumpke paralysis (lesion involving C8–T1 roots). A typical claw hand deformity. Hypothenar and thenar wasting.

Treatment

A dynamic splint is given to maintain the wrist and metacarpophalangeal (MCP) joints in flexion, IP joints in slight flexion and the thumb in flexion and opposition.

The treatment follows on the same lines as described for the combined medial and ulnar nerve lesions.

Brachial neuritis

It is characterized by an acute episode of pain lasting up to 3 weeks or more. It is followed by paralysis of the muscles in the distribution of the brachial plexus. An annual incidence of 1.64/10000 is found in the population between 12 and 47 years age group.

Aetiology

Trauma, infection, vaccination, allergic desensitization or lumbar puncture comprise the aetiology. They may be associated with

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systemic lupus erythematosus, temporal arteritis, polyarteritis nodosa and in rare instances familial disorders.

Nerves commonly involved in brachial neuritis are long thoracic (most common), suprascapular, axillary, musculocutaneous, anterior interosseus and radial.

Prognosis of recovery is good but slow and it takes even up to 3 years or even longer to complete axonal regeneration.

Diagnosis

- Clinical examination of myotomal and dermatomal innervation.
- Electrophysiological studies reveal reduction in sensory nerve action potential (SNAP) amplitudes in the involved nerve distribution; absence of fibrillation in paraspinal muscles.

Treatment

- Rest, splint related to the involved nerve.
- NSAID, corticosteroids.
- Gentle maximal range relaxed passive movements to prevent contracture till recovery occurs.
- Vigorous progressive exercise modes are applied as the gravity of pain is reduced.

Radiation-induced brachial plexus lesion

Usually the onset is delayed after radiation but most patients develop symptoms immediately (common after breast surgery following radiation).

Clinical features

Clinical features involve pain, paraesthesia, paresis or paralysis of the

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innervated muscles of the injured nerve.

Diagnosis

It is confirmed by the EMG (NCV) which indicates:

- Chronic partial denervation and reinnervation.
- Reduced SNAP.

Treatment

On the same lines as described for brachial neuritis.

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CHAPTER
27

Peripheral nerve injuries

OUTLINE

- Formation of a peripheral nerve (PN)
- Structure of the peripheral nerve (PN)
- Pathophysiology of nerve degeneration and regeneration
- Classification of peripheral nerve injuries
- Steps in the evaluation and diagnosis of PN injury
- Injuries to the major peripheral nerves
- Median nerve (nerve roots C5–T1)
- Ulnar nerve (root value C7–T1)
- Radial nerve (C5–T1 nerve roots)
- Obturator nerve (L2–L4)
- Femoral nerve
- Sciatic nerve
- Common peroneal nerve (lateral popliteal nerve)
- Posterior tibial nerve
- Treatment of foot drop

Considering the key role played by them in the achievement of functional independence, it is important to know the following aspects of a peripheral nerve (PN).

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1. Formation of a PN

2. Structure of a PN

3. Pathophysiology of a PN

4. Classification of PN injuries

5. Diagnostic evaluation of PN injuries

6. General principles of management

Formation of a peripheral nerve

The dorsal and the ventral nerve roots arising from the spinal cord come together and join at the level of intervertebral foramina to form the spinal nerves. In our body, there are 31 pairs of spinal nerves – 5 sacral and 1 coccygeal each representing a segment of a spinal cord (8 cervical, 12 thoracic and 5 lumbar). The 12 thoracic spinal nerves provide myotomal and dermatomal supply to each intercostal segment. The remaining 19 spinal nerves (8 cervical, 5 lumbar, 5 sacral and 1 coccygeal) are instrumental in forming four plexuses.

Each spinal nerve has three components – sympathetic, motor and sensory. The sympathetic components of all the 31 spinal nerves leave along 14 motor roots (12 thoracic and 2 lumbar).

Each spinal nerve divides into a larger anterior ramus and a smaller posterior ramus. The anterior rami form a group known as a *plexus*. Each plexus integrates and gives rise to an individual peripheral nerve.

Plexuses

- The cervical plexus is formed by the anterior rami of the upper four cervical nerves.

- The brachial plexus is formed by the anterior rami of the lower four cervical nerves and the upper thoracic nerves.

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- The lumbar plexus is formed by the anterior rami of the lumbar nerve.
- The sacral plexus is formed by the fifth lumbar and part of the fourth sacral nerve.
- The posterior rami supply the skin of the back and the paraspinal muscles.
- Both spinal as well as peripheral nerves are mixed type of nerves.

Structure of the peripheral nerve

It is a mixed nerve. Each peripheral nerve is composed of a compact group of individual nerve fibres, each with an individual neurolemmal tube. The nerve fibre is enclosed in a collagen connective tissue covering known as the *endoneurium.* A number of nerve fibres with endoneurium are bound together by a fibrous tissue covering called the *perineurium.* A group of nerve fibres with their endoneurium and perineurium sheaths together is known as a *faciculus*. A number of such fasciculi is further enclosed by a tough tissue sheath called the *epineurium.* Each peripheral nerve is an individual compact bundle of such fasciculi (Fig. 27-1).

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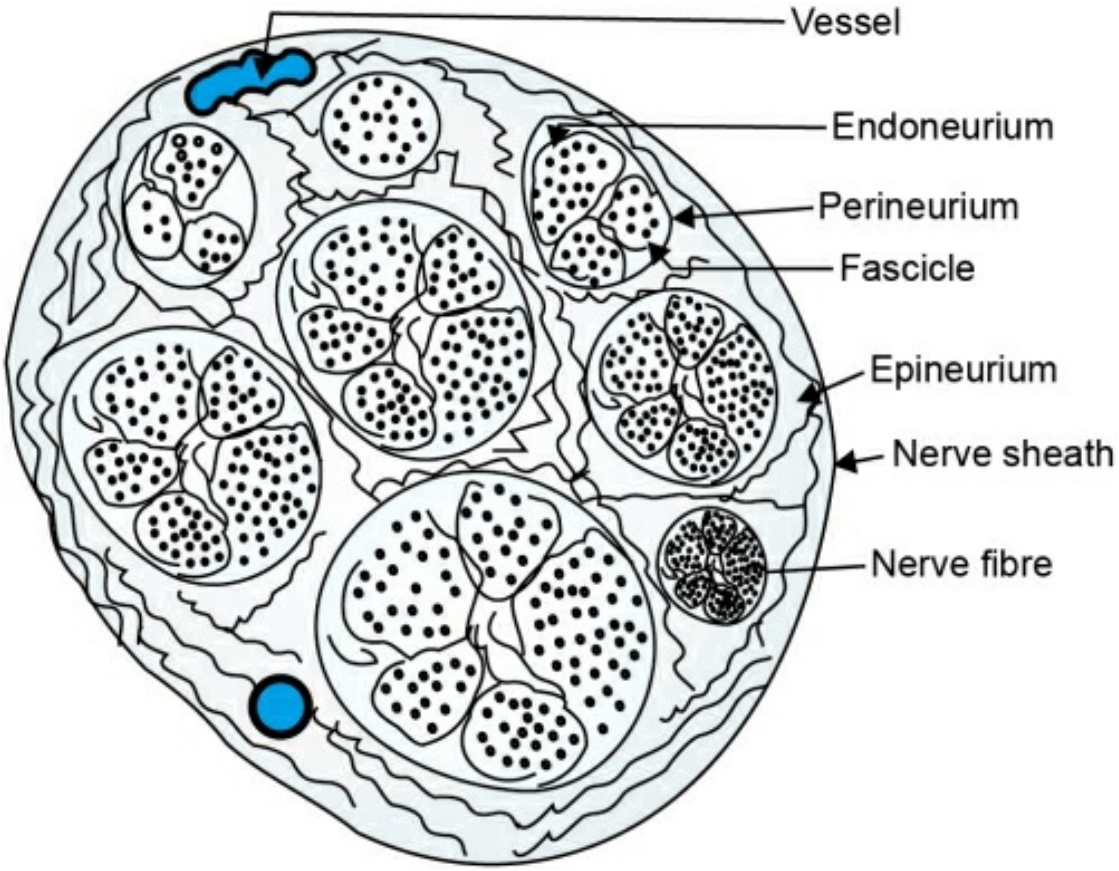

FIG. 27-1 Cross-section of a nerve.

Each nerve fascicle contains Schwann cells, fibrocytes, axons, myelin sheaths, collagen fibrils, endoneurium and the blood vessels.

The diameter of the axons of a PN varies between 1 and 20 microns. The junction between each Schwann cell is called a node of Ranvier where the axons remain insulated.

Pathophysiology of nerve degeneration and regeneration

Degeneration

Structure of the intact PN is shown in Fig. 27-2A. Within 72 h following injury, the part of the nerve (neuron) distal to the site of injury undergoes secondary or Wallerian degeneration and is destroyed by phagocytosis. Whereas, the proximal end of the injured

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nerve undergoes primary or retrograde degeneration for a single node of Ranvier (Fig. 27-2B).

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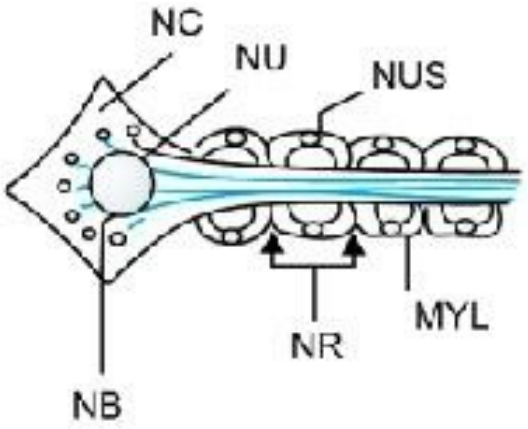

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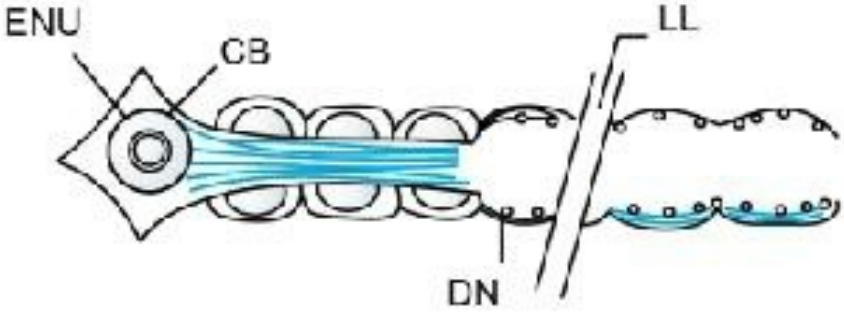

(B)

Types of neuroma

Neuroma in continuity

End neuroma

Side neuroma

(C)

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FIG. 27-2 **(A)** Structure of nerve fibre. NC, nerve cell, nucleus; NB, Nissl bodies and nerve fibrils arising from them; MYL, myelin sheath; NUS, nucleus of Schwann cell; NR, nodes of Ranvier. **(B)** Wallerian degeneration following axonotmesis or neurotmesis. LL, level of lesion; ENU, enlarged nucleus; CB, cell body empty of Nissl bodies; CB, cell body empty of Nissl bodies; DN, degeneration of neurofibrils to the nearest node of Ranvier. **(C)** Types of neuroma.

Regeneration

Regeneration begins within 24 h of injury at the proximal end of the injured nerve only if the endoneurial tube filled with Schwann cells is intact; the axonal sprouts readily pass across the site of injury (termed as *motor march*). The rate of nerve regeneration is 1 mm per day.

When the endoneurial tube is not intact, the growing sprouts (about 100 from one axonal stump) migrate aimlessly into the epineurium, perineurium and into the adjacent area to form *end neuroma* – or *neuroma in continuity*. When the proximal end of the nerve is widely separated from the distal end, it may result in formation of an end neuroma. When the nerve has suffered only a partial cut, it results in the formation of a side neuroma (Fig. 27-2C).

Classification of peripheral nerve injuries

A. **Seddon's classification (1943)**

According to this classification, the severity of injuries to the nerve is divided into three classes.

1. **Neurapraxia**

It is the contusion of the nerve only; anatomically the axis cylinder is well preserved. There is only a temporary physiological disruption of the conduction of nerve impulses. No Wallerian degeneration occurs. Complete

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recovery occurs within 3–6 weeks (e.g., Saturday night palsy).

2. **Axonotmesis**

The axons are damaged but the endoneurial tube remains intact. Wallerian degeneration occurs in the distal segment of the injured nerve. Intact epineurium, perineurium and endoneurium guide the regenerating axons to their appropriate connections. Partial to complete recovery may occur within 3–6 months (e.g., fractures and dislocations).

3. **Neurotmesis**

The nerve is either completely cut or disorganized to an extent where spontaneous recovery is impossible. Wallerian degeneration sets in early and the neural elements mingle with the fibrous elements to form a neuroma, which needs surgery. The prognosis of recovery is poor (e.g., cut injury, open lacerated wound, severe crushing or a traction injury).

B. **Sunderland's classification (1951)**

According to this classification, nerve injuries are classified into five grades in an ascending order depending upon the extent of injury to the axon, endoneurium, perineurium, entire nerve trunk, myelin; motor march; Tinel's sign and overall prognosis of recovery (Table 27-1).

Table 27-1
Sunderland's Classification of Peripheral Nerve Injury

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Grade	I	II	III	IV	V
• Axon	Contusion	Disrupted	Disrupted	Disrupted	Disrupted
• Endoneurium	Intact	Intact	Disrupted	Disrupted	Disrupted
• Perineurium	Intact	Intact	Intact	Few fibres preserved	Disrupted
• Entire nerve	Intact	Intact	Intact	Intact	Disrupted
• Myelin	Intact	Intact	Intact	Intact	Disrupted
• Motor march	Absent	Present	Present	Absent	Absent
• Tinel's sign	Absent	Present	Present	Absent	Absent
• Recovery	Complete recovery	Good recovery	Incomplete recovery	No recovery	No recovery

Remember

PN injuries do not always rigidly follow these classifications. A single nerve injury may include neuropraxia, axonotmesis and neurotmesis simultaneously.

Incidence

The average frequency with which various PN nerves are prone to injuries in percentage of all the PN injuries are as follows:

- Radial nerve: 45–50%
- Ulnar nerve: 20–30%
- Median nerve: 15–20%
- Common peroneal nerve: 10–15%
- Lumbosacral plexus: 3–5%
- Tibial nerve

Aetiology

- Direct injury: Fractures and dislocations alone account for over 40–50%. Sharp cuts, lacerations, piercing injuries, nerve entrapment

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between the fractured bony ends at the time of a fracture.

- General causes: Metabolic diseases, collagen diseases, infections, excessive cooling (freezing) excessive heating (burns), neurotoxic drugs like tetracycline, quinidine, radiation therapy for cancer, carelessly given intramuscular injections directly piercing the nerve, excessive traction or a friction of the nerve (e.g., skeletal or pin traction), prolonged ischaemia (e.g., VIC) and electric shock.

- Late causes: Compressive pathology due to growing tumour, excessive callus, malunion, fibrosis and adhesions.

Clinical features/signs and symptoms

- *Early signs*

- Pain due to injury may be present with stiffness of the adjacent joint.

- Setting in of paresis or paralysis of the muscles innervated by the injured nerve.

- Loss of skin sensation to touch, pain, temperature and steriognosis.

If the motor supply remains intact, the perception of joint position, joint movement, deep pressure and vibration will be preserved.

- Anaesthetic skin area which feels cool and dry.

- Presence of Tinel's sign.

- *Late signs*

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- Muscle paresis gradually progress to paralysis.
- Deep tendon reflexes are reduced or lost.
- Trophic changes like dry, thin and glossy skin, nails appearing brittle, hair fall; even bones develop a tendency for osteoporosis.
- Typical deforming attitude, related to muscular imbalances due to paralysis gradually setting in.
- Atrophy of the muscles of innervation.

Steps in the evaluation and diagnosis of PN injury

1. *History*: Emphasis is needed on three factors; each is directly related to the prognosis.

- When? – How long back?
- How? – Injury type: cut, laceration, blunt injury or nontraumatic?
- What happened following injury? For example:
  - The presence of excessive bleeding indicates associated vascular injury, the onset of numbness indicate break in the continuity of the nerve.
  - The earlier treatment and its response.

2. Extensive motor and sensory evaluation:

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- Motor evaluation: Critical evaluation of the strength and other muscle functions.

- Supplementary action of the projected tendon, e.g., projection of the tendon of abductor pollicis brevis into the terminal phalanx produces strong extension of the terminal interphalangeal (IP) joint of the thumb (in the presence of radial nerve lesion).

Remember

This tenodesis effect as well as other trick movements should be encouraged and strengthened to facilitate hand function in nonrecoverable nerve lesions.

Spot diagnosis (by testing motor status)

Simple and specific physical examination greatly helps in the spontaneous diagnosis of the injured peripheral nerve.

Identification of the injured peripheral nerve by simple observation and clinical examination

1. Clinical motor test of the muscles innervated by the respective peripheral nerve (Table 27-2).

2. Localized atrophy of the muscles (Table 27-3) innervated by a relevant injured peripheral nerve.

3. Typically abnormal postural attitudes as a result of paralysis of the muscle groups innervated by the injured peripheral nerve (Table 27-4).

4. Susceptible areas of the limb where the nerve lies superficially between the skin and the bone (Table 27-5).

5. Site of injury to the bone and the joint where damage is expected to a particular peripheral nerve (Table 27-6).

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6. Impaired sensorium to touch and pain (pin prick) (Table 27-6B).

Table 27-2
Simple Diagnostic Clinical Motor Tests

Nerve	Innervated Muscles	Motor Test
• Median nerve	• Opponens pollicis	• Opposition: Approximation of the palmar surface of the tip of thumb to the tip of the little finger without flexing IP joints (Fig. 27-4)
	• Flexor digitorum profundus to index and middle fingers (Oschner's pointing index finger test)	• Pointing index finger: When the fingers of both the hands are clasped together the index finger remains extended (Fig. 27-5) • Benediction test: Same as aforementioned but here both the index and the middle fingers remain extended, like a clergyman's hand position when he blesses the just married couple
	• Abductor pollicis brevis (pen test)	• Pen test: Hand resting on a table with palm facing up. A patient is asked to touch the pen held up perpendicular to the plain of the palm ; in a case of median nerve palsy, the patient fails to abduct the thumb (Fig. 27-6)
• Ulnar nerve	• Palmar interossei (perform palmar adduction of all the fingers – (PAD)(card test))	• Card test: Grip card or a paper held between the extended fingers (Fig. 27-7)
	• Dorsal interossei (perform abduction of the fingers – (DAB) (Egawa test))	• Egwa test: Resting palm on the table with palm facing down and fingers in extension; the index finger is passively held in abduction; the patient is asked to abduct the middle finger towards the abducted index finger (Fig. 27-8)
	• First dorsal interosseous and adductor pollicis (Froment's sign)	• Book test or Froment's sign: The patient is asked to grip and hold a book between the extended index finger and the thumb; the patient's, attempts to hold result in flexion of the IP joints (median supply; Fig. 27-9)
• Radial nerve	• Wrist drop – loss of extension of the wrist and fingers (total wrist drop)	• Total loss of wrist and finger and thumb extension (Fig. 27-10) • Hitchhiker's sign: Inability to extend the IP joint of the thumb
• Spinal accessory nerve	• Muscle trapezius	• Elevation of shoulder girdle is lost
• Long thoracic nerve	• Serratus anterior muscle	• Winging of the scapula when the patient attempts to push against the wall with extended elbow joints
• Axillary nerve	• Deltoid muscle	• Failure to abduct shoulder
• Sciatic nerve		
(a)	• Extensors and the	• Loss of dorsiflexion of the ankle joint (foot drop; Fig. 27-11)

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Common peroneal nerve	everters of the foot	
(b) Tibial nerve (lateral popliteal)	• Gastrosoleus muscle	• Failure to perform controlled plantar flexion after heel strike (calcaneus gait)

Table 27-3

Localized Atrophy of the Muscles Innervated by the Injured Nerve

• Axillary nerve	Flattening of the shoulder contour due to paralysis of the deltoid
• Median nerve	Flattening of the muscles of the thenar eminence
• Ulnar nerve	Flattening of the muscles of the hypothenar eminence
• Femoral nerve	Wasting over the anterior thigh above knee
•Posterior tibial	Wasting over the calf on the posterior aspect of leg

Table 27-4

Typical Abnormal Postural Attitudes as a Result of Paralysis of the Muscle Groups Innervated by the Injured Nerve

• Brachial plexus	Waiter's or policeman's tip
• Thoracodorsal	Winging of the scapula
• Radial nerve	Wrist drop
• Ulnar nerve	Ulnar claw hand
• Median nerve	Medial claw hand
• Median + ulnar nerve injury	True claw hand involving all the four fingers (Fig. 27-12)
• Median nerve injury	Simian hand or monkey thumb with wasting of the thenar or muscles

Table 27-5

Susceptible Areas of the Limb Where the Nerve Lies Superficially between the Skin and the Bone

• Radial nerve	Laterally winding over the spiral groove over the midshaft area of the humerus
• Median nerve	Palmar aspect of the forearm just proximal to the wrist joint
• Ulnar nerve	Over the medial epicondyle of the humerus

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• Axillary nerve	Close to the fibrous septa in the axilla
• Common peroneal nerve	Winding course over the fibular head and neck

Table 27-6

Site of Injury to the Bone and the Joint Where the Damage is Expected to the Relevant Peripheral Nerve

Fracture of the clavicle – brachial plexus injury
Fracture of the proximal humerus – axillary nerve injury
Fracture of the midshaft of the humerus – radial nerve injury
Posterior dislocation of the elbow – radial nerve
Injury to the palmar aspect of the forearm just proximal to the wrist – median nerve
Monteggia fracture – posterior interosseous nerve
Fracture of the medial epicondyle – ulnar nerve
Posterior dislocation of the hip – sciatic nerve
Anterior dislocation of the hip – femoral nerve
Dislocation of the knee joint – common peroneal nerve
Fracture of the neck of the fibula – lateral popliteal nerve
Fracture of the proximal tibial shaft or ankle injuries – posterior tibial nerve
Impaired sensorium to touch and pinprick (pain): •Index finger – in median nerve lesion • The tip of the little finger – in the lesion of the ulnar nerve

Testing sensory status (fig. 27-3)

Sensory status testing gives a profile of the sensory pathways.

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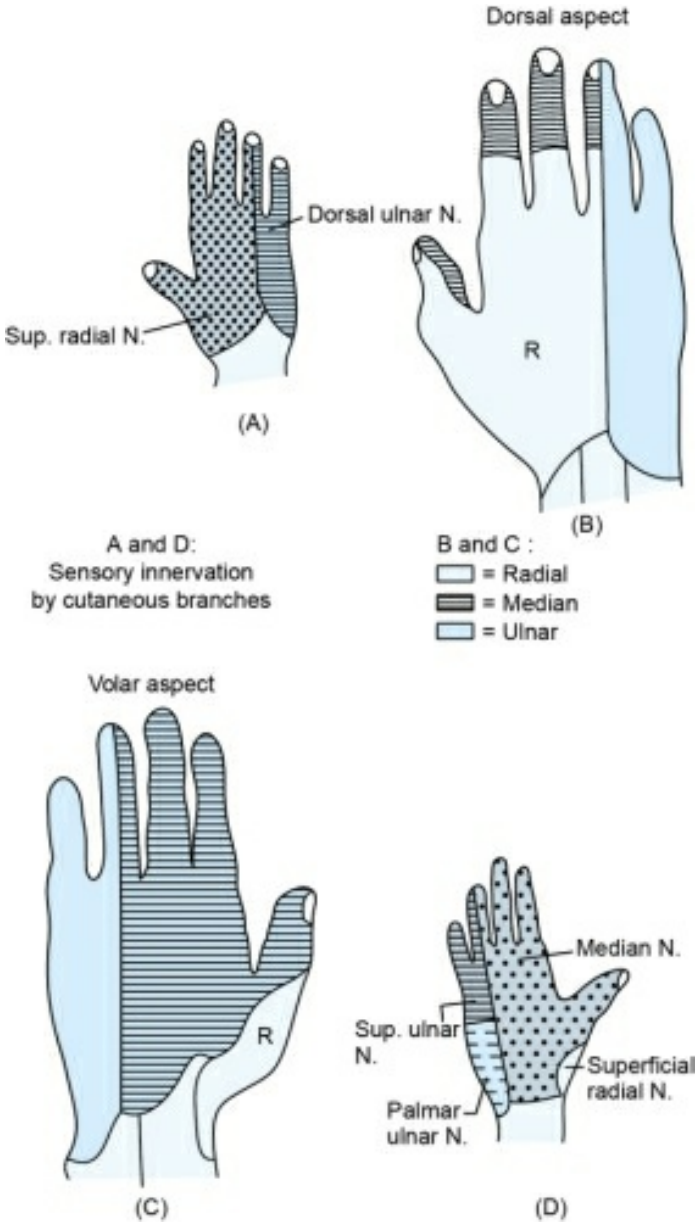

FIG. 27-3 **(A–D)** Sensory innervation of hand.

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FIG. 27-4 True opposition: approximation of the palmar surfaces of the tip of the thumb with the tip of the little finger without flexing the IP joints.

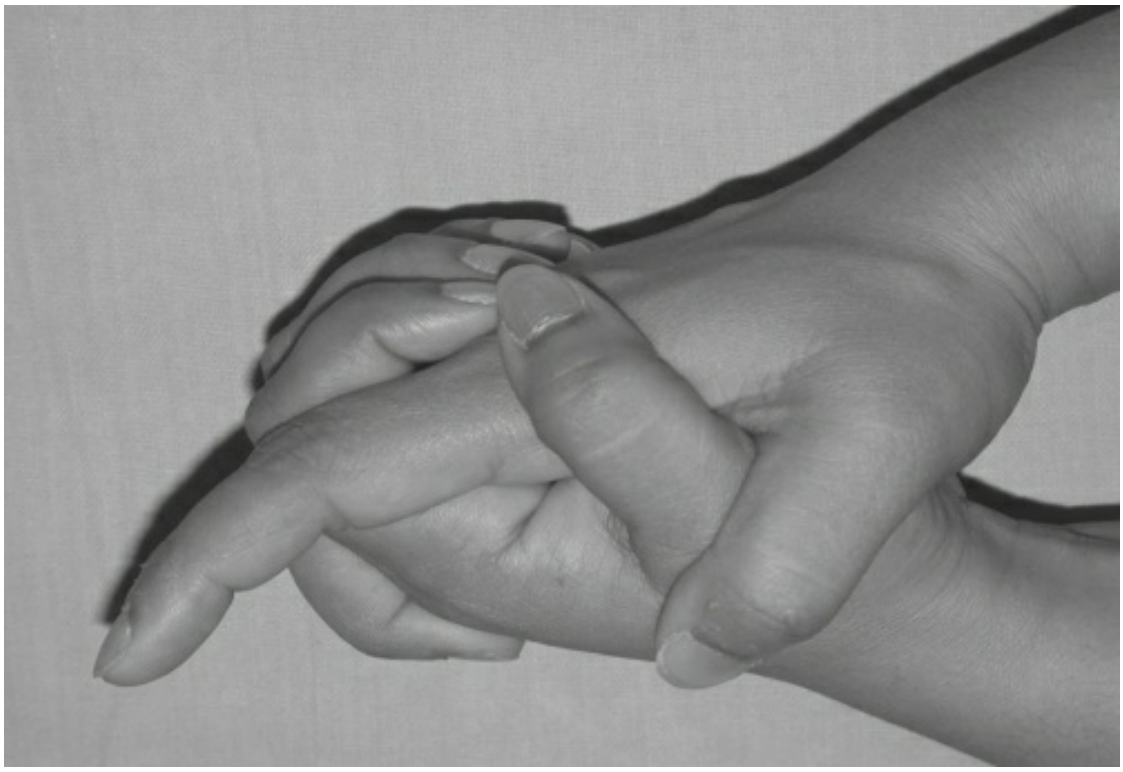

FIG. 27-5 **Oschner's** pointing index test. The index finger remains

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extended due to the paralysis of long flexors in a median nerve lesion.

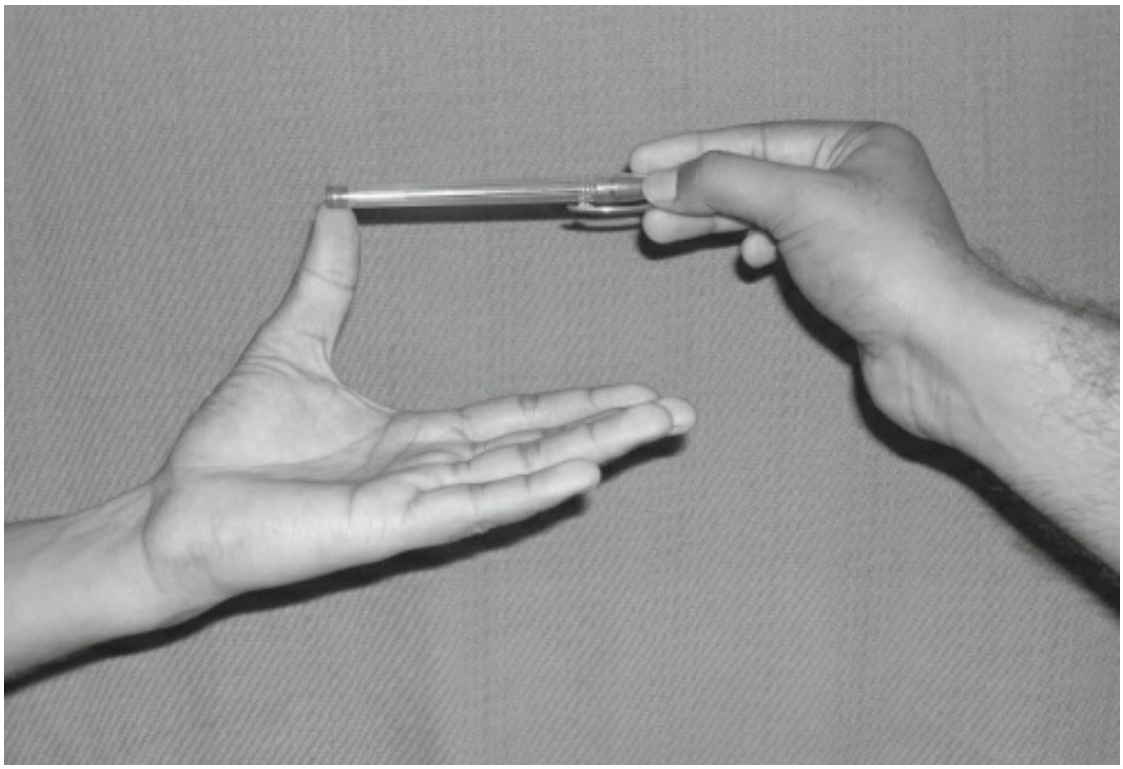

FIG. 27-6 Pen test. In a case of median nerve palsy, due to the paralysis of the abductor pollicis brevis, the patient is unable to perform thumb abduction.

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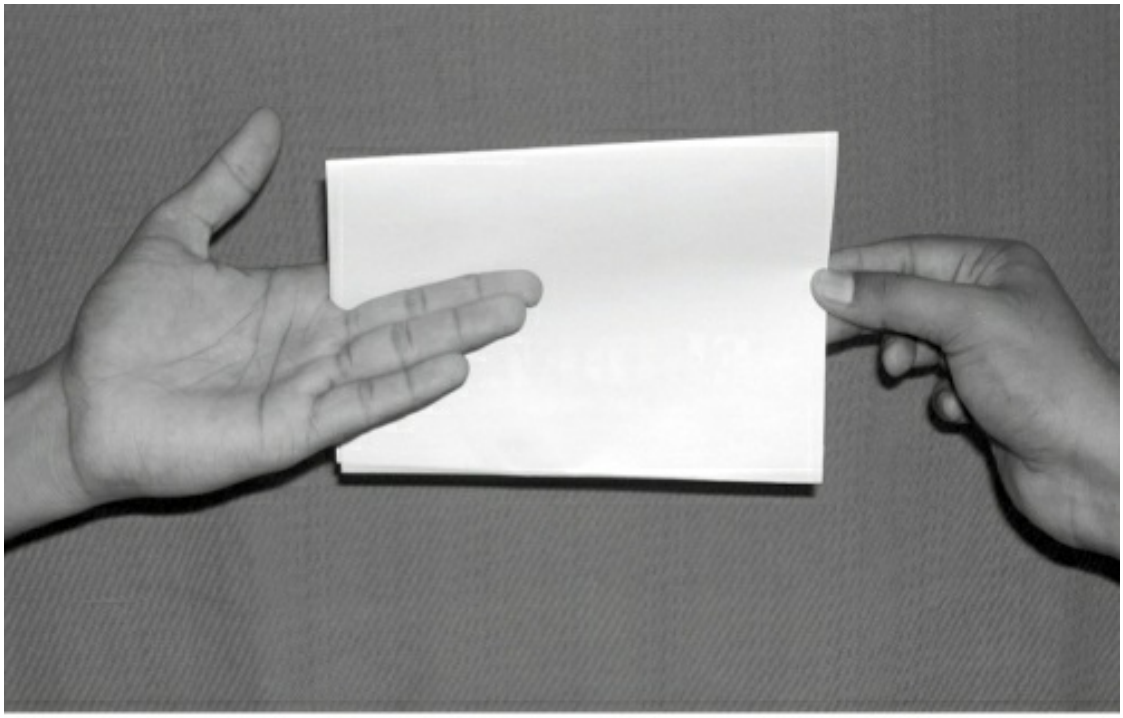

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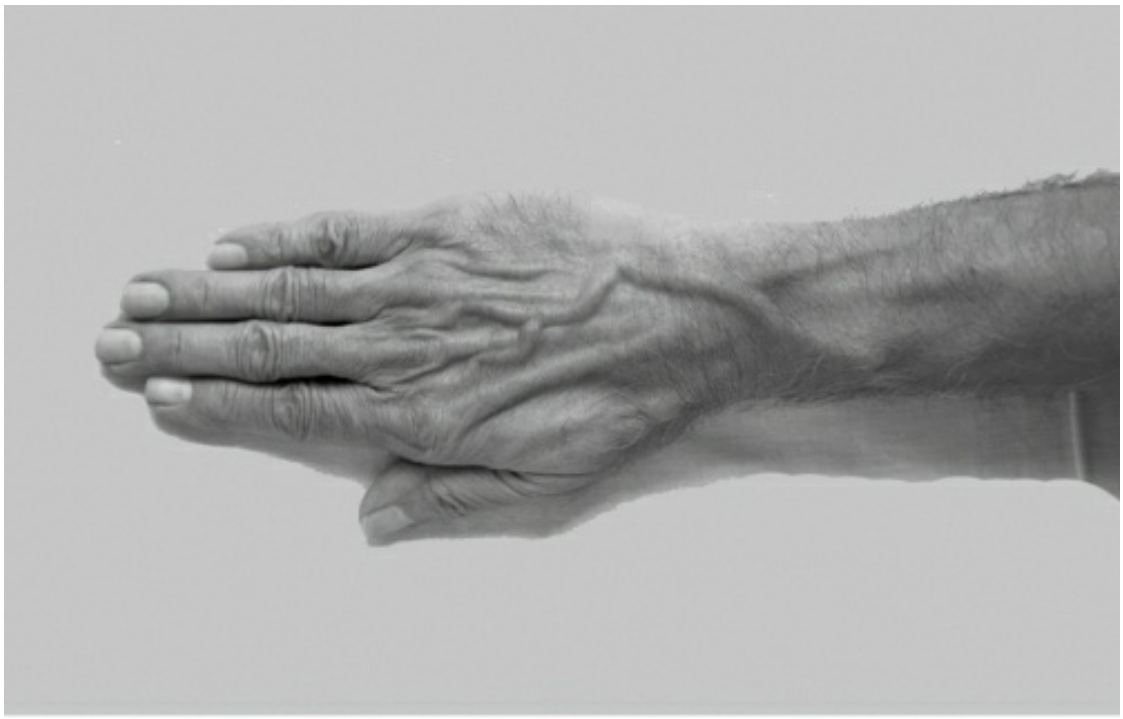

(B)

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(C)

FIG. 27-7 **(A)** Card test for interossei in ulnar nerve injury. **(B)** Testing the palmar interossei by asking the patient to perform adduction of all the fingers. **(C)** Testing the dorsal interossei by asking the patient to perform abduction of all the fingers (ulnar nerve).

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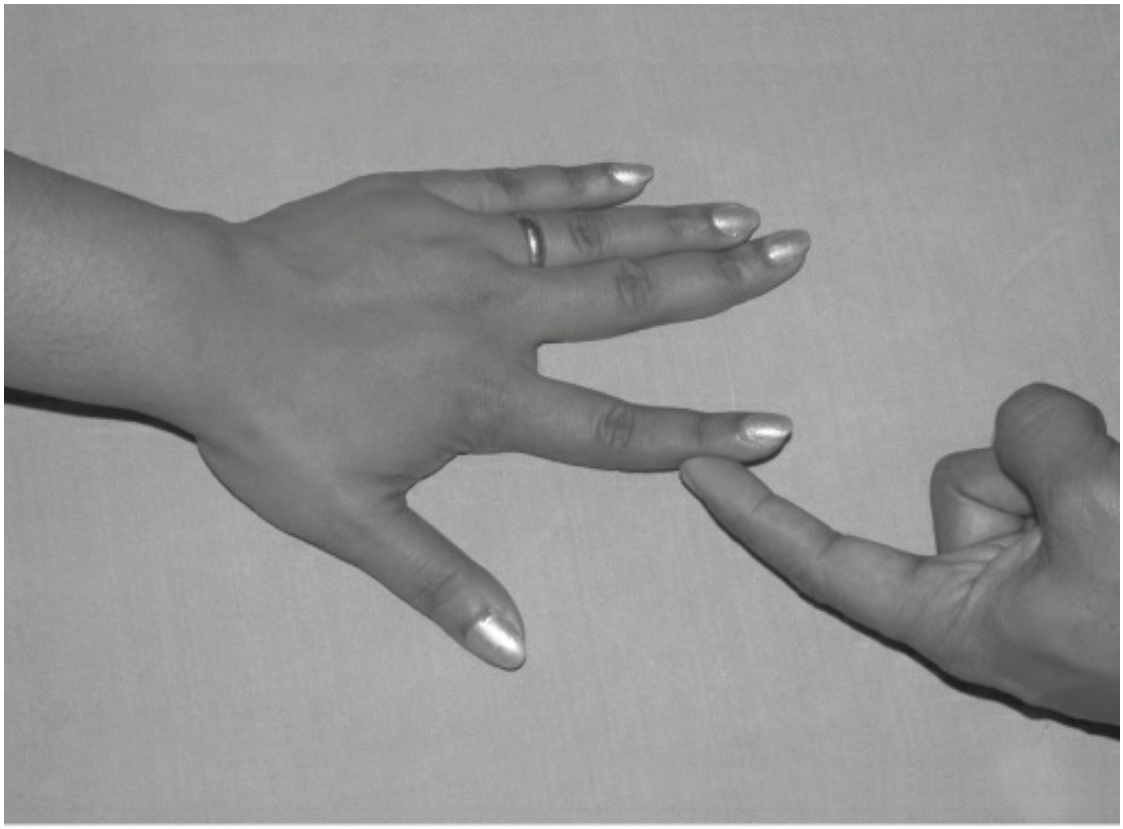

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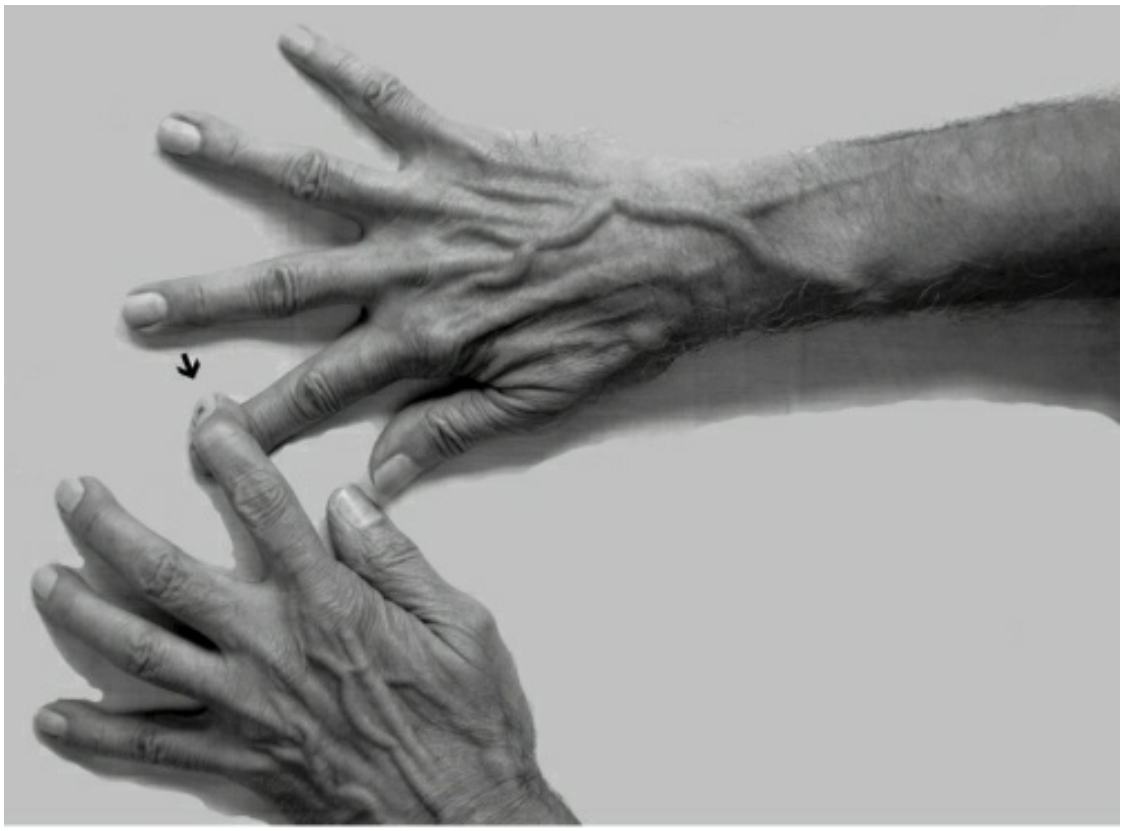

(B)

FIG. 27-8 **(A)** Testing the first dorsal interosseous muscle by asking the patient to perform abduction of the index finger. **(B)** Egawa test: the patient is asked to abduct the middle finger towards the index finger passively held in abduction.

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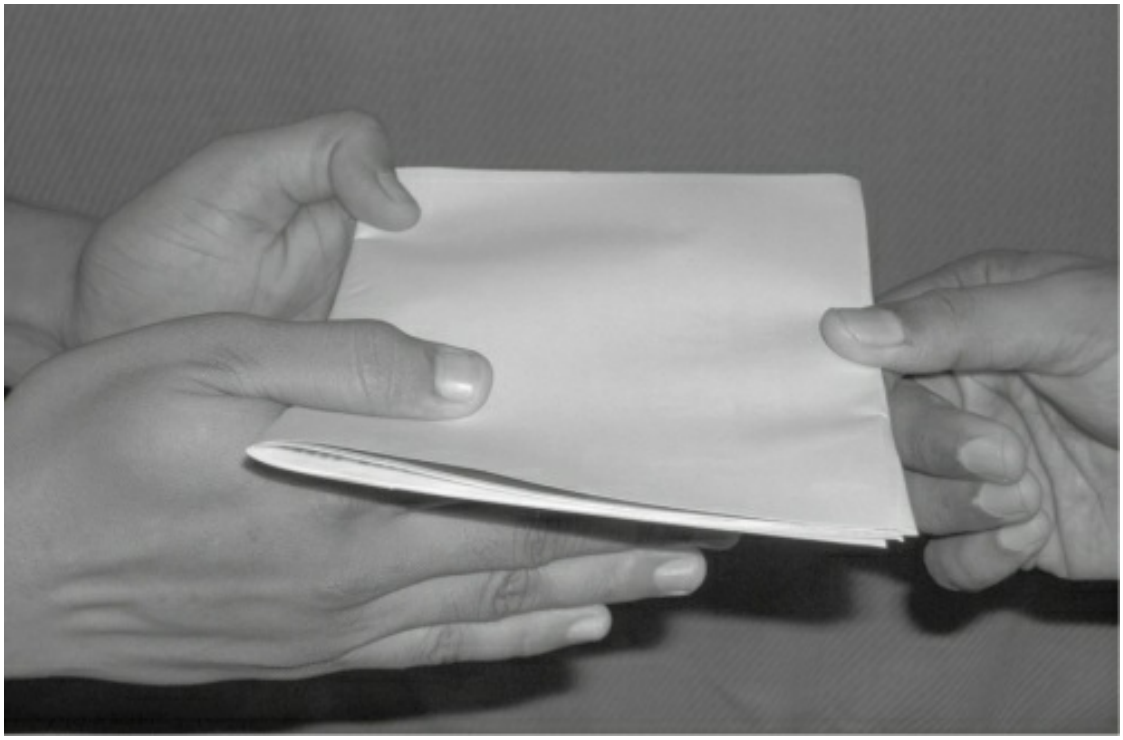

FIG. 27-9 Froment's sign.

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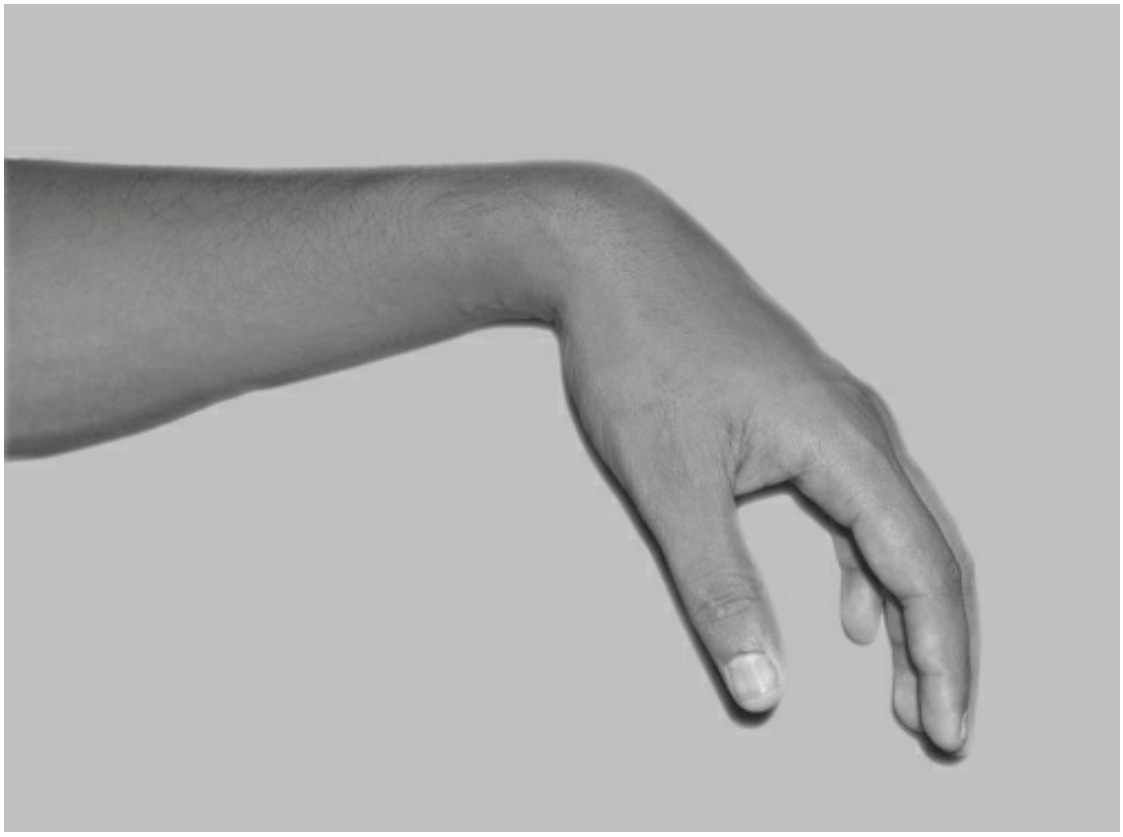

FIG. 27-10 Total wrist drop.

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FIG. 27-11 Foot drop.

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FIG. 27-12 Main-en-griffe true claw hand (median and ulnar nerve damage).

Sensory pathway

The sensory pathways can be divided into four major components:

1. The receptor field

2. The conducting lines – axons

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3. The central conduit – the spinal cord

4. The central decoding apparatus – cerebral cortex

The sensory impulses begin in the receptor field and depend upon the qualities of various receptors.

The axons are divided into three groups: A, B and C.

Group A: These axons are the largest and carry tactile stimuli which can be tested effectively.

(a) Quick adapting fibres: The 90% of A-axons consist of quick adapting fibres, which respond to the stimulus with a short burst of firing and then stop firing till the stimulus is removed. They respond with a rapid short burst of firing as the stimulus is removed. They also respond to vibratory stimuli of varying frequency, either at 30 or 256 cps (cycles per second). These quick adapting fibres can be tested by tuning forks.

(b) Slow-adapting fibres: These constitute the remaining 10% of A-axon fibres. They are responsible for the sensation of constant touch. They respond to a stimulus with a burst of firing and then constantly keep on firing till the stimulus is removed. The fibres are tested by two-point discrimination test.

(c) The sensation of pressure, cold and warmth are conducted by small myelinated axons of the delta group and the smaller unmyelinated axons of group C.

Testing the pattern of recovery of sensibility

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The sequence to be followed:

A. Vibration of 30 cps

B. Moving touch

C. Constant touch

D. Vibration of 256 cps

When a patient recovers these sensibility qualities, the two-point discrimination and Von Frey pressure test can be done.

Early tests

There are six sensory tests:

1. Vibratory test

2. Pseudomotor activity test

3. Two-point discrimination test

4. Von Frey pressure test

5. Pickup test

6. Pin-prick test

1. Vibratory test: It is an important early diagnostic test. This is done with a tuning fork with stimulus of either 30 cps or 256 cps. It stimulates the quickly responding fibres which are also in the majority (90% of A-axon). It should be done early to know the extent and the prognosis of the lesion (Dellon et al., 1972).

2. Pesudomotor activity test: Sweating in the area supplied by the peripheral nerve is one of the initial tests indicative of regeneration, whereas dryness of the skin over the distribution of a peripheral nerve indicates severe laceration.

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3. Two-point discrimination test: To be done when the perception to light constant touch returns. As slow-adapting fibres are being stimulated, the test should include moving as well as static two-point discrimination.

It can be done with an ordinary paper clip, with the patient observing and then with the eyes closed. Ten separate stimuli are given; seven correct responses are essential to adequate conduction (Dellon, 1978; Moberg, 1958; Weber, 1935).

4. Von Frey pressure test: This test is a pressure test to detect the perception of light touch. The hand should be marked into seven zones. The monofilament of a horse hair of varying thickness and stiffness is placed and pressed on the area under examination until it bends; the examiner can judge the force of pressure required to evoke response (Von Frey, 1922).

5. Pickup test: It is important as it combines sensibility and sensory inputs with motion. The blindfolded patient is given nine objects of different shapes and sizes. He is instructed to pick up one object at a time and place it into a small container. Time taken to perform this is compared with the contralateral normal limb. It usually takes 5–8 s for a young adult male.

6. Pin-prick test: This test is commonly used to assess the sensation of pain. The patient is blindfolded and is asked to count the pricks applied intermittently.

Acute laceration of a nerve can be diagnosed by vibratory and pin-prick tests. Two-point discrimination and pickup tests are employed to record recovery after nerve repair. However, a patient with a lesion in continuity needs all the six tests. Development of hyperaesthesia, pain or ‘pins and

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needles' indicates recovery of sensation.

Special investigations

- Electrodiagnostic tests
- Electromyography
- Nerve conduction velocity (NCV) studies
- Strength–duration curves (SD curve)

Electromyography (fig. 27-13)

It is the most useful test to distinguish between:

- The presence or absence of nerve injury.
- When present, whether the nerve injury is complete or incomplete.
- Whether the regeneration of the injured nerve is taking place or not.

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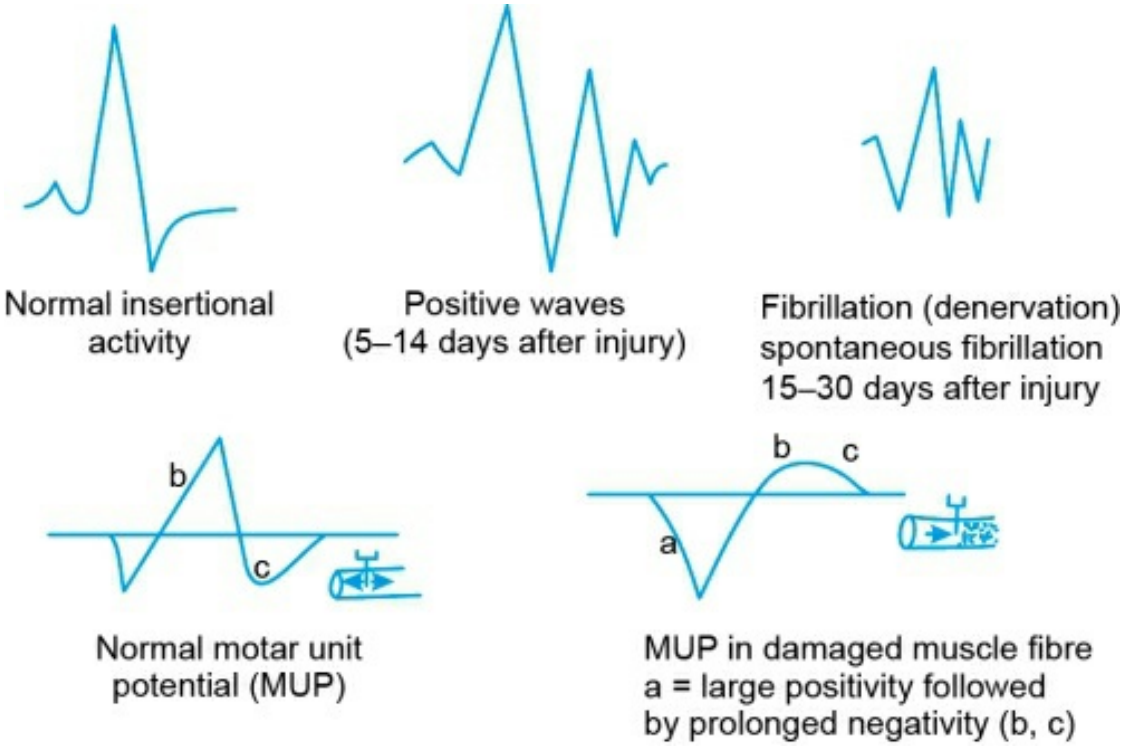

FIG. 27-13 EMG patterns.

It displays on the monitor the various aspects of the nerve injury with precision by virtue of the established patterns of the intact nerve and that of the injured nerve (Table 27-7).

Table 27-7

EMG Characteristics of Normally Innervated Muscle and the Denervated Muscle by Needle Electromyography

Normally Innervated Muscle	Denervated Muscle
• At rest: No electrical activity • At weak voluntary attempt: Displays only a single motor unit action potential • During the attempted strong voluntary muscle contraction – number of motor units firing simultaneously are superimposed giving rise to the interference pattern of motor action potentials	• At rest: Show denervation potentials, with spontaneous electrical activity by 1–2 weeks after injury • If these denervation potentials fail to appear by 3 weeks after muscle denervation, it indicates good prognosis of recovery

However, EMG fails to indicate the level and the degree of injury to the nerve with precision.

NCV studies (table 27-8)

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Motor NCV

The nerve to be studied is stimulated at two levels and the latent period between the application of the stimulus and the ensuring muscular contraction is determined.

- The distance between two levels (D) is measured.
- The stimulating electrode is applied directly at the point over the nerve trunk. The response is picked up by the second electrode placed over the muscle to be stimulated (Fig. 27-14).
- The precise value of the NCV is calculated by dividing the difference between the proximal and distal stimulation in mm.

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$$\mathbf{NCB} = \frac{\mathrm{D}}{\mathrm{PL\text{-}DL}}$$

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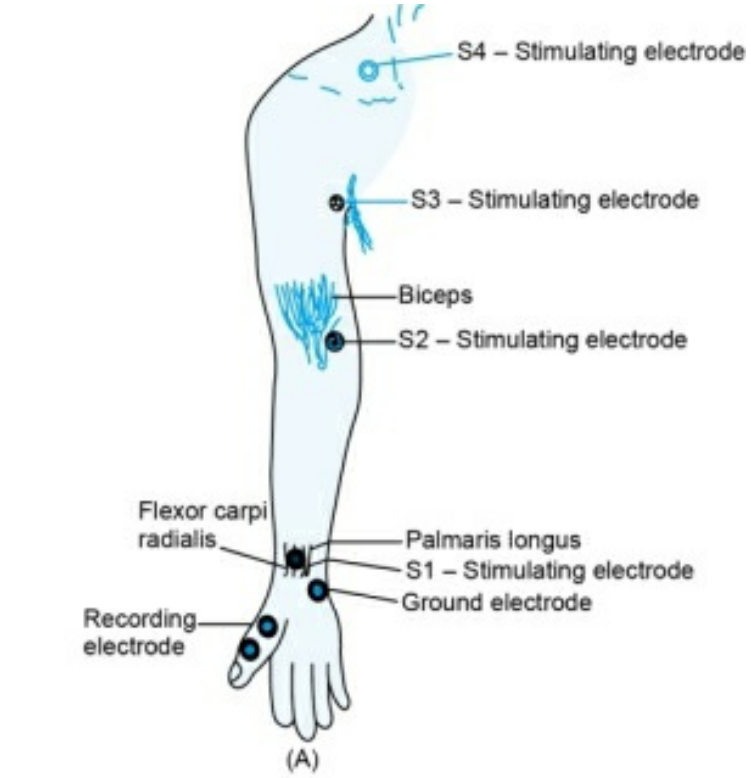
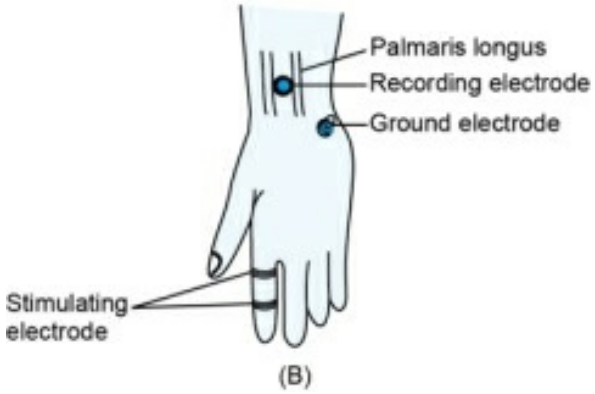
PL = Proximal latency

DL = Distal latency

D = Distance between the proximal and distal stimulation points (ideal distance between the two points of stimulation should not be less than 10 cm).



(A)



(B)

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FIG. 27-14 **(A)** Motor nerve conduction velocity of median nerve (electrode placement). **(B)** Sensory nerve conduction velocity of median nerve (electrode placement).

Table 27-8

Normal Values of the Motor and Sensory Nerve Conduction Velocities (Mean ± SD)

Nerve and the Site of Stimulation	Latency (ms)		Amplitude (mV)		NCV (m/s)	
	Motor NC	*Sensory NC*	*Motor NC*	*Sensory NC*	*Motor*	*Sensory*
• *Median nerve*		Sensory: From digit to wrist				
• Axilla • Elbow	9.81 ± 0.89 7.39 ± 0.69	2.84 ± 0.34	7.2 ± 2.9 7.0 ± 2.7	38.5 ± 15.6	63.4 ± 6.257.7 ± 4.9	56.2 ± 5.8
• Ulnar nerve:	Motor: Recorded from abductor digiti minimi			Sensory: Digit to wrist		
• Axilla • Above elbow • Below elbow	9.90 ± 0.91 8.04 ± 0.76 6.1 ± 1.69	2.54 ± 0.29	5.6 ± 2.1 5.5 ± 1.9 5.5 ± 2.0	35.0 ± 14.7	66.5 ± 6.3 61.0 ± 5.5 58.7 ± 5.1	54.8 ± 5.3
• Radial nerve: • Axilla to elbow • Elbow to forearm • Wrist to thumb	– – –	– –	11.7 ± 7.0 13.0 ± 8.2 13.0 ± 7.5	4.0 ± 1.4 4.0 ± 1.4 –	69.0 ± 5.6 62.0 ± 5.1 –	71.0 ± 5.2 – 58.0 ± 6.0

Sources: Kimura (1986), Kimura (1983), and Trojaborg and Sundrip (1969).

Sensory NCV

Determined by stimulating a point over the skin or a digit with the action potentials picked up by the electrodes along the course of the nerve at two different points. The sensory NCV is calculated by the same method as the motor NCV. However, the conduction of the sensory impulse is much faster than the motor nerve conduction.

Remember

There is always a possibility of overlapping of the sensory innervation in certain nerves. However, a small area of total anaesthesia known as the autonomous zone is present in all types of

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nerve injuries.

The development of hyperaesthesia, pain, pins and needles over the distribution of an injured nerve trunk are good prognostic signs of the recovery.

Normally a muscle when stimulated with a shorter duration (1 ms) current responds with a minimal contraction. It keeps on responding as the duration of the current is reduced beyond 1 ms, although it needs higher intensity current and produces a normal smooth SD (strength–duration) curve.

Whereas, when the muscle is denervated, as the duration is shortened, progressively higher intensity current is required to produce minimal contraction as it stimulates the muscle directly.

The resulting curve for the denervated muscle rises steeply.

The early sign of reinnervation is the appearance of a 'kink' in the curve. The shifting of this kink towards the left side of the curve indicates progression of reinnervation, whereas, when its progress stops, by 6 weeks, it indicates termination of the reinnervation. The kink completely disappears following reinnervation.

Strength–duration curve (SD curve)

- A curve plotted between the strength (intensity) current and the varying durations (ranging from 0.01 to 800 ms) of.
- The nerve is stimulated at the motor point to elicit minimal muscular contraction.
- The SD curve provides objective evidence of the integrity of the nerve as shown in Fig. 27-15:
- By 7 days: Whether the nerve trunk is intact and conducting impulses normally (no RD; the SD curve is smooth)

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- After 3 weeks: When the reaction of degeneration is set in and the nerve responds with a muscular contraction directly through the stimulation of the muscle only at higher intensity of current and longer duration is indication of partial reaction of degeneration (PRD).

- The upward small curve (kink) in the curve indicates the beginning of reinnervation. The progression of the kink towards the left of the curve indicates the progress of reinnervation of the nerve.

- After 6 weeks: The nerve requires not only higher intensity but also stops responding even if the duration of the stimulus is applied indefinitely. It indicates the complete reaction of degeneration with poor prognosis of recovery.

Rheobase and the chronaxy: Rheobase is the least amount of current required to produce minimal perceptible muscular contraction in the stimulated muscle in milliamperes.

Chronaxie is the duration of a current required to excite a muscle with a current strength of double the rheobase.

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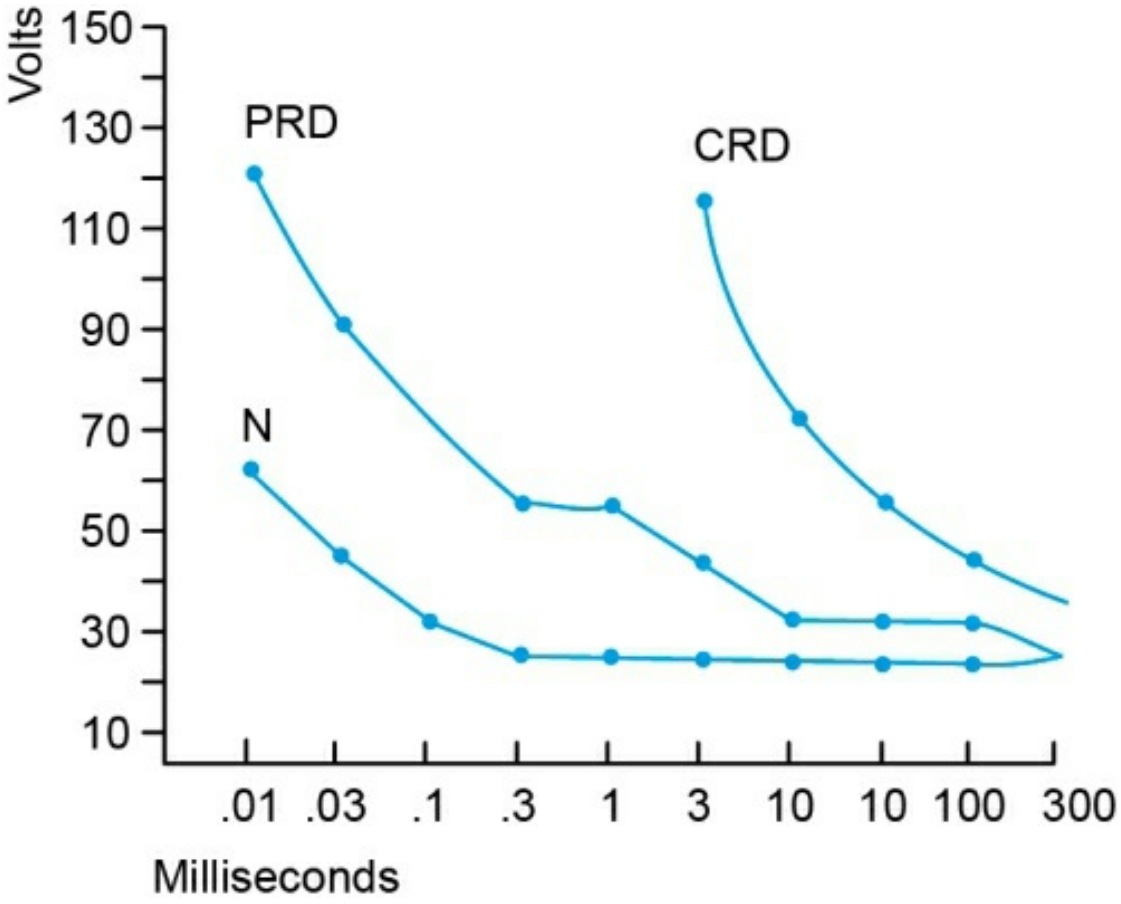

FIG. 27-15 Strength–duration curve. N, normal; PRD, partial denervation; CRD, complete denervation.

Additional tests

Vascular test

A strong association exists between vascularity and nerve conduction. Entire physiologic function including that of the motor and sensory end organs is involved distally (e.g., VIC, diabetes and collagen vascular disease). It is done by palpating distal pulses or plethysmography may be used to assess pulse volume.

Blood flow detection test

The status of arterial and venous blood flow is evaluated by Doppler test.

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Skin resistance test

Sympathetic nerve involvement gives rise to dry and glossy skin. In partial lesions, vasomotor changes like pallor, cyanosis or excessive sweating may occur. Trophic changes like brittle nails and trophic ulcers may also be present.

Sweat test

The presence of excessive sweating over the area of skin within the autonomous zone of the injured nerve indicates only partial interruption in the conduction of impulses, and a good prognosis.

Tinel's sign

A simple clinical test that helps in the diagnosis as well the prognosis of the injured nerve.

Test for tinel's sign

In the process of regeneration of an injured peripheral nerve, the myelination occurs progressively from the proximal to the distal at a rate of about 1 mm a day. When a regenerating nerve is tapped progressively along its course from distal to proximal, a sensation of paraesthesia (pins and needles) is felt due to exposure of raw degenerating neurons.

Thus:

(i) The test locates the exact point of nerve regeneration (Tinel's point).

(ii) The distal advancement of this Tinel's point is the indicator of the progression of recovery or regeneration of the injured nerve.

(iii) If this Tinel's point remains stationary, it indicates the termination of recovery. This may occur as a result of the formation of a neuroma due to the entrapment of the cut ends in a scar (needs exploration).

Treatment planning

After confirmed diagnosis, while planning the methodology of

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treatment, due emphasis must be given to certain factors directly influencing the prognosis of recovery (Table 27-9).

Table 27-9
Factors Influencing the Prognosis of Recovery

Influencing Factor	Prognosis of Recovery
Age	Lower the age, better the prognosis
Tension or stretch at the site of injury	More the tension, poorer the prognosis
Late reporting	No chance of motor recovery, sensory status may recover
Location of injury	The proximal the injury, worse the prognosis
Type of involved nerve	Primary motor nerve has a better prognosis than a mixed nerve
Degree of damage to the nerve	Excessive damage to the nerve (e.g., crush injury), poorer is the chance of recovery
Associated factors	Factors like late reporting, early mismanagement adversely affects the recovery
Size of the gap between the cut ends or separated ends	More the gap, reduced chance of recovery unless grafting is done
Delay in the nerve repair	Reduces the chances of recovery
Associated injuries	Injury to the vessels, tendons, delays the recovery process
Infection	Not only delays the recovery but also may result in poor prognosis due to further damage
Operative neglect	Excessive traction, cut injury, tight POP may directly result in damage to the PN

Due to the multifactorial dependency of the recovery, only the general plan of treatment forms the basic procedures of treatment (Flow chart).

Orthopaedic management

The standard orthopaedic management of fractures is applied. Most of the time, the nerve injury is associated with a fracture.

- Bone and vascular repair takes precedence over the repair of the nerve.

- Primary nerve repair: Carried out within 6–8 h only when the open wound is clean. The cut ends of the nerve trunk are brought close and sutures are applied with a fine silk material. The sutured nerve is immobilized and protected from tension or stretches by orthosis.

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- If the wound is contaminated, the sutures are applied between 7 and 18 days, only after ensuring proper wound care.
- Secondary repair: By 18 days to 3 weeks in certain situations like:
- Failure of the conservative treatment.
- Symptoms of definite nerve irritation.
- No symptoms of recovery.
- Poor general condition of patient.

Late direction

Surgical methods of nerve repair

1. **Nerve suture (neurorrhaphy) and nerve grafting**

   (a) *Epineural repair:* Carried out by suturing the epineurium (Fig. 27-16A).

   (b) *Fascicular repair*: After excising the epineurium, the fascicles are separated. Then the fascicles of both the nerve ends are matched together and sutured using microsurgical techniques (Fig. 27-16B).

   (c) *Both epineural and perineural repair* (Fig. 27-16C): When the approximation of the cut ends of the nerve becomes difficult due to the formation of end neuroma, the excision of the neuroma is carried out, followed by adequate mobilization of the nerve to gain a shortened length; then suturing is carried out by:

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i. Immobilizing the joint close to the course of the nerve in slight flexion. Sutures are applied only after gaining adequate length for suturing, e.g., anterior transposition of the ulnar nerve when injured behind the medial epicondyle of the humerus.

ii. Sacrificing the unimportant branches of the nerve hampering the nerve mobilization.

(d) *Nerve grafting:* When the gap between the cut ends is 10 cm or more, it is bridged over by nerve grafts obtained generally from the sural nerve or the lateral cutaneous nerve of the thigh (Fig. 27-16D).

The neuroma is cut before nerve grafting is performed (Fig. 27-16E).

(e) Decompression of the nerve: Median nerve compressed in the muscular or fibro-osseous tunnel is decompressed surgically (Fig. 27-16F).

2. **Neurolysis**

Sometimes the continuity of the nerve is well maintained but its conductivity is hampered due to its entrapment with the scar formation, fibrosis and excessive callus formation. The fibrosis may be:

□ External – formed outside the nerve trunk.

□ Internal – formed within the nerve trunk.

■ External fibrosis is treated by external neurolysis; the

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nerve is freed from the fibrous tissue without opening the sheath.

- Internal fibrosis – the nerve fibres are freed from the intervening fibrous tissue after opening the nerve sheath (Fig. 27-16G).

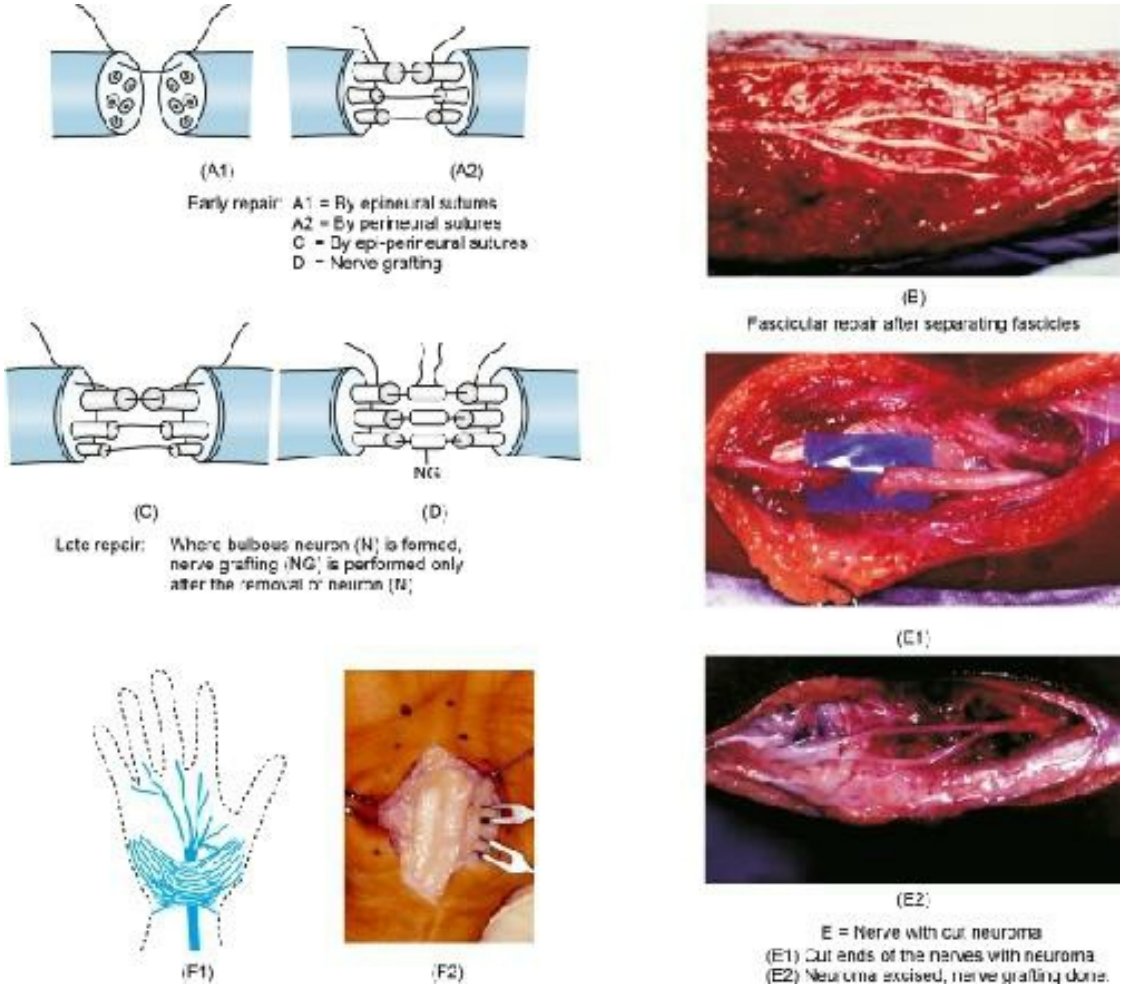

FIG. 27-16 Nerve repair.

Reconstructive surgical procedures

By 18 months, the conduction of impulses across the injured nerve completely stops, indicating complete nerve degeneration. This

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requires reconstructive surgical interventions like:

- Tendon transfers (Fig. 27-17).
- Joint stabilization (arthrodesis) in a functional position to facilitate and restore functional tasks.

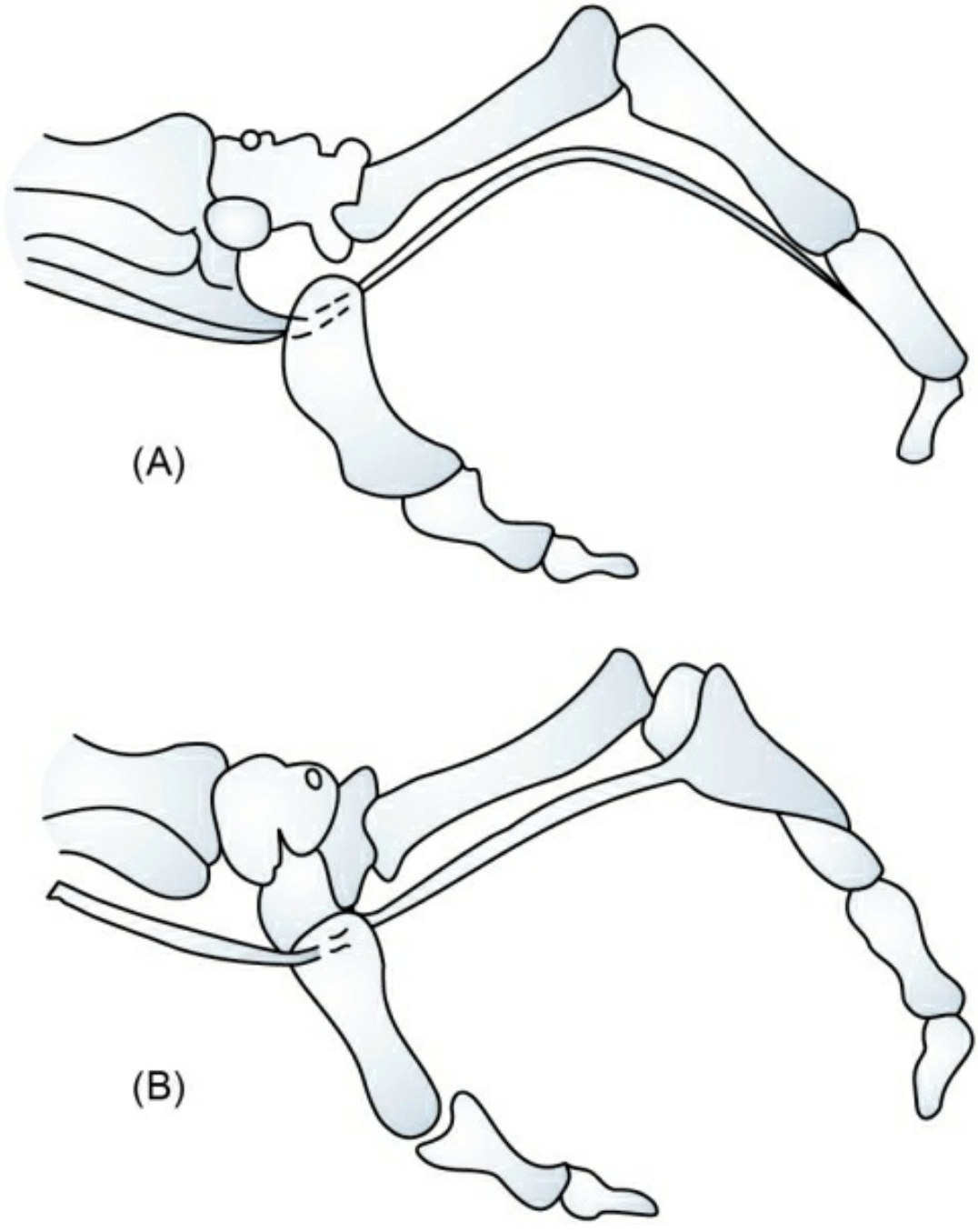

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FIG. 27-17 Bunnell's sublimis tendon transfer operation. **(A)** Preoperative position of flexor digitorum sublimis as flexor of the MP and PIP joints. **(B)** Postoperative position after rerouting and attaching it to the dorsal expansion to facilitate flexion at MP and extension at PIP and DIP joints.

Common tendon transfer procedures

1. To restore elbow extension (in high radial/nerve lesion):

   a. Pectoralis major or latissimus transfer to triceps.

   b. Gradual release of contracted biceps brachii assisted by gravity brings about controlled elbow extension, for functional purposes, when the innervation of biceps brachii is intact.

2. To restore wrist extension: Pronator teres supplied by the median nerve is transferred to the extensor carpi radialis longus and brevis (in a radial nerve lesion).

3. To restore finger extension at the MP joints: Flexor carpi ulnaris is divided into four or five slips and transferred dorsally into four fingers (radial nerve lesion between the spiral groove and the lateral epicondyle).

4a. To restore thumb extension and abduction: The palmaris longus (supplied by the median nerve) is transferred to the extensor pollicis longus or abductor pollicis longus. Alternatively, the pronator teres can also be used (in radial nerve lesion).

4b. To restore thumb opposition: Transfer of flexor digitorum sublimes or extensor indicis to abductor pollicis brevis.

5. To correct ulnar claw hand (Boyle's procedure): The tendons of the flexor digitorum sublimis are transferred to the extensors (e.g., in Hansen disease) (Fig. 27-14).

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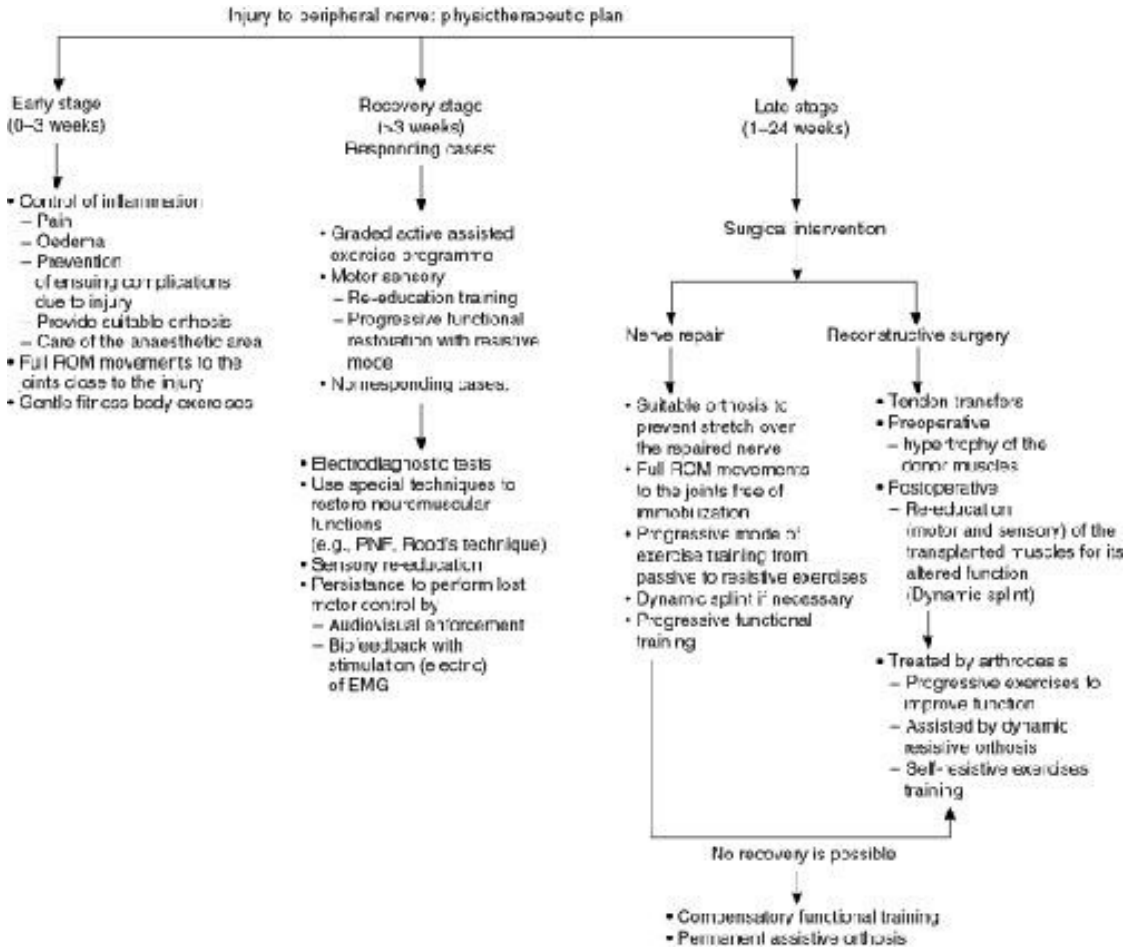
6. To correct foot drop (in lateral popliteal nerve palsy): The muscle tibialis posterior is transferred to the dorsum of the foot.

Physiotherapy management (flowchart 27-1, table 27-10)

Physiotherapy has a most significant role in the management of all the types of peripheral nerve lesions:



FLOWCHART 27-1 Stagewise principles of physiotherapy following injury to the peripheral nerve

Table 27-10

General Plan of Physiotherapy at Various Periods Following Peripheral Nerve Injury

	Patients Treated with

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Patients Treated with Conservative Approach	Surgical Approach
• 0–3 weeks • To assist in confirming the diagnosis • Control of pain, oedema • Measures to prevent possible complications due to injury • Provide suitable orthosis • Care of the anapestic area • Full ROM progressive movements to the unaffected muscles and joints adjacent to the injured nerve • Efforts to initiate small range active contractions in the paralysed muscles with orthosis on	• Nerve repair (0–3 weeks) During immobilization: • Control pain and oedema • Static orthosis to prevent stretch on the repaired nerve • Encourage self-attempted contractions in the muscle group innervated by the injured nerve • Full ROM movements to the adjacent joints and precisely graduated relaxed passive/assisted movements to the affected muscles (by 10 days)
• 3 weeks onwards Confirm neuronal damage by using electrodiagnostic tests • Repeating motor and sensory evaluation and comparing it to the baseline records • Replace static splint with a dynamic orthosis • Motor and sensory re-education • Maximize patients active efforts with: audiovisual re-enforcement • Neuromuscular techniques like PNF, Rood's technique, electrical stimulation or EMG assisted biofeedback • Maximize efforts to perform functional activities • Late stage (18–24 weeks)	Mobilization: 3–6 weeks • Electrodiagnostic tests to apprise status of repaired nerve • Maximize sensory and motor re-education • Special exercise techniques • Audiovisual or EMG biofeedback • Maximize functional training with or without orthosis • Treat with reconstructive procedures • Preoperative sessions of strengthening donor muscles groups • Re-education of the transplanted muscle to perform new role of action with self-efforts or actively assisted guidance • Progressive resistive functional training
Patients with irreversible neural damage • Prepare patients to perform functions by compensatory methods: muscular hypertrophy of the associated muscle groups to compensate for the paralysed muscles, e.g., long head of biceps to compensate deltoid action; altered body mechanics to perform function (e.g., trunk deviation to the opposite side to facilitate shoulder abduction with	

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synchronized shoulder girdle elevation)	

During early stage (first 3 weeks)

1. Control of pain:

- Relaxed totally supported positioning of the affected limb with a suitable orthosis
- TENS over area nearest to the intact sensorium
- Recommended standard orthoses:

o Brachial plexus injury – aeroplane splint

o Injury to the axillary nerve – shoulder abduction splint

- Radial nerve injury – static cock-up splint
- Ulnar nerve – strapping fingers together by a loose rubber strap – to assist passive finger adduction and resistance to abduction
- Median nerve injury – static-to-dynamic knuckle bender orthosis
- Opponens assisting static or dynamic orthoses
- For grasp and release – dynamic wrist assisted orthosis with arrangement to lock wrist in flexion and extension (to assist tenodesis effect)
- Common peroneal nerve injury – BK arthrosis

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- Dynamic toe pickup orthosis

2. To control oedema

- Limb elevation with supportive orthosis
- Repetitive active, assisted or passive full ROM movements to the distal joints
- Gentle effleurage
- Compressive elastic bandage

3. Assist in early detection of possible nerve injury, and the prevention of expected complications due to injury or due to treatment (e.g., tight POP), or skeletal pin traction, or accidental nerve injury during surgery, or due to altered sensorium (anaesthetic areas).

- Identifications of paretic and/or paralysed muscles and baseline motor and sensory evaluation.
- Mapping the areas of paraesthesia and its protection when present. The patient should be instructed thoroughly how to protect these areas.

Three weeks onwards (recovery stage)

- Confirm the neural damage by electrodiagnostic tests and clinical tests like Tinel's sign to apprise status and the prognosis of recovery.
- MMT and the areas of sensory impairment re-evaluated and compared to the baseline data.
- Stretch fully the adjacent joints to the injury, to ensure full ROM.

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- Techniques of assisting active efforts to the paretic muscles or paralysed muscles is promoted through audiovisual of patients efforts and techniques like PNF, using stretch reflex or biofeed by electrical stimulation of EMG.

- Efforts to achieve isometric contraction and sustaining efforts should be guided.

- Possible functional education with or without orthosis should be encouraged.

- Techniques of sensory re-education and motor control should be regularly attempted.

Late stage

- Alternate route of guiding a patient to facilitate functional tasks like:

- Hypertrophy of the muscle groups which can compensate for the permanently paralysed muscles (e.g., use of the long head of biceps to achieve shoulder abduction in the absence of deltoid).

- Static or dynamic orthosis to assist stabilizing the joint (static opponens splint) for functional use.

- Cock-up splint with locking system to lock in extension for a stronger grip or release.

- Altering the biomechanics of the body to assist functional activity (e.g., shoulder girdle elevation synchronized with trunk lateral flexion to the opposite side to facilitate elbow, wrist and hand function in the absence of shoulder abduction).

Remember

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Our body is exceptionally good in acquiring compensatory mechanisms. Study the patient's own efforts in performing functions and guide them.

Injuries to the major peripheral nerves

- Median nerve
- Ulnar nerve
- Radial nerve
- Femoral nerve
- Obturator nerve
- Sciatic nerve
- Common peroneal nerve (lateral popliteal and the posterior tibial (medial popliteal) nerve

Median nerve (nerve roots C5–T1)

- A mixed nerve derived from the C5 to T1 nerve roots via medial and lateral cords of the brachial plexus.
- Common sites of injury – a sharp cut close to the wrist and cubital fossa.

Sites of lesion, clinical features and causes of injury of the median nerve are depicted in Table 27-11.

Table 27-11
Site of Lesion, Clinical Features and Causes of Median Nerve Injuries

Common Site of

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Lesion	Motor and Sensory Innervation (Clinical Features)	Cause of Injury
• In the arm (above elbow)	Motor loss: All the muscles innervated by the median nerve in the forearm and hand; sensory loss: thumb, index finger and radial half of ring finger	Rare site of injury
• Forearm (close to elbow)	Pronator teres, palmaris longus, flexor carpi radialis and flexor digitorum superficialis	Rare injury, if occurs usually cut due to sharp object • Cut injury with a sharp object • Supracondylar fracture • Elbow dislocation
• Distal to pronator teres, as anterior interosseous nerve • Proximal to the wrist carpal tunnel • Distal to the wrist in the hand (commonest site of injury)	• Motor loss flexor pollicis longus, flexor digitorum profundus I and II and pronator qudratus • Sensory: palmar cutaneous • Motor loss: abductor pollicis brevis, flexor pollicis brevis, opponens pollicis, lumbricals I and II sensory Digital (1, 2, 3 and half of 4th digit)	• Cut injury with a glass or a sharp piercing object like knife • Compressive neuropathy (carpal tunnel syndrome)

Notes: Major motor and sensory innervation: except flexor carpi ulnaris, forearm flexors pronators, terminal phalanges flexors and thenar muscles; sensory: lateral aspect of the palm and the dorsal surface of the terminal phalanges along with the palmar surface of 1, 2, 3 and half of the ring finger.Most reliable test to diagnose median nerve lesion: the intact function of the abductor pollicis brevis, as there is always a chance of variation in the remaining two muscles of the thenar eminence – opponens pollicis and the flexor pollicis brevis.

Anatomy

Course and innervation (Fig. 27-18)**:** In the arm, it runs close to the brachial artery and has no supply. It enters the forearm between the two heads of the pronator teres, supplies the pronator teres and gives branches to the palmaris longus, flexor carpi radialis and flexor digitorum superficialis. Then it gives a muscular branch to the anterior interosseous nerve which supplies the flexor digitorum profundus I and II, flexor pollicis longus and pronator quadratus. Proximal to the carpal tunnel, it gives a sensory branch, palmar cutaneous, supplying the thenar eminence, descends down and passes through the carpal tunnel. In the hand, it supplies the abductor pollicis brevis, flexor pollicis brevis, opponens pollicis, lumbricals I

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and II and digital to 1, 2, 3 and the half of the fourth digit.

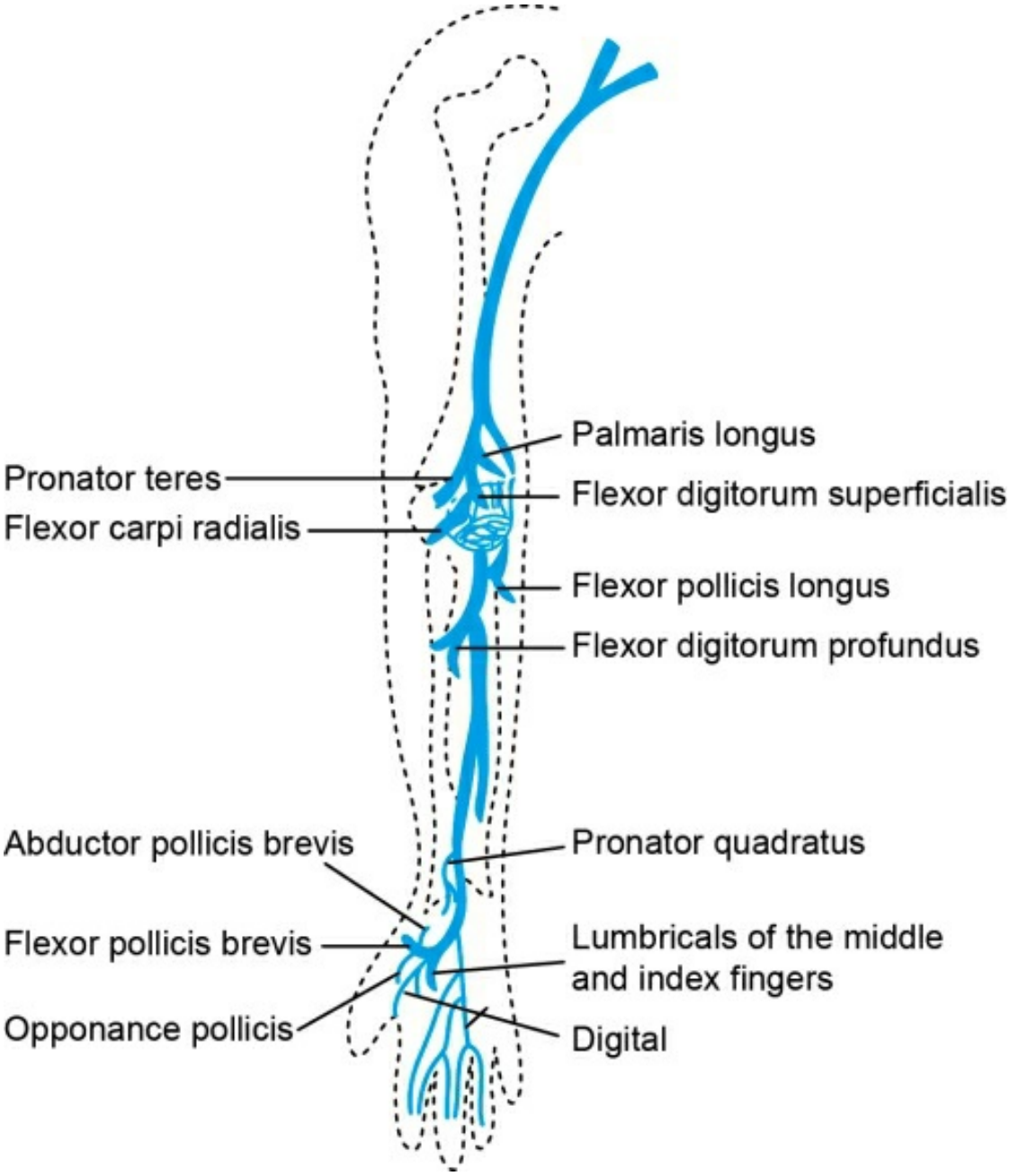

FIG. 27-18 Median nerve (C5–T1 nerve roots): course and innervation.

Deformities: *Ape thumb* – there is wasting of thenar muscles and the thumb lies adducted and in the plane of the palm of hand (Fig. 27-19). *Simian hand* – in this deformity, the plane of the thumb is much more

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in line with the palm, with wasting of the thenar and hypothenar muscles. This deformity, therefore, occurs due to combined median and ulnar nerve palsy.

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FIG. 27-19 **(A)** Median nerve palsy, note the wasting of the thenar muscles and the thumb lying in the plane of the palm (ape thumb). **(B)** Normal hand, note the position of the thumb which lies at right angle to the palm.

Treatment

- Fresh injuries are treated by nerve repair.
- Chronic injuries require excision of neuroma followed by nerve grafting.

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■ In injuries beyond repair, tendon transfer procedures are performed to improve function. Brand's opponensplasty is done using the tendon of the flexor digitorum sublimis of the ring finger in median nerve palsy to restore opposition of the thumb (Fig. 27-20).

FIG. 27-22 Phalen's test in the diagnosis of carpal tunnel syndrome. The position of wrist when kept for 60 seconds precipitates symptoms on the affected side.

In Simian hand, opponensplasty is done using the tendon of the extensor indicis proprius to restore opposition (Fig. 27-21).

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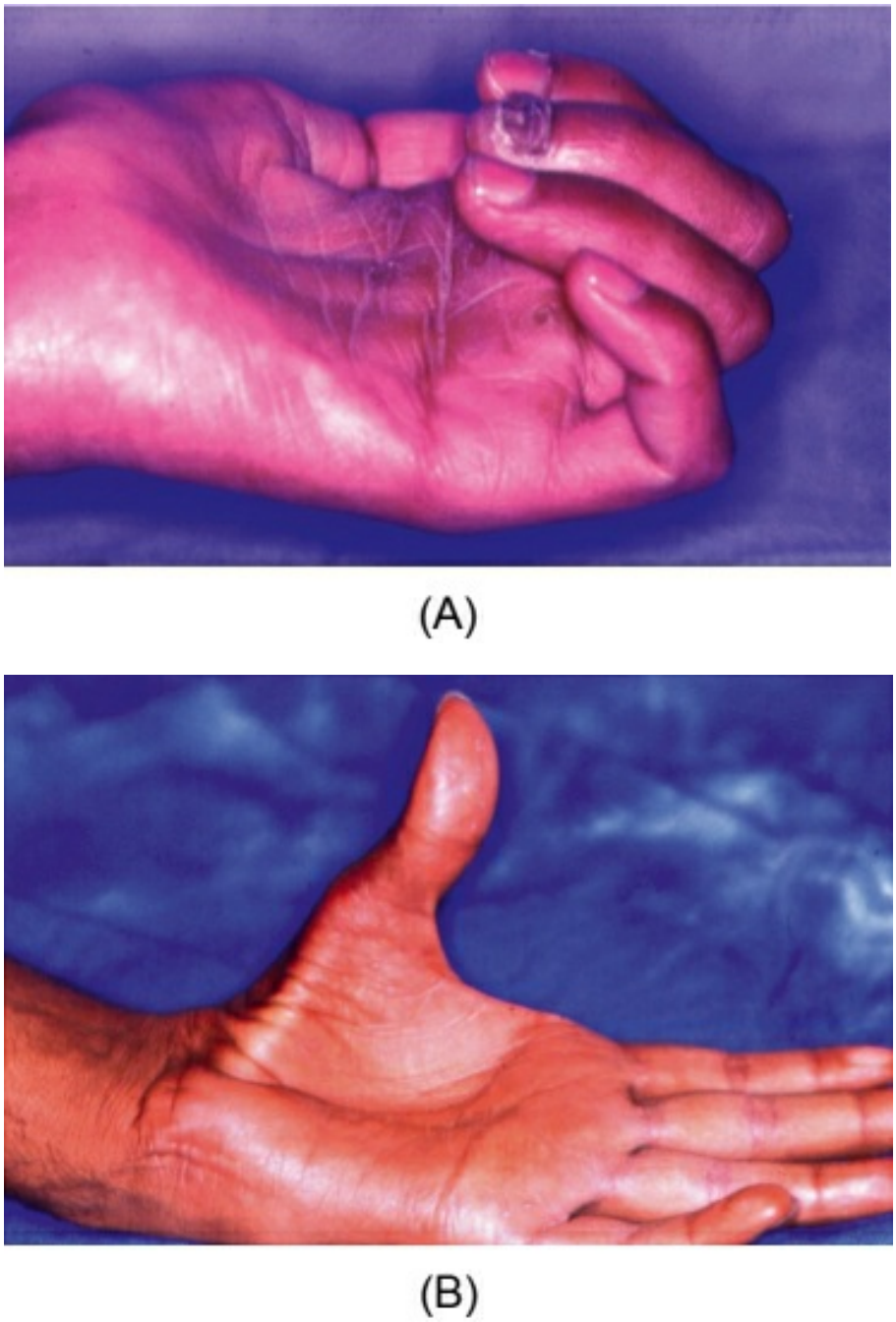

FIG. 27-21 Tendon transfer. (A) Ape thumb deformity due to median nerve paralysis. (B) Opponensplasty performed using the tendon of extensor indicis proprius (EIP). Note the active tendon causing abduction of the thumb.

Compressive lesions of the median nerve

Carpal tunnel syndrome

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Carpal tunnel is the overcrowded fibro-osseous canal formed between three carpal bones (scaphoid, trapezoid and hamate) and the transverse carpal ligament. The median nerve and the nine tendons of the digital flexors pass through this 2–2.5 cm tunnel. Therefore, any bony or soft-tissue pathology to it precipitates compressive forces over the median nerve passing through it.

Aetiology

- Occupational overuse of wrist joint, e.g., computer keyboards
- Malunited Colles' fracture, rheumatoid or osteoarthritis
- Ganglia or haematoma at the wrist
- Connective tissue disorders (amyloidosis)
- Endocrine disorders like DM, hypothyroidism, menopause
- Metabolic causes like gout
- Growth hormone abnormality (acromegaly)
- Pregnancy

Clinical features

- Pain and discomfort at the wrist during movements or even at rest.
- Burning, aching, warmth, paraesthesia in the hand and wrist in the distribution of the median nerve (tingling, numbness or burning sensation); relieved by shaking hands.
- Vasomotor symptoms like swelling, cold, dry and shiny skin.
- Motor weakness of opponens, flexor pollicis brevis results in difficulty in making circle with thumb and index finger. Bottle sign – poor contact of thumb and index finger due to the paralysis of

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abductor pollicis brevis, causing difficulties in gripping a cylindrical object, e.g., bottle or cylinder.

- Loss of true opposition.
- Late stage muscular atrophy – thenar muscles of the hand (clinical tests: Figs 27-4–27-10).

Symptom provocative motor tests

1. Phalen's Test (Phalen, 1966)

Static holding of the wrist in extreme flexion or extension. Positive sign is the appearance of sensory symptoms by 1 min of the hold (Fig. 27-22).

2. Modified Phalen's Test

Forceful flexion of the thumb and the fingers with wrist held in acute flexion for 1 min or more leads to sensory symptoms of tingling, numbness or burning in the hand (Smith et al., 1977).

3. Reverse Phalen's test (Werner et al., 1994)

Wrists as well as the fingers are held in the position of extreme extension. The sensory symptoms begin to appear by 1 min.

4. Tourniquet sign

When the arm cuff of the BP instrument is inflated beyond the level of systolic BP of an individual, the sensory symptoms appear in the distribution of the median nerve.

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5. Bilateral arm percussion test

The sensory symptoms in the innervated area of the median nerve appear on applying equal pressure on the medial side of the palm just about the wrist (over the carpal tunnel area).

6. Vibratory test

Application of a tuning fork of 256 cps over the same area results in appearance of symptoms. Slowing of the conduction of the CNV can diagnose median nerve lesions even before the clinical symptoms.

Treatment

Conservative

- Treatment of the relevant causative factor which has precipitated the syndrome.
- A simple splint that blocks movements at the wrist is adequate to avoid compressive stretches to the carpal tunnel.
- Nonsteroidal anti-inflammatory drug (NSAID) agents
- Local ultrasonic exposure
- Pain-free relaxed passive or speedy active movements are encouraged in the pain-free range by removing the splint.
- Cryotherapy, TENS over the palmar aspect of the wrist may be tried.
- Local corticosteroid injection may be given only after confirming the absence of sensory deficit.

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Surgical

Surgical release of the median nerve may have to be undertaken by the division of the carpal flexor retinaculum and/or transverse carpal ligament either by open surgery (Fig. 27-23) or by endoscopic surgery.

FIG. 27-23 Operative photograph of carpal tunnel release. There is visible constriction of the median nerve, after division of the volar carpal ligament (ligament not seen in the picture).

Anterior interosseous syndrome

Rare pain in the forearm and elbow because the sensory fibres from the wrist and the carpal bones travel in the anterior nerve.

Identifying signs

- Muscles of innervation:
- Flexor pollicis longus

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- Flexor digitorum profundus I and II
- Pronator quadratus
- Functional difficulty in using hand like picking up a cup, tearing a paper, using spoon and fork.
- Motor weakness – performing forearm pronation against resistance.

Ulnar nerve (nerve roots C8–T1)

It is derived from the medial cord of the brachial plexus. It descends medially in the arm close to the brachial artery and the median nerve. It does not give branches. At the elbow, it lies in the condylar groove and enters the cubital tunnel, gives branches to the flexor digitorum profundus III and IV, and flexor carpi ulnaris. At the wrist, it passes between the pisiform bone and the hook of hamate through Guyon's canal, gives the superficial sensory and the deep peroneal motor branch. The sensory branch supplies the ulnar half of the fourth and the whole of the fifth digit. The deep motor branch supplies the hypothenar muscles (opponens digiti minimi, abductor digiti minimi and flexor digiti minimi). Then it deviates to the lateral aspect of the hand, supplying the muscles, adductor pollicis, interossei, 3rd and 4th lumbricals.

It has two other sensory branches supplying to the hand (palmar and dorsal cutaneous branch) arising from the distal forearm but which do not pass through the Guyon's canal.

Course and the branches of the ulnar nerve (Fig. 27-24, Table 27-12):

Deformity Deformities due to the lesion of the ulnar nerve

- 'Main-en-griffe' or *ulnar claw hand* – It results in hyperextension at the MP joints due to the paralysis of lumbricals (lateral two) and unopposed action of the

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extensor digitorum communis, whereas intact long flexors produces flexion at both the IP joints of the ring and the little finger (Fig. 27-18).

- The medial claw hand – the deformity is similar to the ulnar claw hand but instead of the ring and the little fingers, the clawing appears at the index and the middle (Fig. 27-19B).

- The true claw hand: A combined lesion of both the ulnar and the median nerve results in a true hand, where the clawing is present in all the four fingers (Fig. 27-19C) (e.g., Hansen, disease, VIC, PPRP, progressive muscular dystrophy, peripheral neuritis).

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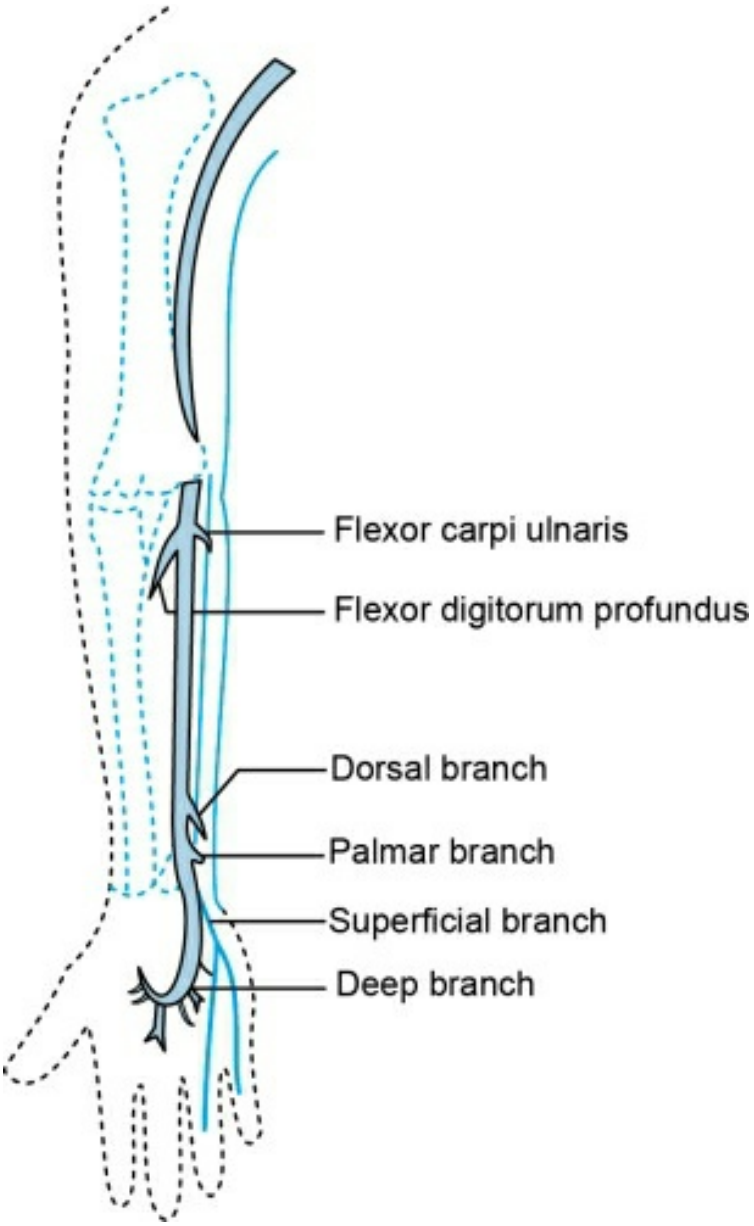

FIG. 27-24 Ulnar nerve (course and innervation).

Table 27-12

Areawise Local Causes of Lesions of the Ulna Nerve

Site of Lesion	Causes
In the axilla	• Constant crutch pressure • Axillary vessel aneurysm in the axilla • Sharp cut injury
In the arm	• Fracture of the humeral shaft

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	• Penetrating injuries like gunshot
At the elbow	• Fracture of the lateral epicondyle of humerus • Repetitive occupational stress (overuse) • Recurrent subluxation of the nerve • Compression by the osteophytes as in RA and OA or by an accessory muscle • Anserina epitrochlearis • Cubitus valgus due to repetitive friction (tardy ulnar nerve palsy)
At the forearm	• Fracture of both bones of the forearm • Penetrating wounds of the forearm
At the wrist	• Compression by the osteophytes • Fracture of the hook of hamate • Compression by ganglion • Injuries to the wrist
At the hand	• Blunt trauma • Penetrating injuries • Operation of high-speed drill on hard surfaces • Associated ulnar artery aneurysm

Ulnar Nerve: the Level of Lesion and the Respective Lost or Spared Function

Site of Lesion	Function Spared or Lost
Above the elbow	All the functions are lost
At the junction of middle and lower third of the forearm	• Spared: FDP and FCU • Lost: motor HTM, INT, LUMB and PB • Sensory: hand over the dorsal aspect
Proximal to Guyon's canal	• Spared: FDP, FCU dorsal sensation • Lost: Valor sensation same as earlier
Distal to Guyon's canal	• Spared: FDP, FCU, HTM, PB and dorsal and valor sensation • Lost: INT and LUMB

Notes: FCU, flexor carpi ulna; FDP, flexor digitrum prefunds; HTM, hyposthenia muscle; INT, interpose; LUMB, lumbricals; PB, palmaris bravis.

Clinical tests for ulnar nerve injury

Froment's sign: The patient is asked to hold a book between the thumb and the other fingers. Coordinated, combined action of these muscles – first palmar interosseous, adductor pollicis and flexor pollicis longus – is required. In ulnar nerve lesion, the first two muscles are paralysed; thus, the patient has to depend only on the flexor pollicis longus which mainly flexes the thumb proximally ; this confirms the lesion (Fig. 27-9).

Card test (a test for palmar interossei): Inability to hold a card or

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paper in between the fingers due to a loss of adduction of the fingers which is performed by the palmar interossei (Fig. 27-7).

Egawa test (a test for dorsal interossei): With palm resting on the table, the patient is asked to move the middle finger sideways towards the index finger held passively in abduction (Fig. 27-8).

Ulnar paradox

The higher the lesion of the median and the ulnar nerve injury, the less prominent is the deformity and vice versa. This happens because in higher lesions, the long finger flexors are paralysed; the loss of finger flexion makes the deformity obvious.

The extent of clawing appears less in spite of the higher level of lesion as a result of the paralysis of the flexor digitorum profundus.

- Functional inabilities due to the claw hand:
- Weak grip due to the weak MP flexion.
- Inability to produce activities like pinching due to the paralysis of interossei.
- Weakness of grasp and the action of finger rolling.

Treatment

- Knuckle bender arthosis to block the hyperextension at MP joints automatically keeps fingers extended.
- Functional training with orthosis

Nonrecoverable lesions

- Tendon transfers: To correct claw hand (Bunnell's operation)
- Wrist stabilization by arthrodesis in 15-degree extension, or

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capsulodesis.

Compressive lesions of the ulnar nerve

■ Tardy ulnar nerve palsy (Fig. 27-25):

The major cause is the repetitive friction or compression of the ulnar nerve in the cubital tunnel in situations like the following:

■ Cubitus valgus deformity

■ Tension over the supracondylar grove or cubital tunnel or repetitive friction due to overuse, e.g., postmedial or lateral epicondyle fracture (malunion), excessive callus formation, Hansen disease and ganglia.

FIG. 27-25 Claw hand deformity due to ulnar nerve injury.

Clinical features

Motor paralysis of the muscles supplied by the ulnar nerve, sensory tingling and numbness in the 4th and 5th fingers with wasting,

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proximally radiating pain.

Diagnostic motor test: The elbow joints are held in complete flexion with the wrists extended fully. In a positive test, by 3 min, the symptoms of pain, tingling and pins and needles begin to appear in the distribution of the ulnar nerve, which disappear on extending the elbows.

Treatment

- NSAID, rest with elbows in extension
- Local US exposure and orthosis
- Release of entrapment by medial epicondylectomy
- Anterior transposition of the ulnar nerve

Claw hand

Claw hand presents as a typical deformity with hyperextension of the metacarpophalangeal joints and flexion of the interphalangeal joints.

The involvement depends upon which of the two nerves is damaged.

When the ulnar nerve is damaged, it will result in isolated ulnar claw hand involving the fingers supplied by the ulnar nerve (e.g., ring and small finger; Fig. 27-25).

Whereas, when the lesion occurs in the median nerve, it will result in median claw hand with clawing present in the index and the middle finger only.

When a combined lesion of both the ulnar and the median nerve occurs, the result will be a 'true claw hand' involving all the four fingers of the hand with an ape thumb deformity where the thumb lies in the plane of the palm (Fig. 27-20).

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FIG. 27-20 Intraoperative photograph of Brand's opponensplasty. FDS tendon of the ring finger harvested through a small incision in the palm, routed through a pulley made of a half tendon of FCU at the wrist, tunnelled subcutaneously and inserted at the level of MCP joint of the thumb.

Clinical features

Hyperextension at the MP joint is most disabling, resulting in the following:

- Fingers lose the stabilizing effect, resulting in a weather grasp,

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pinch, as well as grip.

- There is a loss of sensation on the skin along the distribution of the involved peripheral nerve.
- Wasting and weakness of the intrinsic muscles of the hand, resulting in wasting (hollowing) at the intermetacarpal spaces on the dorsum of the hand.
- Wasting of the thenar and hypothenar muscles.

Treatment

The treatment is centred on controlling the hyperextension at the MP joints, to facilitate the functions of the finger movements. Active method is by surgically transferring the tendon whenever it fulfils all the required criteria.

Radial nerve (C5–T1 nerve roots)

Radial nerve is the continuation of the posterior cord of the brachial plexus. In the upper arm, it supplies the three heads of the triceps muscle and the anchoneus. Then it winds around the shaft of the humerus in the spiral groove; at this level, it gives the sensory posterior antebrachial cutaneous branch. Below the insertion of the deltoid, it is superficial; over the lateral aspect of the arm, it supplies the brachialis, brachioradialis, extensor carpi radialis longus and extensor carpi radialis brevis. At the level of the lateral epicondyle, it lies lateral to the biceps, and enters the forearm between the brachialis and the brachioradialis. In the proximal forearm, it divides into the posterior interosseous and the superficial radial cutaneous branch. The posterior interosseous, supplies the supinator and pierces it. Distal to the supinator, it supplies the extensor digitorum communis, extensor carpi ulnaris, extensor digiti minimi, extensor indicis, extensor pollicis longus, abductor pollicis longus and extensor pollicis brevis. The superficial radial cutaneous nerve descends along the lateral border of the forearm and supplies the dorsum of the hand.

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Course and the innervation of the radial nerve (Fig. 27-26; Table 27-13):

- High lesion above the spiral groove: Total palsy except triceps.
- Low lesion I between spiral groove and the lateral epicondyle: Elbow spared, extensor of wrist, thumb and finger extensors are paralysed.

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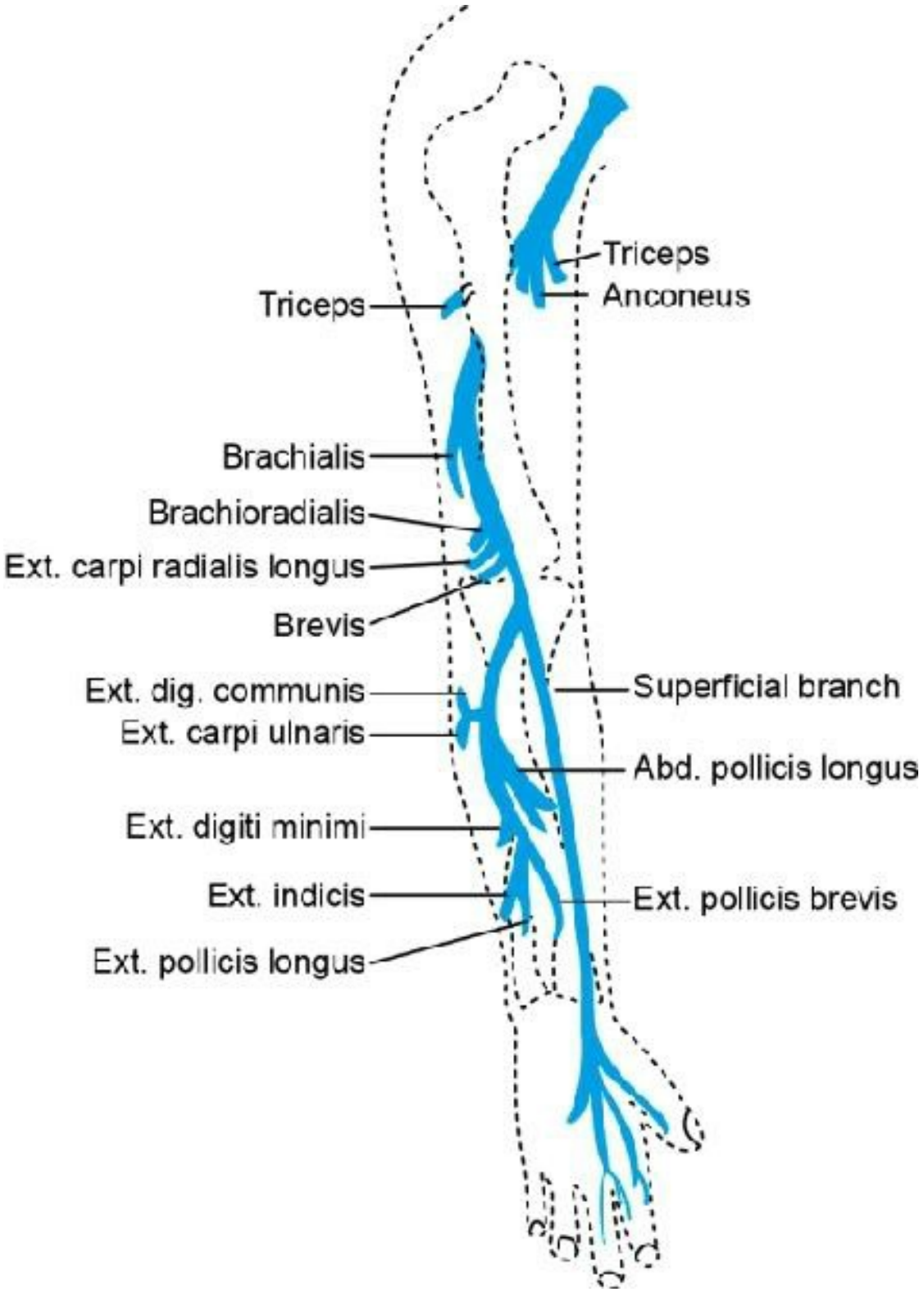

FIG. 27-26 Radial nerve (C5–T1 nerve roots) – course and innervation.

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Table 27-13

Site of Lesions, Innervation and Causes of Injury to the Radial Nerve

Site of Lesion	Motor and Sensory Innervation (Clinical Features)	Cause
• Upper arm • Axilla	Motor • Three heads of triceps and anconeus	• Aneurysm of axillary vessel • Long duration shoulder dislocation • Crutch palsy
• Close to the spiral groove	Motor • Brachialis Sensory: antebrachial posteriors	• Fracture of the midshaft humerus • IM injection • Saturday night palsy • Iatrogenic (excision of the head of the radius) • Surgical positioning (Trendelenburg) • Tourniquet palsy
• Elbow close to the level of lateral epicondyle (cubital fossa)	Motor • Brachioradialis • Extensor carpi radialis longus • Extensor carpi radialis brevis • Supinator	• Dislocation of elbow • Supracondyler fracture • Fracture of the humeral condyles • Cubitus valgus • Fracture of the radial head • Elbow posterior dislocation • Monteggia fracture
• Proximal to forearm: distal to supinator Divides into two: • Posterior interosseous nerve (motor branch) and superficial radial cutaneous (sensory branch)	Motor • Extensor digitorum communis • Extensor carpi ulnaris • Extensor digit minimi • Extensor indicis • Extensor pollicis longus and brevis • Abductor pollicis longus Sensory: Interosseous antibrachii posterior dorsum of first web space	• Fracture of both the bones of forearm • Gunshot or piercing injury • Monteggia fracture

Sensory and Motor Features as Related to the Levels of Lesions in Radial Nerve Injury

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Level of Injury	Features
High level: Above the spiral groove	• Total wrist drop • Sensory loss: Over the dorsum of thumb
Low: Between the spiral groove and the lateral epicondyle	• Spared: Elbow extensors • Lost: Wrist, thumb and finger extensors [a] • Sensory loss: Dorsum of the first web space
Low: Below the elbow	• Spared: Elbow extensors and wrist extensors • Lost: Thumb and finger • Sensory loss: First web space

[a]Misguidance: The dorsal interossei, which are supplied by the ulnar nerve, can actively extend the IP joints as they are inserted into the base of the proximal interphalangeal joints of the first three fingers in the absence of the extensor digitorum due to injury of the radial nerve.

Deformities

- Total wrist drop: Simultaneous extension at the wrist, fingers and the thumb is lost (Fig. 27-26) due to the loss of finger and thumb extensors.

- Hitchhiker's sign: Inability to extend the IP joint of the thumb due to paralysis of the extensor pollicis longus and brevis is the only clinical sign to suspect radial nerve lesion during the early stage of injury.

Treatment

In closed injury

- Cock-up splint, initially static and at the later stage, dynamic.

- Full ROM passive movements to the wrist, fingers and the thumb.

- Progress to active assisted movements, self-effort, Rood's

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technique, EMG biofeedback, or initiating contractions with PNF technique by using stretch reflex.

In open fractures

Nerve repair procedure along with the reduction of a fracture.

- Late or nonrecovered lesions: Surgical procedures like the following:
  - Tendon transfers
  - Wrist joint arthrodesis in the functional position of the wrist

Possible testing error

Remember, intrinsic muscles (dorsal interossei) of the hand are capable of extending the fingers at the interphalangeal joints in the injured radial nerve due to the advantage of their insertion at the base of the proximal phalanges of the first three fingers.

Compressive lesions of the radial nerve

The common sites of compressive lesions could be

1. In the axilla
2. Retrohumeral at the posterior aspect of the humerus (arm)
3. At the proximal forearm
4. At the distal forearm

Lesion in the axilla

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Either due to crutch pressure or during sleep. Crutch palsy, involves triceps and all distal muscles innervated by the radial nerve.

Retrohumeral lesion

A lesion at the posterior aspect close to the spiral groove of the humerus.

- Saturday night palsy – sustained compression due to malpositioning of the arm during deep sleep (common in alcoholics), during general anaesthesia or tourniquet application or wrong IM injection directly on or injuring the nerve may appear late as a result of compression by a callus formation, following fracture of the shaft of humerus.

- Motor weakness – all the extensors of the wrist, fingers and thumb (weakness of supinator and brachioradialis).

- Sensory: Over the dorsum of the thumb.

Lesion at the proximal forearm

- Involves the posterior interosseous nerve.

Motor: weakness of the wrist and MCP joint extensors, extension at the IP joints is preserved as the intrinsics supplied by the median and ulnar nerves are spared.

Lesions at the distal forearm

Superficial cutaneous radial nerve entrapment: A nerve may be entrapped due to compression by a tight cast, a tight band of a wrist watch or a

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handcuff. It results in altered sensorium, over the small area of the dorsum of a thumb web.

Usually a surgical release of the radial nerve at the elbow is indicated.

Treatment

- Static or dynamic cock-up splint
- Full ROM passive movements to the wrist and hand joints
- Educate patient on assisted active movement of wrist, fingers and thumb extension, elbow flexion in supination and forearm supination.
- PNF, biofeedback sessions.

Surgery

When recovery does not take place by 18 weeks, surgical exploration and repair, release or reconstructive procedures is the only alternative.

Peripheral nerves of the lower limb (table 27-14)

The myotomal and the dermatomal innervation of the lower limbs are provided by two plexuses.

1. The lumbar plexus (derived from the anterior rami of the L1–L4 nerve roots).

2. The sacral plexus (derived from the L4–S3 nerve roots) (Fig. 27-27A and B).

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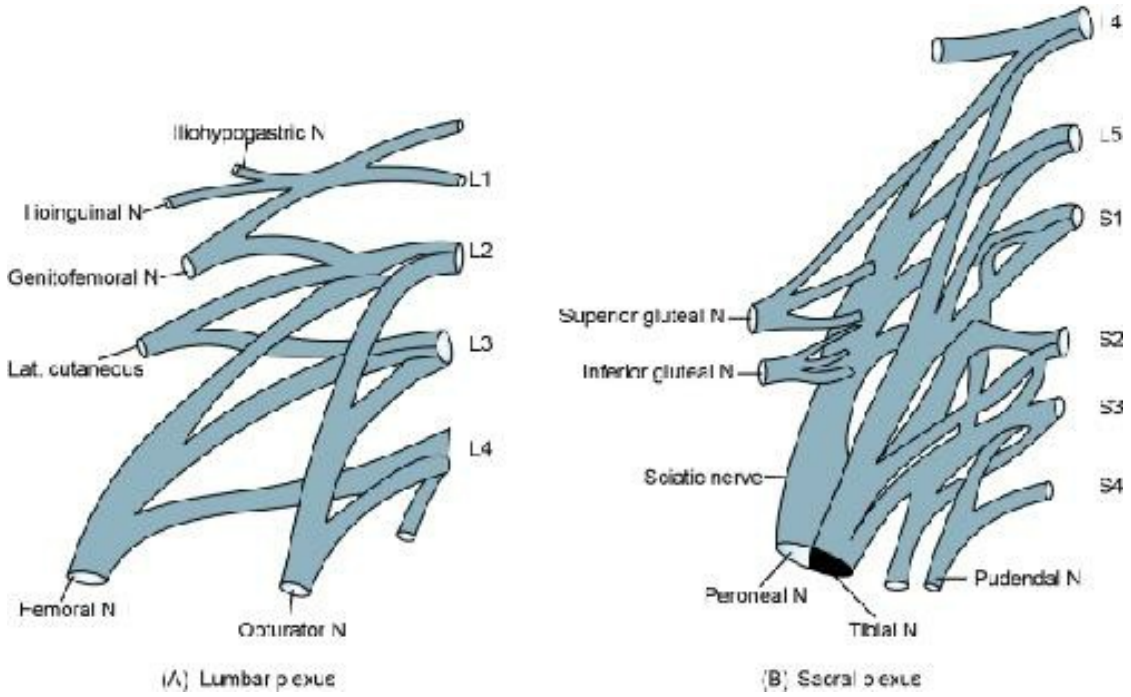

FIG. 27-27 Lumbar and sacral plexuses: **(A)** Lumbar plexus. **(B)** Sacral plexus.

Table 27-14

Lower Extremity Peripheral Nerve Lesions Motor and Sensory Characteristics

Plexus and Peripheral Nerves	Motor Supply	Sensory Supply	Any Other
• Lumbar plexus (L1–L4) • Obturator nerve (L2–L4)	• All adductor muscles of thigh (except adductor magnus which is supplied by sciatic nerve)	• Anterolateral thigh (by lateral cutaneous nerve)	• All PN injuries have general signs and symptoms of pain, tenderness for 1–2 weeks • Followed by wasting over the distribution of the nerve after 2–3 weeks
• Femoral nerve (L2–L4)	• Iliacus, pectinius, psoas, gracilis, sartorius and quadriceps	• Front of the thigh • Medial side of leg and foot	• Positive femoral stretch sign • Absence or loss of knee jerk
• Sacral plexus (L4–S3)			• Deformity: Unstable knee (genu recurvatum at late stage
• Superior gluteal (L4–S1)	• Gluteus medius • Gluteus minimus • Tensor fascia lata	Upper lateral thigh	• Weak or absent knee jerk • Gluteus medius lurch

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• Inferior gluteal (L5–S1)	• Gluteus maximus		• Posterior lurch
• Sciatic nerve (L4–S3)	• Hamstrings • Leg and foot	• Lateral half of leg • Dorsum of the foot and entire sole	• Wasting of thigh, calf and sole of the foot, trophic ulcers or foot drop • Ankle jerk is absent or reduced
• Common peroneal nerve (L4–S2)	• Superficial peroneal branch: • Peroneus longus • Peroneus brevis • Deep peroneal (branch) • Tibialis anterior • Extensor hallucis longus • Extensor dig longus and brevis • Peroneus tertius	• Superficial peroneal: • Front, lateral and posterior leg • Dorsum of the foot leaving extreme medial and lateral strips • Deep peroneal: Small area of skin at the web space between 1st and 2nd digits	• Foot drop • High stepping gait • Toes drag gait
• Posterior tibial nerve (L4–S3)	• Gastroc-soleus • Tibialis posterior • Flexor hallucis longus • Flexor digitorum longus	• Sole of the foot including nail beds and the distal phalanges	• Calcaneus deformity • Calcaneus gait (foot slap) • Later stage: trophic ulcers
• Medial plantar branch	• Flexor digitorum brevis • First lumbrical		
• Lateral plantar branch	• Two, three and fourth lumbricals • Dorsal and plantar interossei • Adductor hallucis	• Sole of the foot	

Lumbar plexus

It gives rise to two major mixed nerves, the femoral and obturator nerves and the purely sensory nerve – lateral femoral cutaneous nerve of the thigh.

Obturator nerve (l2–l4)

It exits the psoas muscle medially and supplies the adductor group of muscles of the thigh.

Femoral nerve (fig. 27-28)

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It is formed by the dorsal portion of the anterior rami of the L2–L4 nerve roots. It descends down and passes between the psoas and the iliacus muscles and lies most laterally in the femoral triangle.

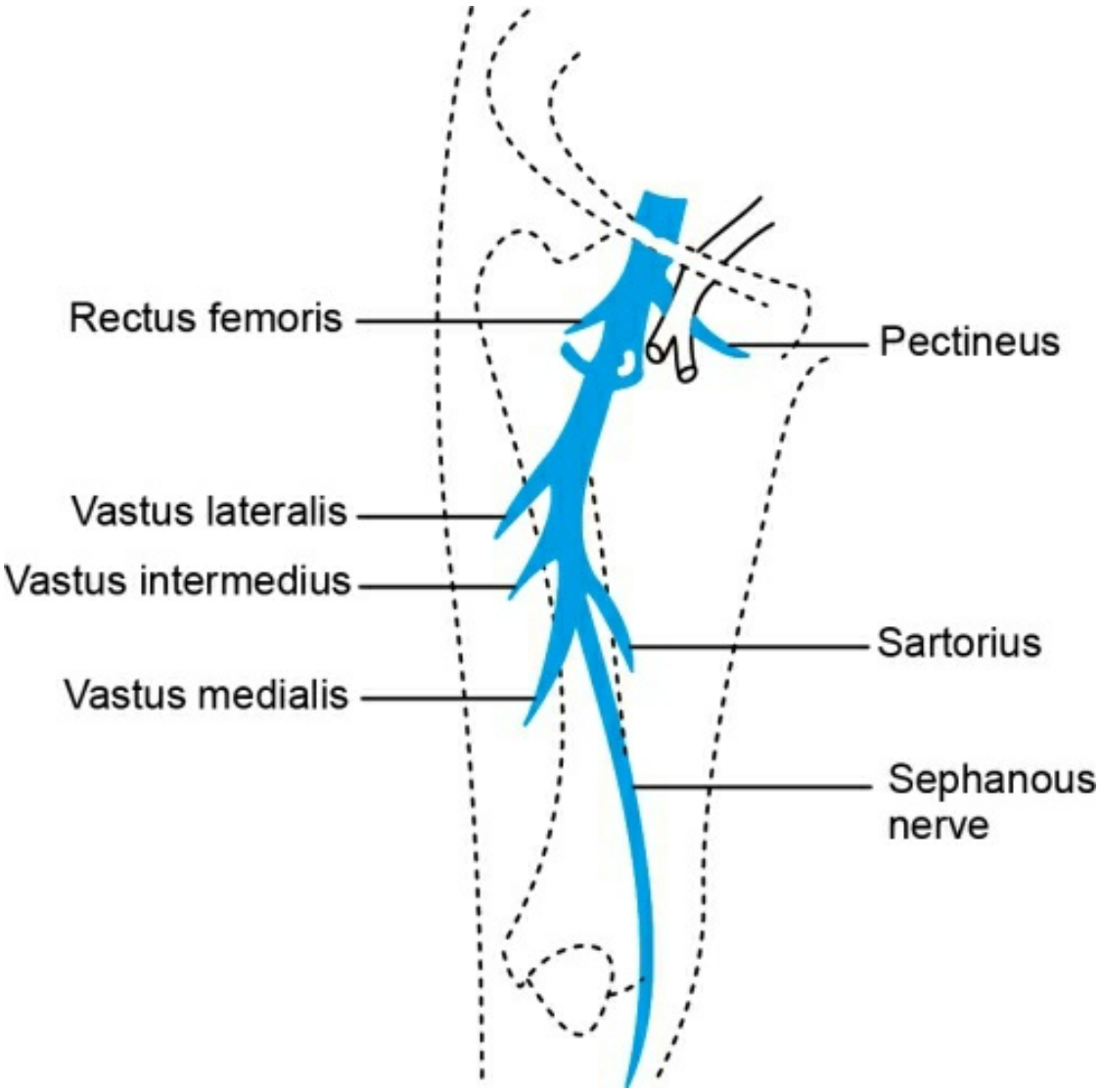

FIG. 27-28 Femoral nerve (course and innervation).

Then it divides into the anterior and posterior divisions. The anterior division supplies the anterior thigh through the intermediate cutaneous branch and the medial thigh through the medial cutaneous branch. The anterior division also supplies to the pectineus and sartorius muscles.

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The posterior division supplies the hip and knee joint, the quadriceps muscle and terminates as a long cutaneous which supplies the skin over the anteromedial aspect of the leg and foot.

In the inguinal canal, it gives the cutaneous branches ilioinguinal, iliohypogastric, genitofemoral and the lateral cutaneous branch.

Sacral plexus

Formed by the L4–S3 nerve roots in front of the sacroiliac joint, it gives two branches:

1. Superior gluteal (L4, L5; S1) innervates the gluteus medius, minimus and tensor fascia lata

2. Inferior gluteal nerve (L5–S1) innervates the gluteus maximus and sciatic nerve (L4, L5; S1–S3)

Sciatic nerve (fig. 27-29)

The longest and thickest nerve in the body, the sciatic nerve innervates important muscle groups of the lower limb. Although strong, it is highly susceptible to injury due to its intrapelvic position.

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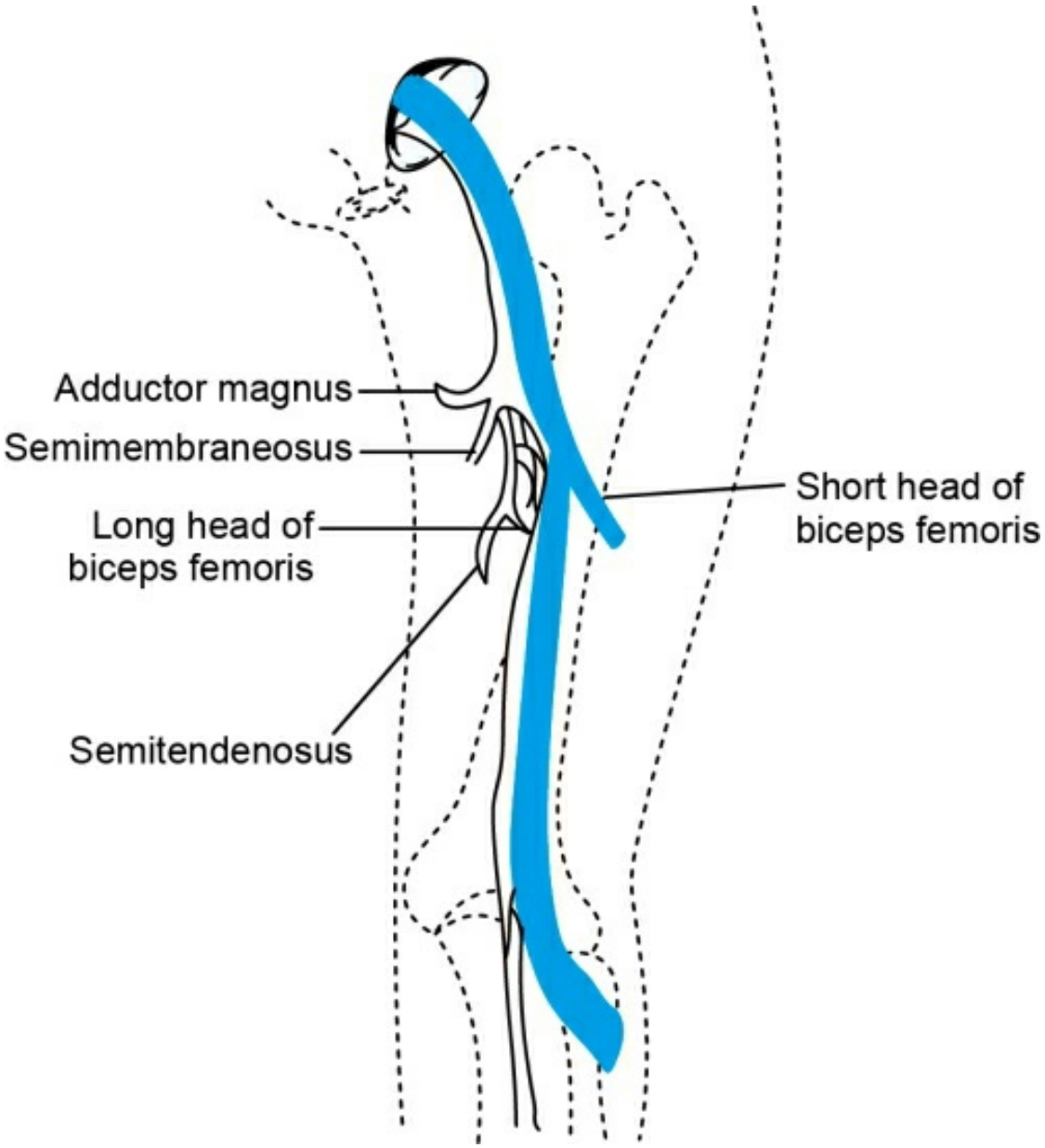

FIG. 27-29 Sciatic nerve (course and innervation).

It emerges out of the pelvis through the sciatic notch along with the superficial gluteal nerve, inferior gluteal nerve and posterior cutaneous nerve of the thigh. In the thigh, it lies at the middle of the posterior aspect of the thigh, a common site of sciatic pain.

The injury to the sciatic nerve may occur due to traumatic or compressive pathology.

Traumatic Causes	Compressive or Stretching (Traction)
• Posterior dislocation of hip joint	• Malpositioning of body

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• Posterior dislocation of hip joint • Fractures around pelvis, hip joint, proximal shaft of femur • Deep surgical incision (e.g., THR) or penetrating injury • Intramuscular injection • Muscular scarring during reduction of hip dislocation following lithotomy position	• Malpositioning of body • Comatose state • Sitting over the edge of hard surface (e.g., bed frame) • Compression due to • Tumour • Lymphoma • Banker cyst • Other causes: • Vasculilis • Thrombosed aneurysm

The proximal lesion of a sciatic nerve in the pelvis or close to the sciatic notch results in:

- Involvement of the gluteal muscles and sensory loss in the distribution at the posterior cutaneous of thigh.
- Weakness of
- Hamstrings
- All the muscles below the knee
- Sensory loss over the leg and foot below knee

Distal lesion

Behind the popliteal fossa, it divides into two branches, the lateral popliteal or common peroneal and the posterior tibial nerve.

Common peroneal nerve (lateral popliteal nerve) (fig. 27-30)

The lateral trunk of the sciatic nerve descends obliquely through the popliteal fossa as a lateral cutaneous branch supplying the anterior, lateral and posterior aspect of the leg, then it winds round the fibular neck where it is most superficial, and therefore, a common site of injury. Then it passes through the fibular tunnel and divides into two branches:

1. Superficial peroneal

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The superficial peroneal innervates the peroneus longus and brevis and provides cutaneous supply to the anterolateral leg and dorsum of the foot.

2. Deep peroneal nerve

The deep peroneal nerve innervates the anterior compartment muscles:

(a) Tibialis anterior

(b) Extensor digitorum longus and brevis

(c) Extensor hallucis longus

(d) Peroneus tertius

The terminal cutaneous branch supplies a small area (web space) between the first and the second toe.

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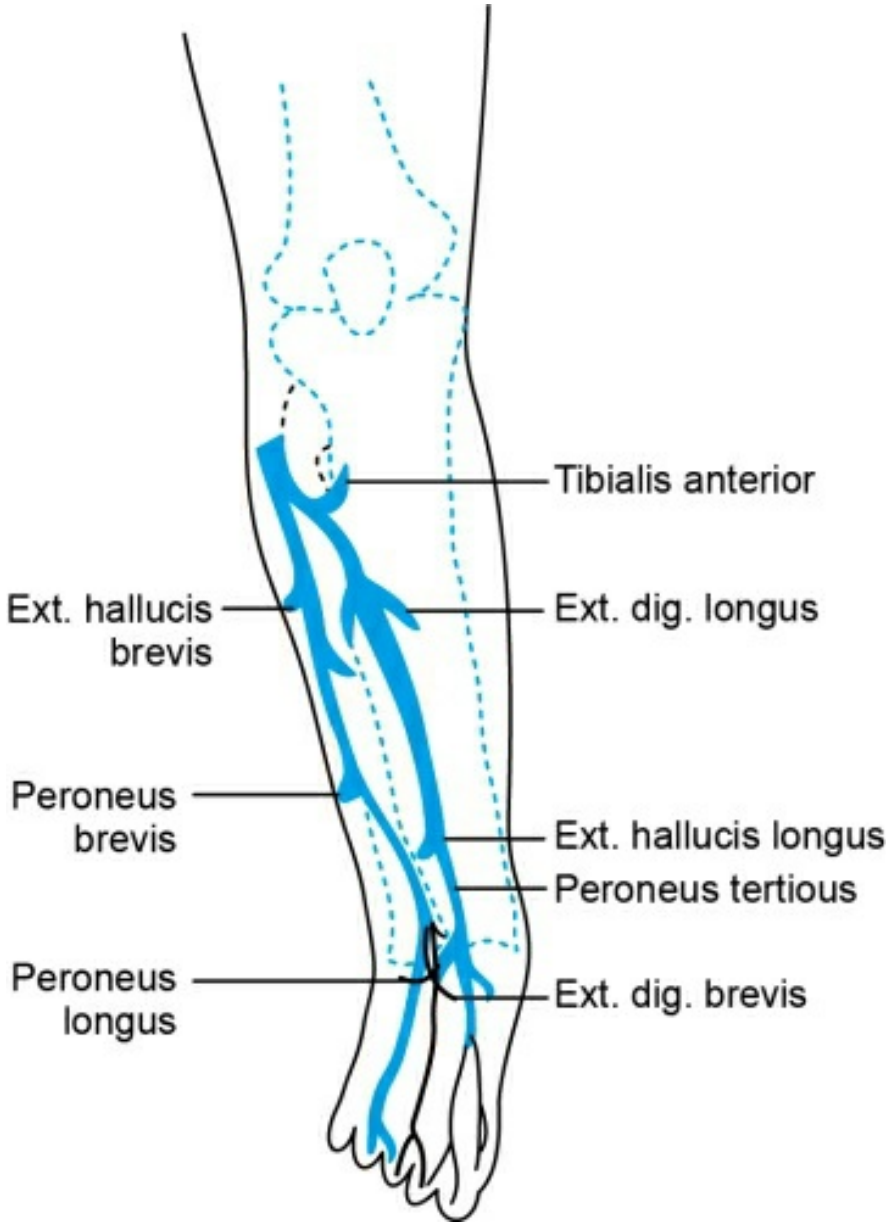

FIG. 27-30 Common peroneal (lateral popliteal) nerve – course and innervation.

Posterior tibial nerve (fig. 27-31)

The medial trunk of the sciatic nerve continues posteriorly below the popliteal fossa as a posterior tibial nerve. It innervates:

- Both heads of the gastrocnemius and the soleus muscles

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- Tibialis posterior, popliteus, flexor digitorum longus and flexor hallucis longus.

- At the ankle under the flexor retinaculum (tarsal tunnel), the posterior tibial nerve divides into the medial and lateral plantar nerves after giving a branch to calcaneum.

- The medial plantar branch innervates the first lumbrical and the lateral plantar branch innervates the second, third and fourth lumbricals. The sensory innervation of the dorsal as well as the plantar surface comes from various cutaneous branches: saphenous, superficial and deep peroneal; medial and lateral plantar nerve, calcaneal and sural nerve.

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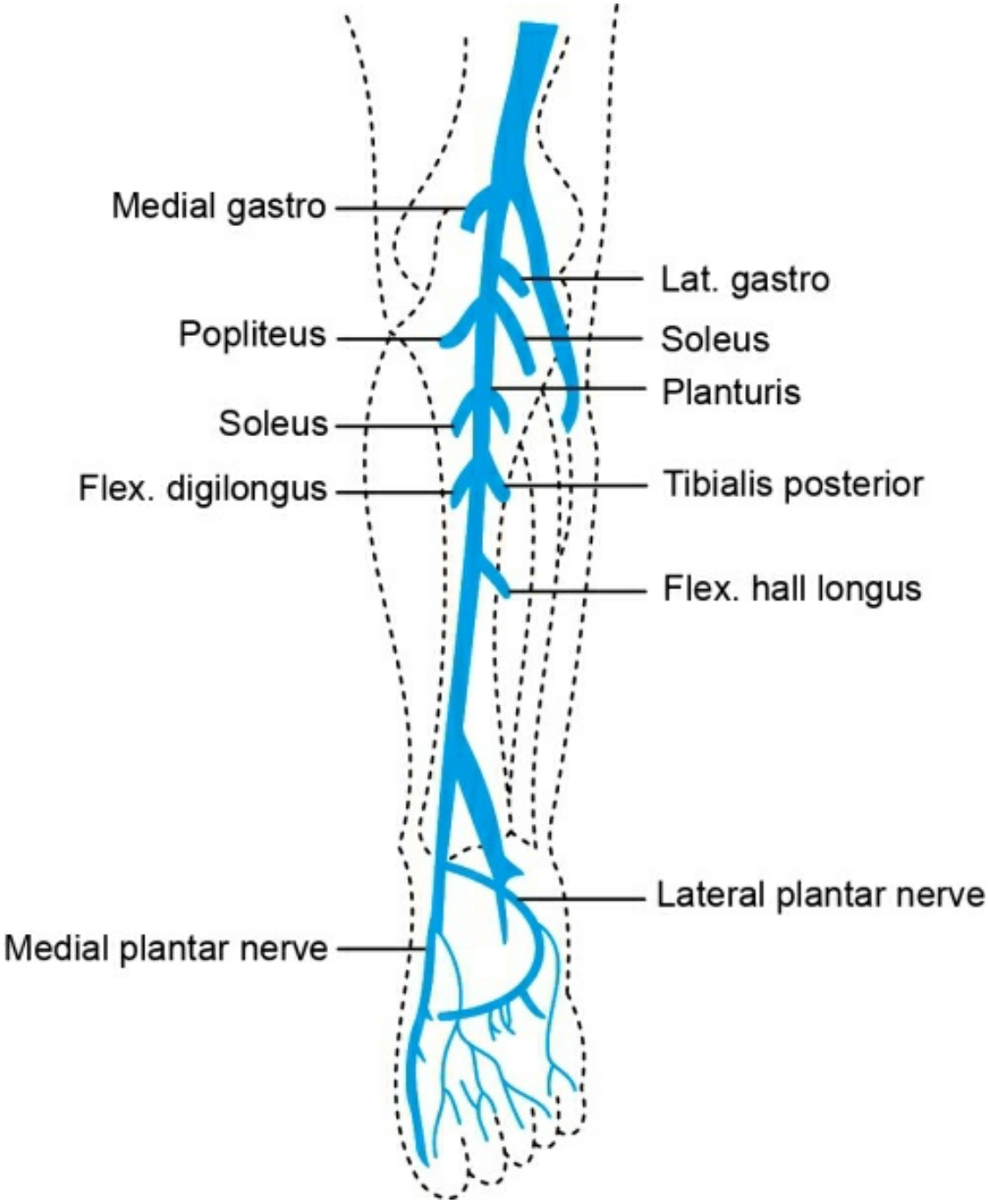

FIG. 27-31 Posterior tibial nerve (course and anterolateral innervation).

Sural nerve

It is purely a sensory nerve from S1 to S2 roots. It is formed by the joining together of two branches, the medial branch is derived from

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the tibial and the lateral branch from the peroneal nerve.

Being deep, it is rarely injured. It may be compressed by Baker cyst, scar tissue following fractured fifth metatarsal, ganglia, etc.

It innervates the posterolateral aspect of the distal leg, a small strip over the lateral-most foot (Fig. 27-32).

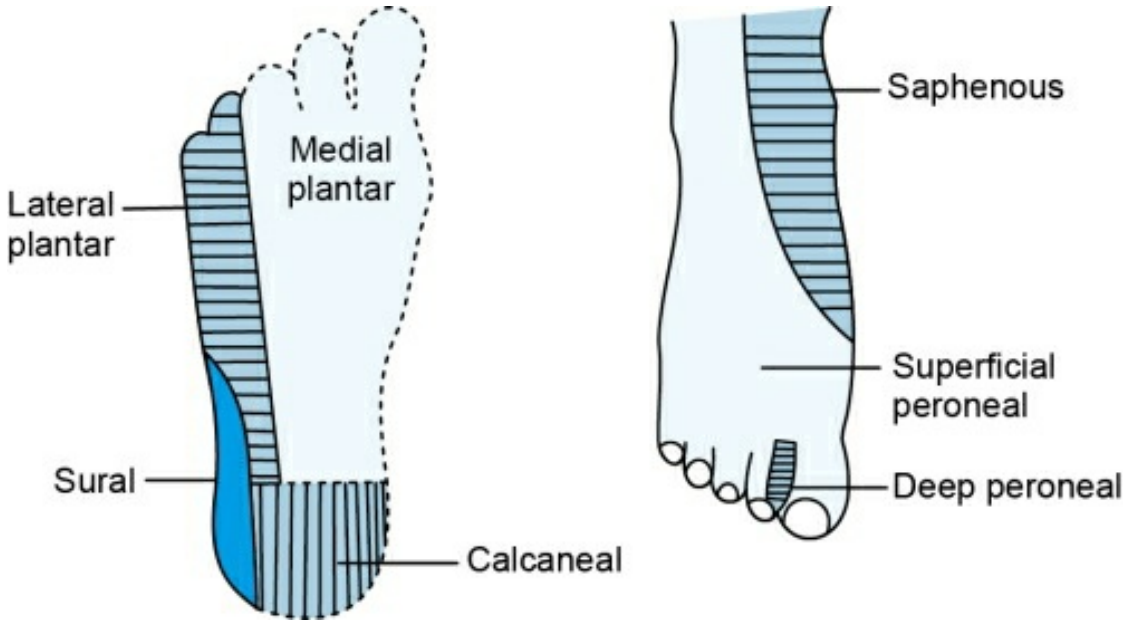

FIG. 27-32 Sensory innervation foot (plantar aspect).

Note: The lateral-most aspect of the foot is supplied by the sural nerve.

Foot drop (see fig. 27-11)

Foot drop or dropping of the foot into plantar flexion position is the most common disability encountered of all the peripheral nerve injuries.

Foot drop may arise due to several causes extending from spine to foot.

Causes

At the Spine	At and Around Knee
• PIVD	• Fracture of the neck of fibula

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• Spina bifida • Localized spinal tumour	• Fracture of the lateral femoral or tibial condyle • Knee dislocation at superior
• At the hip: Posterior dislocation and fractures around the hip, and femur and acetabulum and deep IM injection	• Lateral meniscal injury, cyst or tumour
• At the thigh: Deep IM injection or deep penetrating injury • Fracture of the shaft of femur	• Dislocation of superior tibiofibular joint • Tight POP cast around knee or while applying tibial skeletal traction • Direct piercing injuries, e.g., gunshot • Hansen disease

Level of lesion:

The motor and sensory involvement depends upon the level of the lesion.

High lesion: Above the knee before the division of sciatic nerve	Both common peroneal and tibial nerves are involved; causing TRUE FOOT DROP involving all the foot muscles (flail foot) Sensory: spared peroneus longus and brevis
Low lesion: Lesion below the knee Common peroneal nerve involvement (lateral popliteal)	All the extensor group of muscles of the ankle and toes including peroneus tertious are involved Spared: plantar flexors and toes flexors (intrinsics) Sensory: first web space
Posterior tibial nerve	Paralysis of the plantar flexor group, toe flexors (intrinsics) Spared: ankle and foot dorsiflexors, peroneus longus, brevis Sensory: distal part of the calf and sole of the foot

Early detection

- Common peroneal high stepping gait or toe drag.
- Posterior tibial lesion: Foot slap immediately following heel strike (calcaneus gait).

Treatment of foot drop

Early treatment

- Whatever may be the causative factor, the first priority is to provide a splint which will maintain the foot in neutral position of dorsal and plantar flexion. Avoid soft tissue stretching and stretch on the

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involved peripheral nerve.

- Orthosis could vary from static POP posterior slab, KFO or toe pickup orthosis (Fig. 27-33A and B).

- Depending upon the causative factor and ascertaining the diagnosis, anti-inflammatory or steroid agents may become necessary.

(A)

(B)

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FIG. 27-33 **(A)** Below-knee splint to prevent equinus deformity. **(B)** Toe pickup orthosis.

Physiotherapy

Extensive evaluation will dictate the line of treatment.

- Control of pain
- Control of inflammation
- Preventing joint stiffness or fixed deformity due to skeletal or soft tissue contractures
- Exercise forms the basis of therapy. The choice of the type of exercise depends upon the degree of involvement and the progress of recovery
- Full ROM passive movements
- Assisted active movements – slowly done, maximum effort by patient is very important.
- PNF technique of bilaterally symmetrical pattern combined with a strong stretch reflex at the initiation of a pattern or even repetitive stretches to ankle plantar flexion stimulate the lost muscular action of the ankle and foot dorsiflexion, which is very encouraging to a patient.
- EMG – biofeedback using visual as well as auditory feedback, sensation of the areas close to the anaesthetic area by electrical stimulation helps in regaining lost sensation along with other techniques.
- Providing the necessary orthosis
- **Gait training:** Static or dynamic splint

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- Complete foot drop (involvement of both common peroneal and tibial nerve), static moulded BK splint which keeps the ankle joint in neutral.

- BK brace with foot drop stopped at 90 degrees.

- Toe pickup orthosis which maintains foot in neutral but allows active plantar flexion is ideal when the posterior tibial nerve is spared or in upper motor lesions.

Surgical procedures

The type of surgical procedure to be chosen depends on the site, the extent and the severity of neuronal damage.

- Fixed equines due to TA tightness or contracture – tendo-achilles lengthening.

- Paresis or paralysis due to thickened and tender nerve caused by tuberculoid leprosy (Hansen) – peroneal nerve stripping.

- Fixed varus deformity of the foot – subtalar joint stabilizing procedure (arthrodesis).

- Fixed varus at the subtalar joint – triple arthrodesis.

Tendon transplant procedures

- Single transplant: Tibialis posterior which escapes paralysis in common peroneal lesion is transplanted to the midfoot.

- Double transplant: Anterior transposition of tibialis posterior fixed transferred to the extensor hallucis longus combined with peroneus brevis transfer to prevent excessive valgus due to strong peronei.

Physiotherapy following surgery (table 27-15)

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Initial (< 3 weeks) stage

Immobilized limb: Measures same as described earlier to reduce pain, inflammation; exercise to improve (muscle and joint) functions of unaffected joints.

Table 27-15
General Principles of Physiotherapy

Paralytic stage (up to 3 weeks)	• Splint, control of pain, oedema • Prevent contractures • Full passive ROM (relaxed and slow)
Postparalytic stage (>3 weeks)	• Emphasis on motor and sensory, re-education by using electrical stimulation, EMG biofeedback techniques, dynamic orthotic aid/static orthosis • Functional training with/without orthosis
Nerve repairs	• Active or assisted motor and sensory re-education • Static or dynamic orthosis • Functional re-education
Tendon transfers	• Encouraging and re-educating the altered action of the donor tendons

Intermediate stage

- After 3 weeks: Electrodiagnostic test, assisted active exercises to the affected joints related to the nerve repaired without causing stretch to the repaired nerve, progress to active strong sustained efforts.

Late stage: After (6–8 weeks)

- Add graded resistance to the muscle action of the repaired nerve.
- Maintain full passive ROM of the related joint.
- Initiate functional activities.
- Functional use of upper extremity.

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- Standing, balancing, gait training with or without orthosis.

Comprehensive Physiotherapy Measures

During the Stage of Paralysis	During the Postparalytic Stage
Measures to reduce pain and oedema	Motor and sensory re-education with self-performed exercises with emphasis on audiovisual feedback synchronized with active efforts
Immediate orthotic splint to control tendency for developing tightness or soft tissue contracture	Diagnostic electrical stimulation
Prevention of joint stiffness	Therapeutic electrical stimulation as a feedback synchronized with patient's own active efforts
Protection of anaesthetic areas from injury or stretch	Guidance on maintenance and the correct use of orthosis with gait training or functional use
Emphasis on both motor and sensory re-education	Provide ambulatory aid but do not let the organization of a limp

Remember

Preoperative education and emphasis on the following:

- Hypertrophy or strengthening of the donor muscle groups at least to grade 4 of MMT.
- Repetitive slow and sustained longitudinal stretching session (self) to the donor muscle and related joint to facilitate postoperative mobility.
- Postoperative education to the new role.
- Training and re-education on the exact groove of the expected movement which differs from its normal (a new role) earlier action.

Compressive lesions of the lower limbs

Meralgia paraesthetica

Occasionally the lateral cutaneous femoral nerve of the thigh gets entrapped at the inguinal tunnel or at the fascia medial to the anterior

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superior iliac spine.

Causes

- Tight corset, seat belt or obesity
- Psoas abscess, retroperitoneal tumour or postoperative scarring in the region of the iliac fossa.
- The patient complains of pain and paraesthesia in the distribution of the nerve, i.e., on the anterolateral aspect of the thigh, which gets worsened by weight bearing or ambulation.
- Sensory loss restricted to a small size over the anterolateral aspect of the thigh.

Treatment

- Anti-inflammatory or neuronal drugs
- Local steroid infiltration
- Surgical decompression of the lateral cutaneous nerves (rare)

Sciatic nerve: Heavy retraction during surgery of hip dislocation may cause sciatic nerve compression.

Common peroneal nerve: The most common lesion.

Subcutaneous compression over the neck of fibula, e.g., tight BK cast, or BK orthosis, ganglia at the proximal tibiofibular ligament, sustained cross-leg sitting and side sleeping on a hard bed.

It results in foot drop.

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Posterior tibial nerve (tarsal tunnel syndrome): Compression over the medial aspect of the ankle following arthritis of the ankle or marked valgus deformity of the ankle. The nerve is compressed between the tendons of flexor digitorum longus and flexor hallucis longus. The patient presents with burning pain over the plantar surface of the foot.

- Orthosis is prescribed with modifications in the shoe.
- NSAIDs.
- Cortisone injection may be tried locally.
- Excellent results with surgical release of compression.Scarred nerve excision and nerve repair may be done.

Physiotherapy management

It follows the same pattern as detailed for foot drop in both the treatment approaches. Motor and sensory re-education plays a major role in both the therapeutic approaches along with extensive guidance to the patient to prevent damage to the anaesthetic area.

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CHAPTER 28

Poliomyelitis

OUTLINE

- History
- Virology
- Pathology
- Clinical characteristics
- Differential diagnosis
- Course of recovery
- Treatment
- Prevention of late effects of poliomyelitis

Poliomyelitis is an endemic and epidemic infectious viral disease, mainly affecting children under the age of 5 years.

The disease is transmitted by droplet infection and by oral ingestion. The period of incubation varies from 3 to 30 days.

In the nonimmune stage, there are three distinct phases of the disease:

1. Initial incubation period

2. Prodromal nonparalytic stage

3. Definitive paralytic phase

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The symptomatic illness following infection is due to the destruction of the *anterior horn cells* of the spinal cord and the brainstem for which the virus has a selective affinity (Fig. 28-1). The result is flaccid paralysis without a sensory loss.

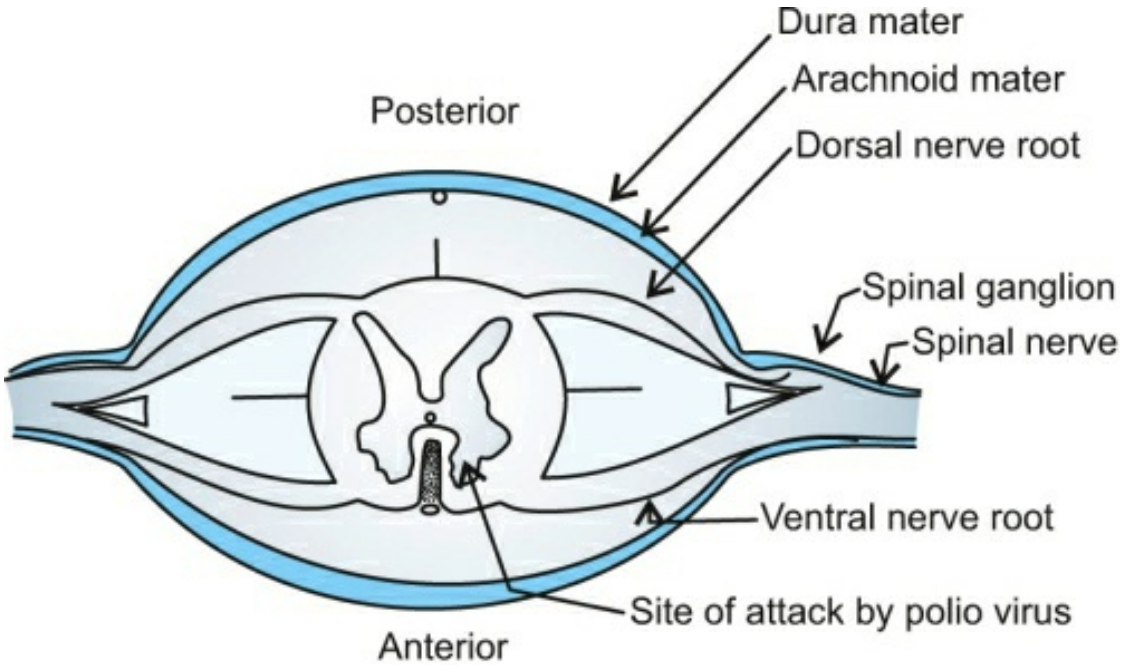

FIG. 28-1 Section of the spinal cord showing the site of attack by polio virus, at the anterior horn cells.

The involvement is predominant in the lower limbs, particularly in the extensor group of muscles. Muscular weakness and muscular imbalance are the main factors in producing the crippling deformities.

History

The withered and deformed limbs noted in the ancient Egyptian mummies trace the incidence of poliomyelitis nearly to 6000 years back. The first known description of polio was provided by Underwood in 1789. The first epidemic of polio was reported in the island of Helena in 1834; Duchenne in 1855 first reported the involvement of the anterior horn cells. In 1909, Landsteiner successfully transferred the disease to monkeys. The first type of virus

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was detected by Bodian in 1949. The year 1954 saw the first large-scale trial of Salk dead vaccine (1956) by injection. An effective immunization came in 1958 by the use of the oral sabine (live attenuated) vaccine (1959).

Virology

The poliovirus is a spherical virus of 25–27 microns in diameter. The following three types of viruses, responsible for causing poliomyelitis, have been isolated:

- Type I – Brunhilde
- Type II – Lansing
- Type III – Leon

Infection by one type will give immunity to all the strains of that type, but not to the other strains of the virus. The virus is resistant to all antibiotics and may survive for months in the infected stools. It is destroyed by oxidizing agents and heat at 55°C for 30 min. The virus colonizes and grows in the intestinal tract, and prevents growth of virulent strain – a common cause of failure of the sabine type of vaccine in tropical countries. The clinicopathological effects of each type of virus are indistinguishable.

Pathology

The virus makes its entry into the tonsillopharyngeal lymphoid tissue, Peyer's patches and in the corresponding regional lymph nodes. The virus It then multiplies and disseminates throughout the body (Bodian, 1952; Horstman & McCollum 1953; Horstman et al., 1954). The antibody, when present, inactivates the virus while it is in circulation in the blood. This is the stage of minor illness. During this phase, symptoms like sore throat, gastrointestinal upsets and transient fever may be present in about 40% cases. These symptoms are so mild

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that they usually go unnoticed. During the phase of major illness, there is widespread entry of virus into the neurons throughout the central nervous system giving rise to inflammatory reaction of the nervous tissue and meninges, a classical manifestation of poliomyelitis. The onset of meningitis corresponds to a highly dangerous phase of virus multiplication within the nerve cells of the spinal cord and brain. There may be associated symptoms like fever, malaise, nausea and vomiting. Pain and tenderness in the spine, trunk and limbs is of diagnostic value in this phase. Inflammatory cells in the acute stage are polymorphs, which are later replaced by lymphocytes. Degeneration of the anterior horn cells begins with the loss of Nissl's granules and the nucleus, which complete the disappearance of the cell. The cell death is so rapid that the fate of the involved neurons is settled within a few hours. The motor fibres arising from the destroyed cell disappear.

Occasionally, posterior horn cells, posterior columns and other spinal cells may also be affected in this stage, but their residual effects are rare.

The true cerebral lesions are usually confined to the brainstem, with the involvement of the lower cranial nuclei. Short-term unconsciousness, impaired sphincter control, unilateral facial paralysis and irregularity of respiration due to the involvement of the respiratory centre may be present (polioencephalitis).

Clinical characteristics

Incidence

Incidence is maximum in children under 12 months of age but may occur up to 5 years of age.

Sex: No differentiation.

In the affected limbs and muscle groups there is localized pain, tenderness and awkward limb positioning due to acute muscle spasm.

Involvement

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Lower extremities predominate; however, the whole body may be affected including bulbar paralysis.

Paralysis or paresis is asymmetrical and flaccid in nature.

Deltoid in the upper extremity and quadriceps and tibialis anterior in the lower extremities are commonly affected.

- No sensory impairment.
- Cold limbs due to impaired circulation.
- Reduced or loss of reflexes.

Early detection

- Tenderness over the affected muscle groups.
- Flaccid paralysis.
- Restlessness may be associated with fever.
- Usually history of inadequate or no vaccination against all the three polio viruses.

Stages of the disease

1. ***Acute phase (0–2/3 weeks)***

During the acute phase, the child is restless and irritable due to pain and muscular tenderness, with spasm in the muscle groups. Joints of the affected limb may be painful because of stretching of the muscles that are in spasm as a result of neuronal irritation.

General malaise, headache and bowel upsets may be present with low-grade fever and sore throat. In rare cases, there may be involvement of the brain giving rise to varying

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symptoms of polioencephalitis.

2. ***Convalescent or recovery phase (week 3 to 12 months)***

As soon as the acute symptoms subside, the phase of recovery begins. In this phase, there is either spontaneous recovery (up to 5 weeks) of the affected muscles or various grades of paralysis may develop. The rate of recovery slows down, and hardly continues beyond 6–12 months.

3 ***Chronic or residual phase (12–18 months)***

There is no hope of further neuronal recovery. The pattern of paralysis is organized in the affected muscles. The degree of paralysis depends on the extent of neuronal damage and the efficacy of physiotherapeutic management during theconvalescent phase.

Physical examination of the patient

Major characteristic features of poliomyelitis:

- Predominantly lower extremities are involved.
- Asymmetric nature of paralysis.
- Deltoid in the upper limb and quadriceps in the lower limb have paresis but tibialis anterior is a common muscle which tends to be completely paralysed.
- Reflexes are reduced but sensorium remains undisturbed.
- General observation of posture to detect the areas of involvement.

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- A thorough examination is essential to assess the degree of involvement. The degree of consciousness, choking, squint, spontaneous nystagmus, facial paralysis, disinclination to move or change position, feeble cry or cough, diminished respiratory excursion and accumulation of secretions should be carefully examined to detect a brain lesion. Inability to move one particular limb indicates the involvement of that limb.

- Spinal rigidity: Neck and the whole spine should be examined for rigidity.

- Strength of intercostals, diaphragm and abdominals can be assessed by simple observation.

Intercostal and diaphragmatic weakness will be indicated by insufficiency of inspiration whereas weakness of abdominals will produce deficient expiration. Paralysis of diaphragm is associated with some segmental involvement of the muscles of the neck and shoulder. In extensive paralysis of the trunk, an acting leaf of the diaphragm will balloon to the corresponding side of the abdomen during inspiration. Paralysis of the intercostals can be detected by direct palpation of the intercostal spaces. Feeble cry or feeble coughing will indicate deficient abdominals. Deviation of the umbilicus upwards, downwards or to one side indicates segmental weakness of the abdominals.

The ability to ventilate can be measured by spirometry.

5. Extremities: The extremities are examined to (a) recognize gross weakness of the limb and (b) assess the degree of paralysis in the

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individual muscle groups. Manual muscle testing is done by using MRC scales (Medical 1943). This will help predict the future course of muscle recovery or possible complications due to muscular imbalance.

6. Reflexes and sensations: The tendon reflexes disappear as paralysis develops. Therefore, the absence of reflexes confirms a lower motor neuron lesion. The plantar reflex is absent, or generally flexor. The absence of the abdominal reflex indicates involvement of the abdominal muscles. Sensations are not affected in poliomyelitis.

7. The degrees of contractures and deformities should be accurately assessed and recorded at each stage to control them with early care.

Common Causative Factors for Developing Contractures

During the early acute phase	Faulty limb positioning due to pain and spasm in the affected muscle groups
	Wrong habitual postures
During the convalescent phase	Asymmetry or imbalanced recovery of muscle strength
During the chronic phase	Tightness of muscle and soft tissue contractures

To plan appropriate measures of physiotherapy, it is important to understand the pathology and the pattern of recovery following poliomyelitis.

Differential diagnosis

Poliomyelitis needs to be differentiated in both the acute and the late stages from other conditions (Table 28-1).

Table 28-1
Poliomyelitis: Distinguishing Characteristics

Acute Condition	Distinguishing Characteristics
Pyogenic meningitis	Muscular spasticity instead of flaccidity
Guillain–Barre	Bilaterally symmetrical involvement

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syndrome	
Acute osteomyelitis	Signs of localized acute inflammation (warmth, redness at the bony ends with painful limitation of joint movement)
Peripheral nerve injury	Definite history of injury, paralysis involves muscle groups innervated by the injured peripheral nerve
Spina bifida	Congenital, bilaterally symmetrical paralysis of muscles
Cerebral palsy	Spastic paralysis with exaggerated reflexes, typical arm posture of adduction and internal rotation
Erb palsy	H/o birth trauma, involves only one upper extremity
Muscular dystrophies	Bilaterally symmetrical with characteristic involvement of muscles like hypertrophy in PMD, paralysis of limb girdle muscles in limb girdle, muscular dystrophy; paralysis of facial-scapulohumeral muscles in the onset is late
Myopathies	Bilaterally symmetrical involvement; commonly occur late

Course of recovery

Maximum spontaneous recovery occurs during the 3rd, 4th and 5th week after the onset and is due to the reversal of acute neuronal disturbances (Table 28-2). However, the spurt of recovery is considerable during the first 6 months, it becomes slow from 6 to 10 months, and by 12 months, 92–95% of the total possible recovery is attained. It becomes negligible 16 months onwards (Green, 1949).

Table 28-2

General Pattern of Paralysis and Expected Recovery Following Acute Episode

Day 1 to 2–3 weeks	Period of the onset of maximum paralysis
Week 3–5	Period of spontaneous recovery
Week 6 to 6 months	Period of slow recovery
6 months to 12–16 months	Period of negligible recovery
After 18 months to 2 years	Negligible recovery

REMEMBER:

Vigorous concentrated physiotherapy from week 3 or as soon as tenderness subsides up to 6 months is crucial. Maximum advantage should be derived at this stage.

Neuropathology of muscle recovery

The early spontaneous recovery occurs due to the following:

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1. *Reversal of the sublethal injury*: A process of reversibility occurs in the cells where destruction does not attain a lethal injury. Such cells revert to complete normalcy in due course of time.

2. *Resolution of temporary interruption*: The mechanical compression exerted by the inflammatory exudate during the acute phase blocking the conduction of the cells, eventually gets resolved with absorption of the exudate. This relieves pressure on the nerve cells and they start functioning.

3. *Reversal of function at higher levels of CNS*: The reversal of temporary dysfunction at the cortical and subcortical levels facilitates the excitation of internuncial and lower motor neurons, which in turn, promote recovery.

4. *Return of the cells to normal morphology*: The second phase of recovery, which lasts up to 10 months, is the result of some cells returning to normal morphology. Mild cellular reaction in the form of perivascular cuffing reverting the morphological abnormalities occurs in some cell bodies (Bodian, 1959).

5. *Re-routing of functional pathways*: The final phase of neuronal recovery, which goes on up to 16–18 months could be because of re-routing of functional pathways in the spinal cord in the vicinity of the severe neuronal destruction. In some living cells, the short terminal axonal segment may degenerate centripetally at the initial stage, but subsequently regenerate (Brooks, 1953).

6. *Axonal sprouting*: There exists a definite histological evidence of axonal sprouting in the active neurons, extending their field of action by branching terminally. This will lead to re-innervation to the adjacent denervated muscle fibres (Hoffman, 1959; Morris, 1953).

7. *Neuronal hypertrophy and hypertrophy of the surviving muscle fibres*: The motor neurons supplying active muscle fibres in a paretic muscle have a tendency and potential for hypertrophy. Therefore, there is

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every possibility of improving the strength and endurance of muscle fibres by producing hypertrophy of these surviving muscle fibres (Edds, 1950).

8. *Involvement of large anterior horn cells*: The largest of the anterior horn cells are preferentially destroyed in the spinal cord in poliomyelitis (Russel, 1956). This is the underlying pathology of early fatigue of reduced endurance, which is one of the basic characteristics of the paretic muscles.

Therefore, there is a definite evidence to plan effective physiotherapeutic programme based on the potentials of various processes of recovery and compensatory mechanisms that occur in the affected neurons.

Physiotherapy management

The focus of physiotherapy should be planned precisely on the pattern of paralysis and the recovery of muscle power (Table 28-2).

Objectives

- To restore maximum strength and endurance in the affected muscle groups.
- Maximum emphasis on the prevention of deformities.
- Allot extra time to educating parents on simple exercises for home management.
- Provide early assistive aids or orthoses to promote independent ambulation and to prevent organization of deformities.

Possible problems

Early stage

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- Possibility of developing contractures.
- Overenthusiastic parents.
- Institute early weight-bearing process as tenderness begins to wean off.
- Discouraging and disheartening process of slow recovery, especially when the upper extremity is paralysed.

The important aspects to be emphasised precisely from the early stage are as follows:

1. Accuracy of manual muscle testing

2. Correct assessment of the prognosis of recovery of the affected muscle groups

3. Prevention of deformity

4. Educating the parents on simple specific exercises for home treatment

Manual muscle testing (table 28-3)

This should be done with great precision.

1. Check the consistency of one's own testing by repeating the test without referring to the previous test data within an interval too short for any recovery to take place.

2. The accuracy of testing is to be kept in mind while testing functionally important muscle groups.

3. Extra time, efforts and skill are needed in assessing certain groups like the muscles of the trunk, rotators of the hip and serratus anterior. Final grade should be given only after repeating the test.

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4. Muscle power imbalance in the groups opposite to each other (agonists and antagonists) should be done precisely and noted, as this could be a causative factor in future contractures.

5. While assessing the progress of recovery from grade 4, it must be remembered that the grade 4 muscle requires double the time to progress by one grade (i.e., from grade 4 to grade 5) as compared to the grades 1, 2 and 3. In other words, when the muscle in grades 1, 2 and 3 progresses to 2, 3 and 4, respectively, the grade 4 muscle must have progressed only to 4+ and not 5 (Sharrard, 1955b). Therefore, it is necessary to add grade 4+ in the manual muscle test (MMT) chart as equivalent to 1 unit of recovery so that the normal grade or grade 5 will remain constant for the other grades of the paretic muscles.

6. Manual muscle testing also needs to be put into proper perspective. It has been identified that grades alloted by manual testing markedly overestimate paretic muscle strength.

The clinical grade of 5 (normal) was found to be only about 60% of the torque registered by the normal muscle (Beasley, 1961; Hill et al., 1983). Sharrard (1953) found that the muscle graded as 4 by MMT may have the destruction of more than half of its anterior horn cells. This could be explained by early fatigue in the polio-affected limb in the presence of clinically good (grade 4) muscle power. These observations clearly limit the extent of exercising to the level short of fatigue.

7. The expected recovery status of the affected limb as a whole should be determined in relation to the future functional independence.

8. The prognosis of the individual paretic and paralytic muscle groups should be predicted and recorded to evaluate the efficacy of the therapeutic programme.

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Table 28-3

Manual Muscle Test (MMT) Grades

100%	5	N	Normal	Normal complete range of motion against gravity with full resistance
75%	4	G	Good	Complete range of motion against gravity with some resistance
50%	3	F	Fair	Complete range of motion against gravity
25%	2	P	Poor	Complete range of motion with gravity eliminated
25%	1	T	Trace	Evidence of slight contractility; no joint motion
0	0	0	Zero	No evidence of contractility

Prognosis of recovery in relation to the initial assessment of muscle power

All the muscle groups of the affected limb should be divided into two groups:

1. Group I – muscles that are partially paralysed (MMT grade = 1 to 3)

2. Group II – muscles that are totally paralysed (MMT grade = 0)

The patterns of recovery of these two groups are different and predictable at a particular interval from the onset. This has been extensively studied and reported by Sharrard (1955a). His observations are as follows:

Group I – the prognosis of recovery in partially paralysed or paretic muscle groups: Paretic muscles will always increase in power after the first month. It is predictably so uniform, that the eventual power of any paretic muscle can be determined at any point of time from the onset.

(a) *One month after the onset:* Few failed to improve. Most improved by one, two or three grades. Few gained as much as four grades.

Average increase of about two grades was made by all the muscles in the lower limbs and two and a half grades in

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the upper limbs; whether their grade at that time was one, two or three.

(b) *Two months after the onset:* Small proportions failed to improve. Small proportions made spectacular recovery. Most improved by one or two grades. Average increase being about one to one and a half grades in lower limb and two grades in the upper limb.

(c) *Four months after the onset:* One-fourth of the muscles improved by two grades. Another quarter of them failed to improve. The rest improved by one grade. Average increase in grade being one grade in the lower limbs and a half grade in the upper limbs.

(d) *Six months after the onset:* Almost half the muscles improved by one grade, over one-third failed to improve, and a small proportion improves by two grades.

Average increase in the muscle grade being three-quarters of a grade in the lower limbs and one grade in the upper limbs.

On an average, the final grade of a paretic muscle in the lower limb may be estimated by adding two to its grade at 1 month, one and a half to its grade at 2 months, one to its grade at 4 months, and three-fourth to its grade at 6 months; the corresponding figures for the upper limbs being two and a half grades by 1 month, two grades by 2 months, one and a half grade by the end of 4 month and by one grade at the end of 6 months.

This uniform trend of the quantum of recovery of the paretic

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muscles is of great significance in clinical practice. It provides valuable guidance:

1. to determine the final grade of the expected recovery of a muscle group.

2. to determine the expected quantum of recovery at a definite interval.

3. to assess whether the recovery is progressing as expected.

4. to warrant alteration in the therapeutic regime if the progress is unsatisfactory.

5. to assess the final picture of recovery of the whole limb and its possible ultimate functional status.

Group II – the prognosis of recovery in totally paralysed muscles: The prognosis of recovery of the totally paralysed muscle groups depends on the degree of destruction of the motor cells and their topographical relationship in the spinal cord segment.

1. When all the motor nerve cells in the spinal cord supplying the muscles are destroyed, the muscles cannot recover.

2. If the motor nerve cells are destroyed partially, clinical activity in the muscle fibres will return and can be detected at any point of time. A muscle that shows no clinical recovery at 1 month has only about 50% prospect of any degree of recovery at all. If no recovery is noticed by 6 months, 90% will remain permanently paralysed.

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However, when a muscle shows return of activity, it follows the pattern of recovery same as that of the paretic muscles.

3. The process of destruction of the motor cells in the spinal cord has been found to occur regionally (Elliot, 1942; Sharrard, 1953). Therefore, the extent of paralysis of the muscles supplied by the same and the adjoining spinal cord segment can provide information regarding the course of recovery of the totally paralysed muscle. The muscles supplied by the same or the adjoining spinal cord segments are referred to as associated muscles. For example, complete paralysis of quadriceps (L2, L3, L4) and tibialis posterior (L4, L5) indicates that the tibialis anterior (L4), which, if completely paralysed, has practically no chance of recovery. If both the associated muscles of the quadriceps (hip flexors and adductors) are paretic, the possibility of recovery of the paralysed quadriceps is very good. Guidance for the topographical relationship of the associated muscles and the possibility of its recovery for the lower limb is given in Table 28-4.

Prognosis is bad when all the muscles of a limb or of the same spinal segment are paralysed.

Table 28-4

Segmental Association of Major Muscle Groups of the Lower Limb

Muscle or Muscle Group	Associated Muscle Group
Hip flexors	Quadriceps, hip abductors
Quadriceps	Hip flexors, hip abductors
Hip abductors	Gluteus maximus, tensor fascia lata
Gluteus maximus	Hip abductor, biceps femoris
Tibialis anterior	Tibialis posterior, extensor hallucis longus
Tibialis posterior	Tibialis anterior, extensor hallucis longus

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Extensor hallucis longus	Extensor digitorum longus, peronei
Extensor digitorum longus	Extensor hallucis longus, peronei
Gastrosoleus	Biceps femoris, flexor digitorum longus
Peronei	Extensor digitorum longus, extensor hallucis longus

Deformity

Contracture, which gets organized into a deformity, complicates the process of recovery in the following ways:

1. It prevents the surviving motor units to participate in the process of recovery as they remain inactive.

2. It causes disuse of active muscles and makes them weak.

3. It produces angulation, stiffness and even displacement of the joints.

The causative factors are as follows:

1. Muscle spasm

2. Influence of gravity

3. Muscular imbalance

During the acute phase of the disease, muscle spasm of the involved muscle groups results in contracture which may lead to deformity. Weight of the limbs, habitual postures and malpositioning compounded by the influence of gravity and muscle weakness may also result in deformity.

During the subacute phase, the deformity results from the muscular imbalances due to asymmetrical paresis or paralysis of the muscle groups controlling a particular joint. If the deformity is not properly controlled at this stage of the disease by appropriate physiotherapeutic measures and appliances, it deteriorates further,

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when the concerned joint is exposed to stresses of weight bearing.

Prescribing correct appliance, checking its proper fit and educating patient on its correct use, as well as its maintenance is the responsibility of the treating physiotherapist.

During the chronic phase, there is always a tendency of discarding the appliances. This not only results in deterioration of the deformity but also causes secondary complications by exposing the joints to imbalanced stresses.

Therefore, prevention of deformity forms the basis of treatment not only during all the phases of the disease but even in the later phases of life.

The common sites of deformity and their causative factors have been well documented by Singer and Roseinnes (1963) and are illustrated in Table 28-5.

Table 28-5

Common Deformities and Their Causative Factors

Possible Deformity	Deforming Forces
1. Early, extensively paralysed patients	
Flattening of all spinal curves	Gravity, supine position
Shoulder adduction–internal rotation	Adductor spasm, deltoid failure, malpositioning, e.g., in respirator
Elbow flexion	Flexor spasm, wrong positioning
Palmar flexion at wrist	Gravity, supine position
Hip flexion–abduction–external rotation	Abductor spasm, gravity in supine position
Flexion at knee	Flexor spasm
Ankle equinus	Calf spasm, gravity
Forefoot equinovarus	Gravity, tibialis posterior and toe flexor spasm
2. Axial weakness	
Neck flexion and atlanto occipital extension	Gravity, erect posture
Rib droop	Intercostal weakness, gravity, supine and erect posture
Scoliosis	Gravity, erect, intercostal, paraspinal and abdominal weakness
Pot belly	Abdominal weakness, gravity, erect posture and sitting
3. Upper limb	
Vertical subluxation of shoulder	Gravity, erect posture, severe paralysis
Elbow extension	Gravity, flexor failure
Forearm supination and ulnar deviation of wrist	Gravity, pronator and radial extensor failure
Flat nonopposable thumb	Thenar muscle failure
4. Hip and knee	
Trendelenburg dip at the hip	Abductor failure, early weight bearing

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Subluxation of hip Genu recurvatum External rotation of tibia	Abductor, extensor, internal rotator failure Quadriceps failure or hamstrings failure, early weight bearing, gastrosoleus spasticity Gravity, supine, weight bearing on valgus foot, medial hamstrings failure
5. Ankle and foot	
Valgus foot First metatarsal head depression Inversion Equinovarus with inversion of heel Calcaneovalgus	Invertor failure, weight bearing A component of isolated tibialis anterior paralysis Evertor failure, weight bearing Failure of all but plantar flexors, intrinsic muscles and invertors Failure of plantar flexors and evertors, weight bearing

Treatment programme (table 28-6)

Acute phase (first 3–5 weeks)

It is also called the *prodromal* or *preparalytic stage*. Complete physiological rest to the nervous system with maximum possible measures to achieve relaxation of the whole body is the basic aim.

1. Relief of pain.

2. Supportive medication for the relief of pain and relaxation.

3. Relaxation of painful spasm: Local tenderness and pain due to spasm of the offending muscle groups can be effectively managed with hydrocollator packs or warm wet towels placed over the tender muscle groups. Excessive heating should be strictly avoided.

4. Prevention of contractures: It is a major goal to be achieved during early convalescence (Green, 1949). Proper positioning of the whole body and especially the involved limb is critical. The contracture and deformities begin to appear at this stage. Therefore, a carefully planned educative management programme needs to be followed at this stage. It is preferable to put the limb in proper position for prevention of deformities rather than applying rigid splints. Parents should be guided on the methods of proper positioning of the limb. Special care in positioning should be taken at the common sites of contractures and deformities.

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Common sites of early contractures (Table 28-7)

- Hip – flexion abduction
- Knee – flexion
- Ankle and foot – plantar flexion (equinus), varus or valgus
- Shoulder – abduction
- Elbow – flexion

Whenever muscular pain or spasm permits, relaxed passive movements to be initiated at least once in a day. Contractures later on organize into deformity.

5. Avoidance of activity: Any type of unnecessary activity is contraindicated at this stage of the disease. The contrary effects of excessive physical activity have been proved experimentally (Levinson et al., 1945).

6. Prevent invasive techniques: Inoculation, injection, local trauma and any surgical procedure should be avoided as these induce cell vulnerability (McCloskey, 1950).

7. Least exerting transfers: Transfers of patients should be carried out carefully especially when involving long distance journey and muscle power assessment. The extent of paralysis is assessed only cursorily as detailed examination is difficult and may even be harmful.

8. Special care of the severely affected patients: Patients having involvement of the whole body or bulbar palsy with respiratory paralysis need intensive care.

Table 28-6

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General Principles of Management at Each Phase of the Disease

Phase	Measures to Control
Phase I. Acute phase of paralysis (onset to 2–3 weeks)	
• Sick and irritable child may be associated with respiratory failure • Low grade fever for the first 2–3 days • Tendency to develop spasm and tenderness in the affected muscle groups • Faulty deformity prone limb positioning and wrong postural attitudes • *Strictly prevent the development of deformity due to tenderness and muscle spasm*	• Bedrest or resting the affected limb in a comfortable position • In cases with bulbar paralysis, ventilator support may be necessary • Drugs to control fever and other associated symptoms • Warm and moist packs to control tenderness, spasm and stiff, painful joints • General tendency to adopt flexion attitude of the limbs, e.g., knees, which is relaxing but prone to develop permanent contractures should be discouraged and corrected as much as possible • Corrected position has to be maintained by plaster splints, or at least by using sand bags
Phase II. A phase of recovery: (A) 3–5 weeks from the onset; (B) 6–12 weeks from the onset	
• A focus on specific exercises to the paretic muscle groups to further strengthen graduated steps from active movements to resistive mode • Warn parents not to put undue emphasis on standing or walking unsupported or without an orthosis • In a limb with asymmetrical or imbalanced return of muscular power, a danger of developing deformity persists; correct, check and control by an appropriate orthosis is a must	A. 3–5 weeks is the period of spontaneous muscle recovery as the swelling due to inflammation interrupting the nerve conduction is resolved • Critically carry out MMT and formulate-plan-exercise programme accordingly • At this stage, pool exercises are ideal, which are most acceptable to kids • Teach simple specific exercises as needed to parents for home management • Repeat muscle chart after 2 weeks of therapy to judge the extent and pattern of muscle recovery, and continue • Provide protective orthosis if there is a tendency for unsupported ambulation, with deformity • Continue progressive recovery modes to the weaker but voluntarily active muscles B. 6–8 weeks to 6 months: As the neuronal recovery is rapidly weaning, emphasis should be placed and functional education and guidance given to patients on home treatment programme
Phase III. A phase of residual paralysis (after 18 months of the onset)	
As there are maximum chances of developing deformity due to the progression of tightness of the soft tissues – progressing to the deformities – protection and prevention of such attitudes deserves first priority	• Critical objective examination of the affected limb in relation to the whole body's activities • Assess the physical abilities and disabilities as related to the ADLs • All the possibilities of improving functional performance should be assessed for further care and re-education, e.g. • Modification and alterations in the orthoses or a brace • Strengthening and encouraging compensatory body movements • Is there any chance of rehabilitative and

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	reconstructive surgical procedure? • If so, what mode of physiotherapy should be ideal to facilitate functional independence? • Plan a new therapeutic training schedule, e.g., hypertrophy of the muscle group chosen for transplant • Check-up orthosis with the wrist joint fixed in 15 degree of extension, before planning wrist arthrodesis • Encouraging 'trick movements' to compensate for weak functions

Table 28-7

Common Causative Factors for Developing Contractures

During early acute phase	Faulty limb positioning due to pain and spasm in the affected muscle groups; wrong habitual postures
During the convalescent phase	Asymmetry or imbalanced recovery of muscle strength
During the chronic phase	Tightness of muscle and soft tissue contractures

Bulbar paralysis

Pharyngeal paralysis: This leads to inability to swallow; the patient chokes even on liquid food and is unable to swallow saliva. It can cause death if not prevented. At the same time, difficulty in coughing or speaking is also noticed.

Bulbar paralysis may be associated with polioencephalitis.

Respiratory paralysis: Respiratory paralysis results in mental disturbances or even coma. This may be as a result of the involvement of:

(a) Respiratory centre

(b) Intercostal muscles: It could be asymmetrical, if intercostals are unilaterally involved.

(c) Involvement of diaphragm will give rise to paradoxical

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respiration. The early signs will include breathlessness, suffocation, cyanosis and use of alae nasi.

Tracheostomy or intermittent positive pressure respiration (IPPR) or a respirator may be necessary. The most important role of the physiotherapist is to use postural drainage and improve vital capacity.

Recovery phase (4–18 weeks)

This is divided into two phases:

1. Early convalescence

2. Late convalescence

1. **Early convalescence (3 weeks to 6 months):** Treatment at this vital phase of recovery has to be planned and carried out with utmost skill. The emphasis of the therapeutic programme should be clearly distinguished on the basis of the MMT. The treatment programme needs to be individualized for the paretic or paralysed muscle groups. The methodology of treatment in the department by the physiotherapist differs markedly from that of the home treatment.

(a) At the department

(i) Planned exercises to the specific individual muscles to attain maximum physiological hypertrophy of the intact muscle fibres.

(ii) Use of advanced neurophysiological techniques like PNF.

(iii) Pool therapy: Exercises in warm water pool are extremely effective at this stage. While giving them, the natural tendency for compensatory tricky movements should be prevented. Therefore, the exercises in water

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should be done with absolute specificity of the groove of the movement.

(iv) Assisted exercises like tricycling (may be by tying ankles and feet for the peddling) provide high incentive and maintain proper groove of the movement.

(v) Unnecessary splinting should be avoided to reduce the effect of immobilization. If at all splints are given, they should be used to provide graduated exercise (Wickman, 1913).

(vi) Children who attempt to stand with support and take steps on their own should immediately be given necessary appliances. This should be done irrespective of the accepted usual rule of prescribing appliances only after 6 months of onset. This is done to prevent deformities occurring due to early weight bearing.

(b) Home treatment

(i) Initially, only important muscle groups should be included for the exercises. Simple but specific methodology should be taught to maintain the efficacy of the exercise. Frequent checking of the basic principles is necessary.

(ii) Only one or maybe two exercises should be taught in one session.

(iii) Methods of prevention and/or management of contractures and deformities should be checked regularly.

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(iv) Parents should be warned against any weight-bearing activities on the affected limb at this stage. Enthusiastic early weight bearing on weak muscles may lead to deformities like subluxation of the hip (Dutta et al., 1975), genu recurvatum (Joshi et al., 1976), genu valgum, genu varum and valgus foot.

(v) Parents should be instructed to bring the child regularly for physiotherapy to the department and not just depend on the home exercise programme. The recovery of muscle power has been found to be much better in children treated in the department by a physiotherapist as compared to those managed on home treatment programmes alone (Joshi et al., 1979).

2. **Late convalescence (6 months to 1 year):** This is a phase of recovery that is due mainly to the hypertrophy of the residual muscle fibres that needs an adequate programme of graded resistance to the concerned muscles.

Resistance becomes more acceptable when given during the performance of daily activities. Resistance can be applied to a great advantage while tricycling. The feet are lightly secured to the peddles; graded resistance is applied at the seat when the child moves the tricycle with own efforts. This not only helps in offering resistance but also improves coordination as it becomes a competitive sport and is very well accepted by a child.

Another method of applying natural resistance is by resisting the gait or resisting the movements performed with braces. Prescribing adequate bracing, training in their appropriate use and maintenance are the responsibilities of a physiotherapist.

Aerobic programmes like swimming, fast walking and sports can be initiated and made competitive whenever feasible.

Limb length discrepancy is commonly seen in children with unilateral

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lower limb involvement. It needs to be assessed and properly compensated at regular intervals.

Chronic or residual phase (after 1 year to 18 months)

As the chances of neurological recovery are practically nil at this stage, more emphasis should be on further strengthening the functional needs of the patient. Singer and Roseinnes (1963) observed a small degree of muscle recovery up to 24 months associated with intensive training. Instead of specific muscular exercises, the emphasis should be on functional exercises. These movements should be made stronger by graduated resistance. Any additional guidance aids or supports to facilitate functional as well as physical work requirements may be given, if necessary.

The maximum importance is to be given to stop the posture, positions and activities that put compressive or stretching forces on the involved muscles and the joints supported by them.

Correct use of braces, canes, crutches, wheelchairs or any orthosis is to be assured.

Advice on the prevention of contractures and deformities will remain a constant feature at all times.

Functional recovery

Functional recovery plays an important role in providing functional independence to the patient. It should be initiated as early as possible. However, it is important to observe certain methodology in relation to the stages of recovery and the degree of muscle power.

1. During the phase of recovery, the functional activity should not be replaced by compensatory muscle action (tricky movements). This will result in lack of concentration to the exercise necessary for hypertrophy of the weak but innervated muscle.

2. Proper and adequate support by orthosis is needed to prevent fatigue of the recovering muscle groups and overstretching of the paralysed muscles and joints.

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3. When the recovery phase is over, compensatory mechanisms to perform functional activities should be encouraged and strengthened by a programme of resistive exercises PRE.

4. Avoid pain or fatigue during functional activities as recent studies have demonstrated the ill-effects of such excesses (Agre et al., 1998).

Functional assessment

Assessment of the following activities:

1. Ability to turn

2. Ability to sit up

3. Assistance to sit

4. Ability to sit up without assistance – posture and balance.

5. Ability to stand – (a) support required, (b) independent, (c) balance and (d) posture of head, spine, hips (Trendelenburg), knees and feet.

6. Walking – unaided, aided – what aids gait and speed.

7. Braces – details.

8. Managing curbs, stairs – independent, with aid (type of aid); ability to do floor sitting, squatting, cross-leg sitting.

Surgery

During this phase, some surgical intervention may be necessary.

The common surgical procedures are correction of the soft tissue contracture; correction/prevention of deformity by tendon transfers or bony stabilization procedures; tendon transfers to improve function and correction of limb length disparity.

Upper limb

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Abduction at *the shoulder* can be improved by transfer of a strong trapezius muscle to the neck of the humerus or by arthrodesis in functional position (Fig. 28-2). Postoperatively, plaster of Paris (POP) shoulder spica is given for 6 weeks after muscle transfer and for 8–12 weeks after arthrodesis.

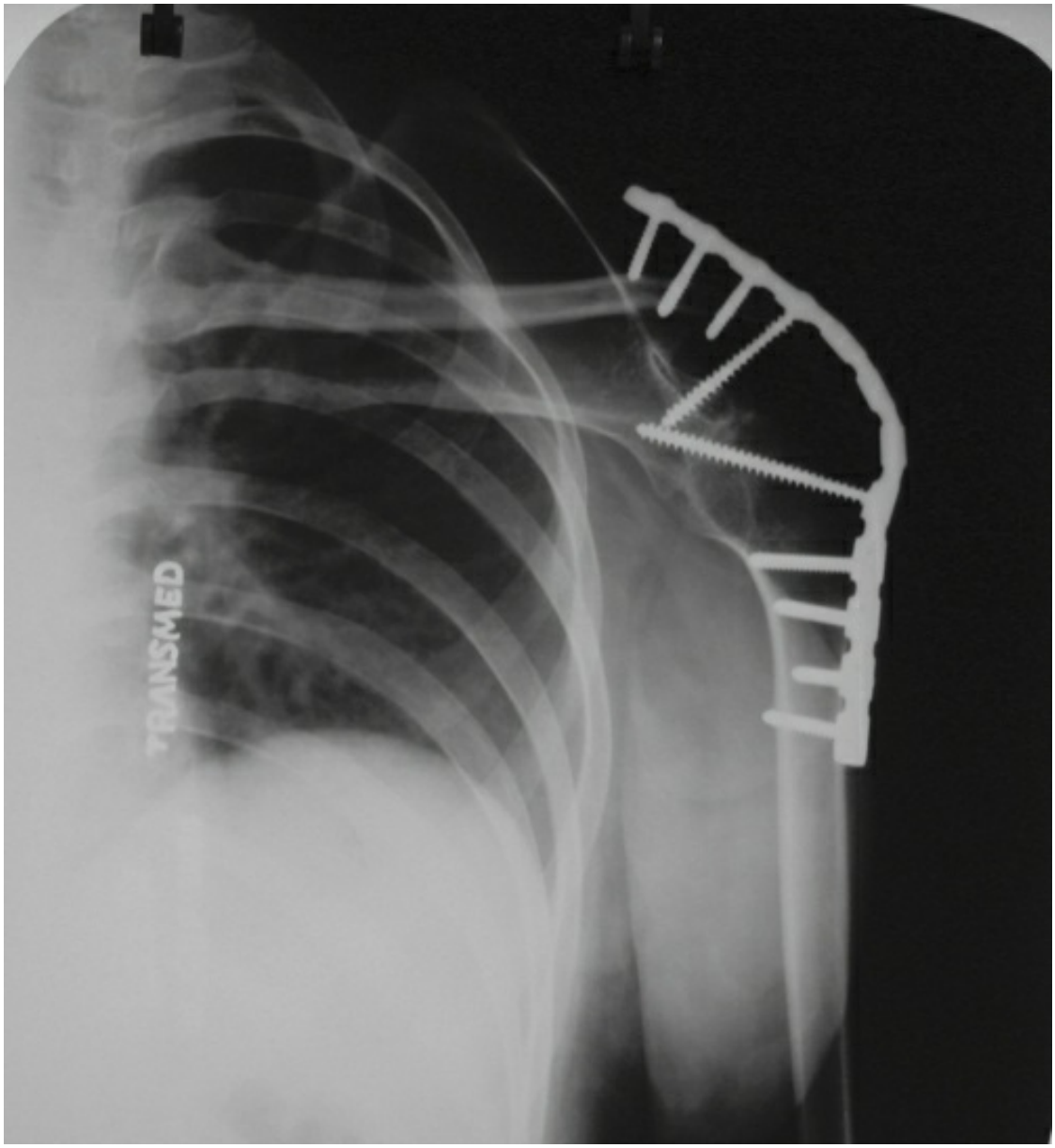

FIG. 28-2 Arthrodesis of the shoulder.

Paralysis of flexors of *the elbow* results in loss of active flexion at the

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elbow. However, if the forearm and finger flexors are strong, the common origin of the flexor group of muscles, at the medial epicondyle of humerus is transferred to the front of the lower end of the humerus (Steindler's flexoroplasty Fig. 28-3). An above-elbow POP slab is given for 4–6 weeks postoperatively. Training of the muscles after removal of the slab improves elbow flexion to a functional range. There may be limitation of the terminal 20–30 degrees of extension at the elbow.

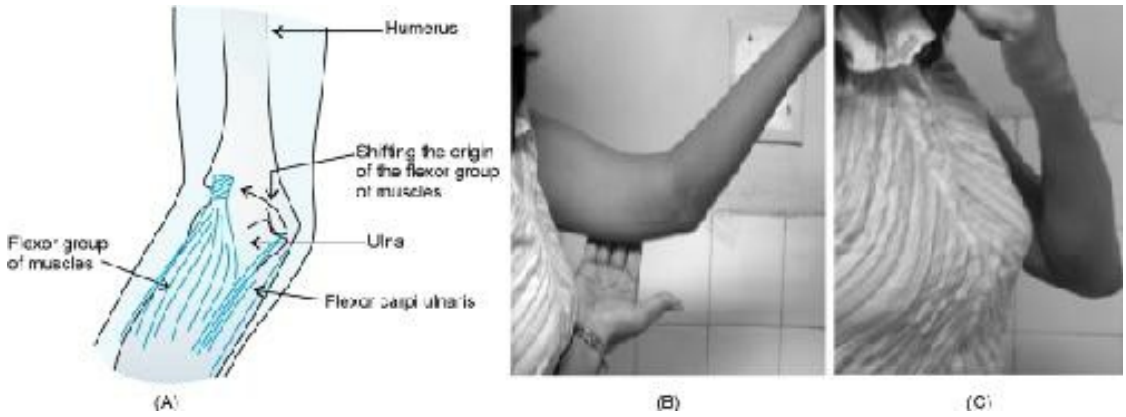

FIG. 28-3 **(A)** Steindler's flexoroplasty: common flexor muscle origin is detached from the medial epicondyle and transferred to the lower end of the humerus – in front. **(B)** and **(C)** postoperative result after Steindler's flexoroplasty.

Function at the *wrist* can be improved by tendon transfers (Fig. 28.4) or by fusion of the wrist (see Fig. 27-20). Wrist flexors are transferred to the finger extensors to improve extension of the fingers.

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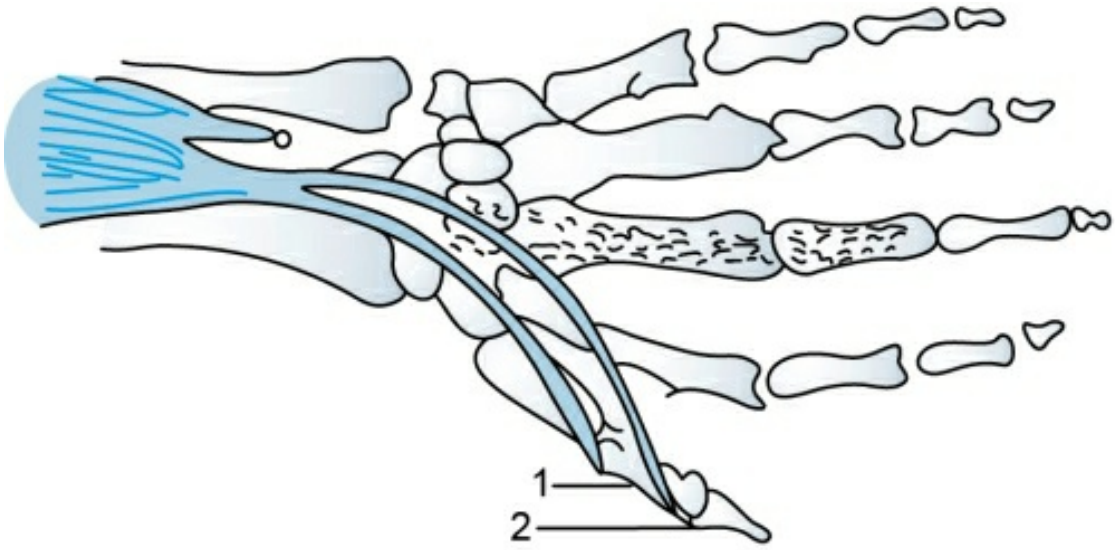

FIG. 28-4 Transfer of flexor digitorum sublimis from the middle phalanx of the middle finger to the thumb, to facilitate (1) carpometacarpal and metacarpophalangeal opposition and flexion (2) extension at the interphalangeal joint.

In the hand, loss of opposition is a disabling problem and may require a tendon transfer (opponensplasty). Usually the sublimis tendon is detached from its insertion on the middle phalanx and is transplanted into the abductor pollicis brevis to improve opposition of the thumb (Fig. 28-4). Plaster immobilization with thumb in opposition is given for 3–5 weeks.

Spine: Paralysis of trunk muscles results in scoliosis. It usually causes a long dorsolumbar curve that is largely correctable. It needs surgical treatment in the form of spinal fusion with or without anterior or posterior instrumentation.

Lower limb

Release of soft tissue contractures

Hip: The flexion contracture at the hip is corrected by Soutter's operation in which the tight structures along the anterior iliac crest are released and the deformity is corrected. The abduction contracture is corrected by release of abductors, fascia lata and the

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iliotibial band. Postoperatively, the patient is given a POP hip spica, in the corrected position, for about 4–6 weeks. The joints are then mobilized but the correction is maintained in a caliper.

Knee: Mild flexion contractures are generally due to tight iliotibial band that is divided. Moderate degrees of flexion contracture can be treated by lengthening of the hamstrings. Severe flexion contractures require lengthening of hamstrings and posterior capsulotomy of the knee (Wilson's operation). Postoperatively, an above-knee plaster cast for 4–6 weeks followed by mobilization is the usual regime. The correction is maintained in a caliper.

Ankle: The commonest deformity is equinus, which results from contracture of the tendoachilles. Lengthening of the tendoachilles by Z-plasty is undertaken (Fig. 28-5). An above-knee plaster cast for 3–6 weeks is given after operation. A below-knee caliper is usually worn for 3–6 months to prevent recurrence.

Foot: Contracture of the plantar fascia produces a cavus deformity of the foot. The tight plantar fascia is stripped from its attachment to the calcaneus (Steindler's operation). In the postoperative period, a below-knee plaster is given for 2–4 weeks, after which a night splint is used for 2–4 months.

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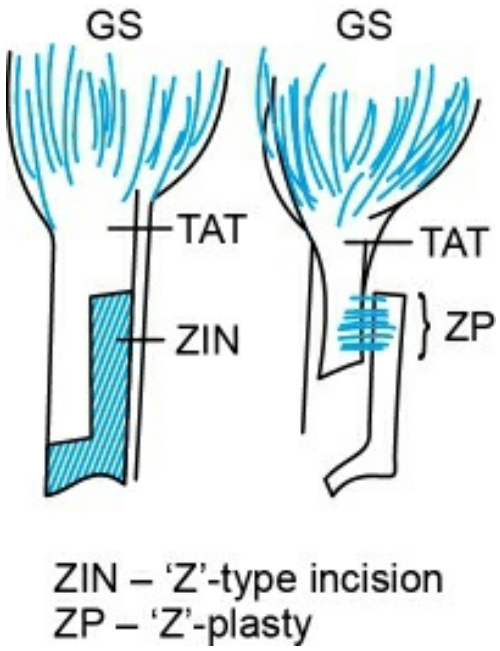

FIG. 28-5 Lengthening of the contracted tendoachilles by Z-plasty. GS, gastrosoleus; TAT, tendoachilles tendon.

Tendon transfers

Hip: Paralysis of the glutei can result in serious disabilities including paralytic dislocation of the hip. Gluteus maximus paralysis causes exaggerated lumbar lordosis and a backward lurch during walking. Paralysis of the gluteus medius produces a lateral lurch on the same side with an unstable gait.

Surgery for paralysis of these muscles is rarely undertaken as the results are unpredictable. However, iliopsoas or erector spinae muscles are transferred into the gluteus maximus for paralysis of the latter, while the tensor fascia lata is transferred posteriorly for gluteus medius paralysis.

Knee: Quadriceps paralysis is commonly seen in poliomyelitis. The quadriceps may be strengthened by transfer of hamstrings into the patella. Postoperatively the knee is immobilized in an above-knee plaster cast in full extension for 4–6 weeks, followed by a night

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splint for another 4 weeks.

Foot: Tendon transfers for correction of paralytic foot deformities are usually done in conjunction with stabilization operations on the foot. The basic principle of tendon transfers in the paralytic foot is to remove the deforming force and to use an active muscle to replace the paralysed muscle.

The following could be deformities of the foot:

1. ***Talipes equinus:*** It can be corrected by Lambrinudi triple arthrodesis (Fig. 28-6A). Since this operation is generally performed after 12 years of age, the paralytic equinus deformity can be corrected by a caliper in the early years of life. Organized equinus can be corrected by triple arthrodesis (Fig. 28-6B) by a fusion of the three joints of the foot – the subtalar, calcaneocuboid and talonavicular joints after taking suitable wedges to correct the deformity (Fig. 28-7).

2. ***Talipes calcaneus:*** It is a progressive deformity caused by the paralysis of the gastrocnemius. In addition to the calcaneus, a cavus deformity of the foot may develop subsequently. In the younger children, the deformity is corrected by a two-staged surgical procedure (Elmslie's operation). In the first stage, the cavus deformity is corrected by fusion of the talonavicular joint and release of the tight plantar fascia (Steindler's operation). A below-knee plaster is maintained for 6–8 weeks. In the second stage, the active tendons of the tibialis posterior, peronei and long toe flexors are transferred into the tendoachilles, in association with fusion of the subtalar joint. Postoperatively, a plaster cast is maintained for 8–

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10 weeks.

3. ***Talipes varus:*** Paralytic varus deformity of the foot results from paralysis of the peronei muscles and the overaction of the tibialis anterior and posterior muscles.

This deformity is corrected by transfer of the tibialis anterior tendon into the cuboid bone. Postoperatively, a below-knee plaster cast is given in the corrected position for a period of 3–6 weeks, after which the foot is mobilized.

4. ***Talipes valgus:*** It is caused by paralysis of the tibialis muscle. The overaction of the peronei results in valgus deformity and also causes drop of the first metatarsal. Since the tibialis anterior is paralysed, the long toe extensor acts as dorsiflexor of the ankle and further aggravates the clawing of the big toe.

The valgus deformity is corrected by transfer of the peroneus brevis into the medial cuneiform bone. Bony stabilization of the talocalcaneal joint, with the help of a strut graft can correct this deformity in children above 4 years of age.

The first metatarsal drop is corrected by an operation (modified Jones' operation) consisting of transfer of the extensor hallucis longus tendon into the neck of the first metatarsal and fusion of the interphalangeal joint of the big toe. A below-knee plaster cast is given for 6–8 weeks after the operation. In cases untreated up to the age of 13 years, triple arthrodesis is indicated to correct the deformity.

Triple arthrodesis: This is a commonly performed bony stabilization procedure for paralytic foot. It is performed after 13 years of age. If

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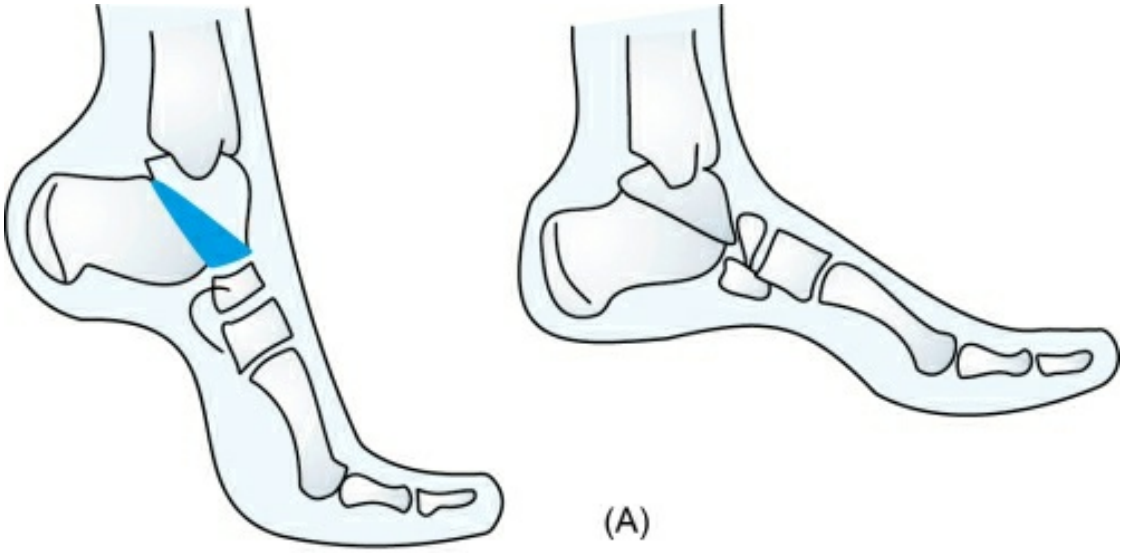
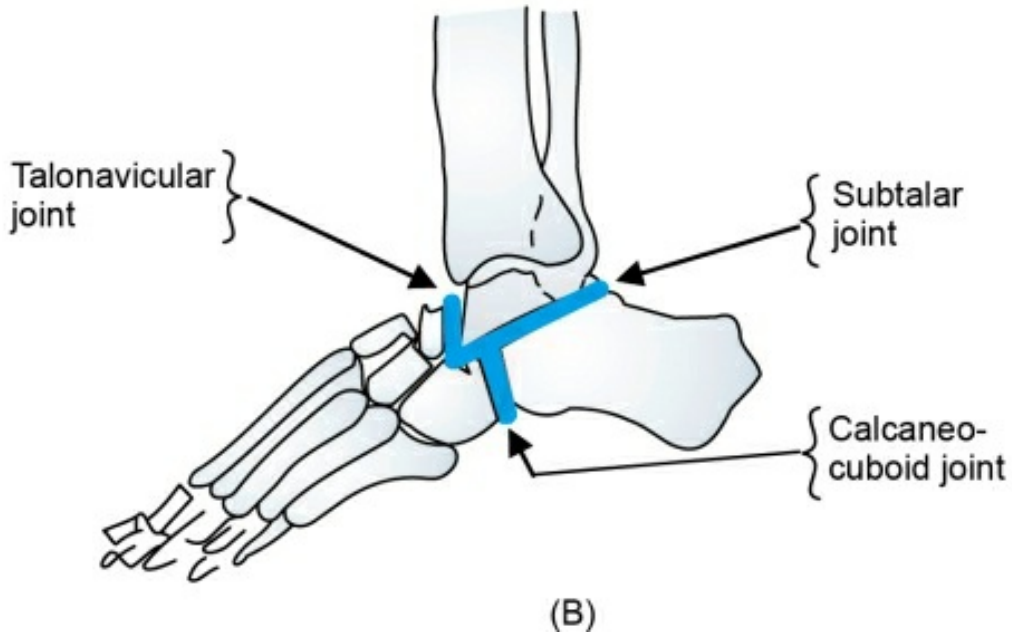
performed earlier, the fusion may not be solid due to abundance of cartilage and may also result in a short foot due to growth disturbances.

In this operation, the subtalar (talocalcaneal), talonavicular and calcaneocuboid joints are fused. A below-knee plaster cast is applied for 3 months after the operation.



(A)



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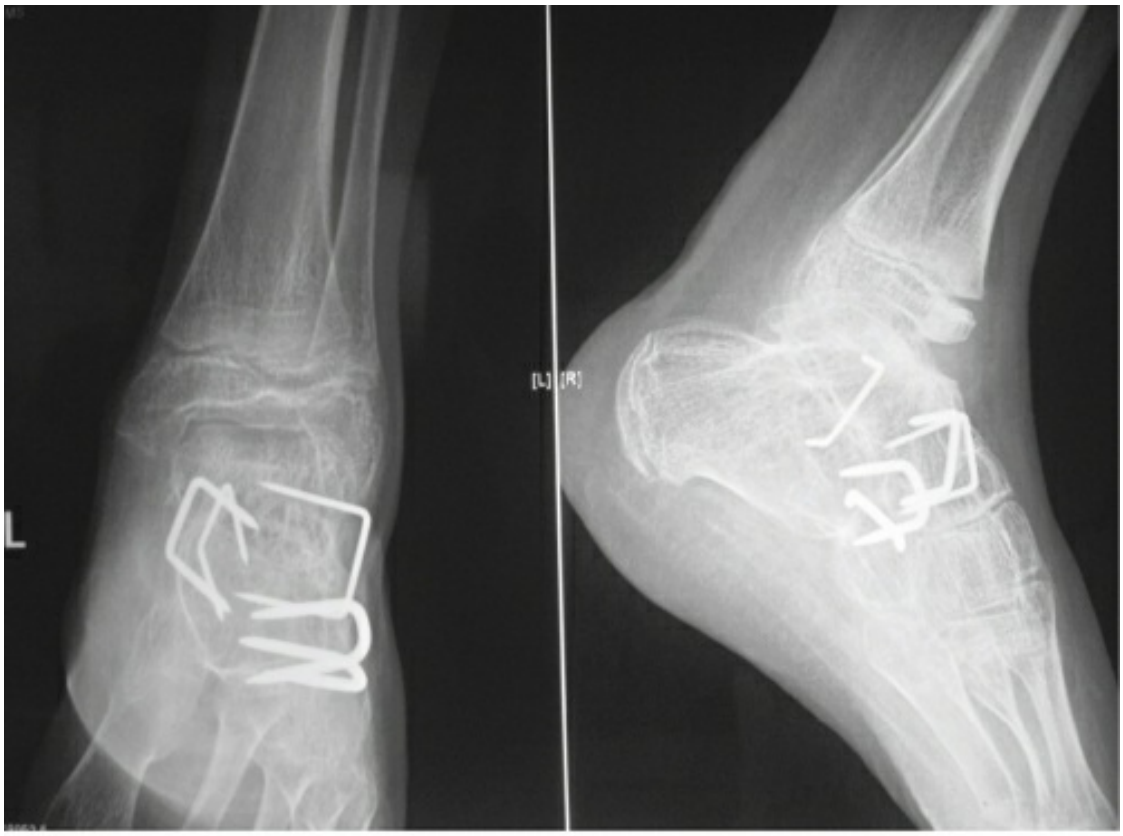

(C)

FIG. 28-6 **(A)** Lambrinudi triple arthrodesis. Bones in the shaded area are excised to get the correction of the deformity. **(B)** Triple arthrodesis. **(C)** Postoperative X-ray showing triple arthrodesis using staples.

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FIG. 28-7 Triple arthrodesis. Note that the talonavicular, talocalcaneal and calcaneocuboid joints have fused well. The joints have been fixed with multiple screws.

Correction of the limb length disparity

Moderate-to-severe paralysis of the lower extremity almost always results in shortening of the affected limb. The degree of shortening perhaps has some relationship with the severity of the paralysis, i.e., the more severe the paralysis, the more will be the shortening.

The methods of correction of disparity in the lower limb are as follows:

1. *Shortening of the normal (or longer) limb:* The normal limb may be shortened by arrest of the epiphyseal growth or by resection of bone from the femur or tibia. This operation is, however, rarely ever performed.

2. *Lengthening of the affected (short) limb:* The procedure of lengthening

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is undertaken in the femur or tibia depending on the site of shortening. The degree of real shortening of the limb is measured both clinically and by scanograms. The amount of lengthening to be achieved is then calculated accurately and the surgery is planned. If the shortening is in both the femur and the tibia, the bones can be lengthened simultaneously or in stages.

The lengthening of the femur or tibia can be undertaken by any of the following methods:

(a) **Tubular fixator (Wagener's technique)/femoral lengthening:** The femur is osteotomized (cut) through the shaft and an external fixator (with distractor) is applied (Fig. 28-8). The femur is then gradually distracted every day, achieving the desired amount of lengthening over a period of time (usually in weeks). The lengthened portion of bone gets filled up spontaneously with bone or alternatively, bone grafting and plating is done to hasten the process of consolidation. In the former situation, the external fixator is maintained for a period of 3–6 months, till the bone forms adequately; while in the latter case, the fixator can be removed at the time of plating operation. Mobilization of the adjacent joints may be started early, in consultation with the surgeon, while weight bearing is delayed till the bone consolidates.

Tibial lengthening: It is carried out in two stages. In the first stage, the lower fourth of the fibula is fixed to the tibia so that the ankle mortise remains stable during the second stage of leg lengthening (Fig. 28-9). The rest of the procedure is same as that for femur, i.e., osteotomy of the tibia followed by gradual distraction. It can also be continued either in the external fixator or fixed internally with a plate.

(b) **Ring fixator (Ilizarov technique):** In this method, thin wires are passed into the bone under tension and connected to half- or full-circle rings. The most commonly used ring fixator is called the Ilizarov

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fixator, after its innovator. The bone is cut (by corticotomy) in the area of metaphysis (either the proximal or distal) and gradual distraction is done to increase the length of the bone. New bone, called *regenerate*, forms into the gap, thus created by distraction.

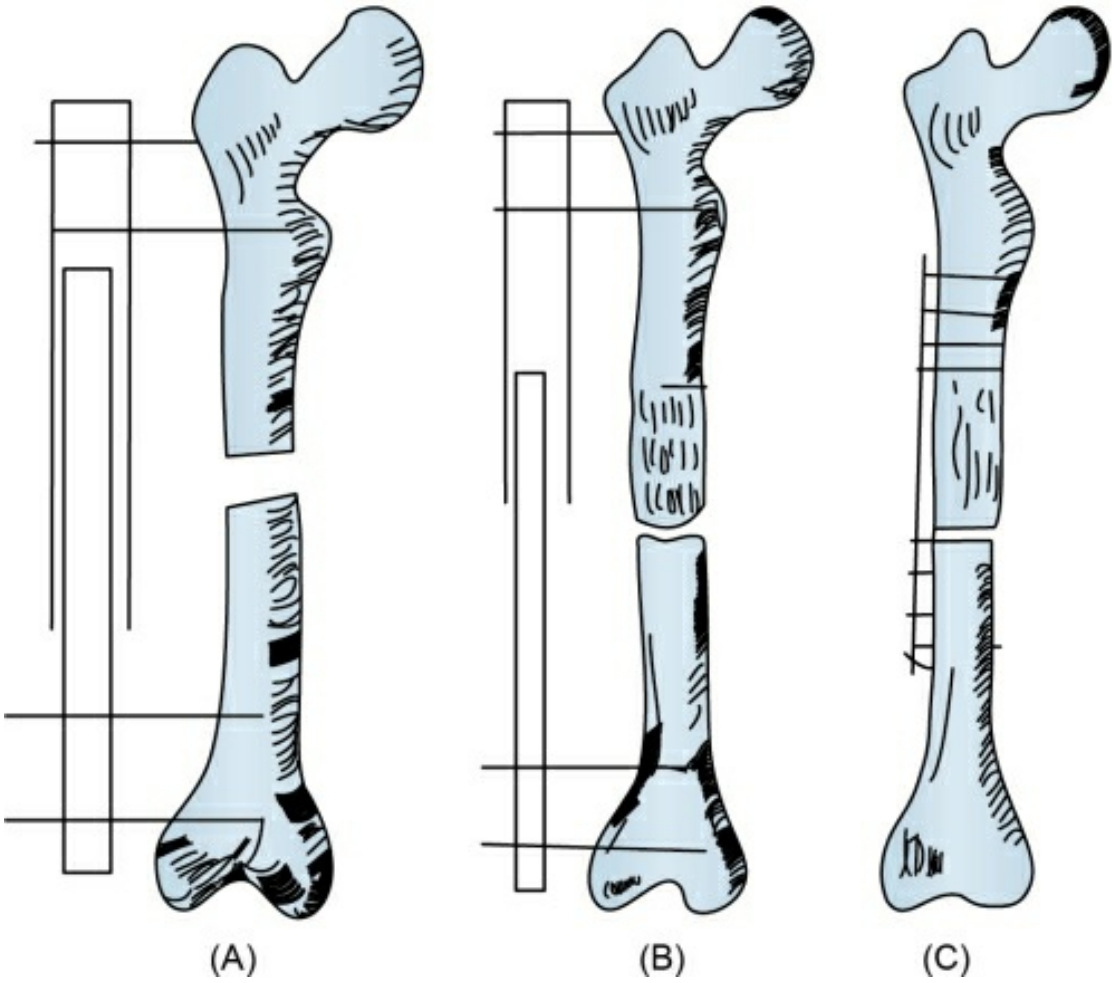

FIG. 28-8 Femoral lengthening (Wagener's technique). **(A)** Femur osteotomized at shaft and external fixator with distractor applied. **(B)** Desired lengthening has been achieved and bone formation has taken place in the gap. **(C)** Plate and screws are applied and external fixator removed.

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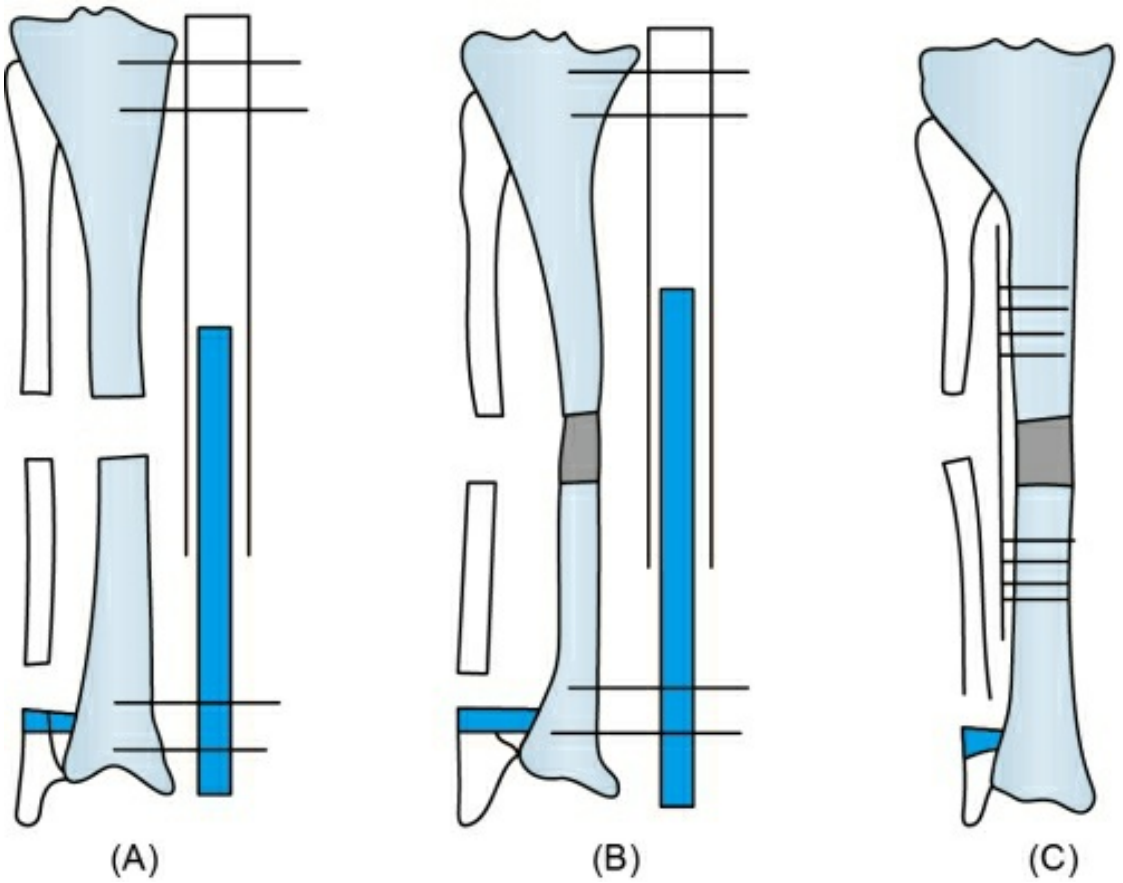

FIG. 28-9 Tibial lengthening (Wagener's leg lengthening technique). **(A)** Tibia and fibula are osteotomized and the distraction apparatus is attached medially, leaving the desired gap between the bony ends. **(B)** Bone formation takes place in between the osteotomized bony ends. **(C)** Plate and screw fixation is done to achieve consolidation of the new bone formed and external fixator is removed.

Complications

1. **Nerve complications:** These develop due to rapid distraction. The patient complains of tingling, numbness and pain in the part distal to the lengthening. If these symptoms develop, the distraction is stopped temporarily till the symptoms disappear.

2. **Vascular complications:** These are rare. Sudden distraction may cause spasm of the arteries leading to vascular embarrassment of the distal segment of the limb.

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3. **Deformities of the foot:** These are common in tibial lengthening. Tight heel cord causes equinus deformity of the foot. Manipulation or surgical stabilization may be required for correction of the deformities.

4. **Pin tract infection:** Infections in the pin tract may have some pus discharge requiring regular dressings. Pin tract infection may also loosen the pin requiring replacement of the pins.

5. **Arthritis of the adjacent joints**

6. **Fracture through the lengthened part:** Premature weight bearing, before the bone consolidates, may cause fracture of bone through the lengthened segment. This may require prolonged plaster immobilization.

Physiotherapy following surgery

The basic approach of physiotherapy varies according to the type of the surgical procedure:

1. After release of the soft tissue contractures, measures should be taken to avoid recurrence of contracture.

2. Following tendon transplants, the emphasis is on re-education of the transplanted muscle to its new role.

3. Following the joint arthrodesis, the emphasis is on educating the functional use of the limb in which the joint is arthrodesed.

Release of the soft tissue contractures

Preoperatively, the joint over which the contracted soft tissue passes is kept in a state of maximum mobility by passive stretching and passive movements. Postoperatively, during immobilization, vigorous exercises are given to the joints that are free from immobilization.

1. Positioning: Positioning of the operated limb in particular and of

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the body as related to the joint of the soft tissue release is of primary importance. This positioning should not facilitate recurrence of the contracture. Long periods of prone lying are important to prevent recurrence of hip flexion contracture following Soutter's release. Maintaining optimal extension at the knee after release of the iliotibial band and the hamstrings are important. Maintaining neutral dorsiflexion is mandatory in the release of tendoachilles. Many a times, it is necessary to retain the posterior shell of POP or suitable orthoses till the position of correction is maintained with active efforts by the patient.

2. Mobilization: Graded mobilizing procedures are used to regain early full ROM at the joint related to the soft tissue release. Relaxed passive movements following soothing heat are ideal.

3. Muscle strengthening and endurance exercises: To achieve active maintenance of the corrected position of the joint concerned, exercises are given to improve strength and endurance of the muscle groups antagonistic to the ones that were released surgically. Therefore, gluteus maximus in the release of hip flexion contracture and quadriceps in the release of knee flexion contracture need special attention. Agonistic control as well as overall strengthening of the other muscle groups of the limb should not be neglected. Surgical scar should be mobilized by friction massage or ultrasound, to avoid it getting adherent.

4. Re-education: Re-education in the proper use of the joint, weight bearing and gait is done to avoid recurrence of soft tissue contractures.

5. Home treatment programme: Simple regular regime of correct positioning and exercises need to be continued at home.

Tendon transfers

Preoperative management and training – preoperatively, four factors need special consideration:

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1. Due to imbalanced muscular action, the concerned joint is most likely to get stiff in the direction of the weaker muscle, e.g., limitation of inversion in dorsiflexion when anterior tibial group is paralysed and peronei are strong. The transplant can never be effective unless full ROM is achieved at the concerned joint in the direction of the proposed action of the transplant.

2. The muscle to be transplanted is bound to get weak after the transposition and therefore it should be stronger before surgery. Therefore, concentrated sessions of preoperative training of strengthening and isometric holding of the muscle to be transplanted is a must.

3. There is a tendency for the transplanted muscle to continue its previous action even after transposition. This is avoided by adequate training of the patient on the contralateral limb, e.g., correct groove of dorsiflexion with inversion is repeatedly practised on the contralateral limb before undertaking peroneal transplant for the paralysed anterior tibial group.

4. Specific strengthening procedures are given to the associated muscle groups of the movement for which the transplant is planned. These muscle groups are instrumental in assisting the performance of the transplanted muscle. For example, extensor digitorum and hallucis longus are strengthened when the peroneal transplant to the dorsum of the foot is planned to assist dorsiflexion.

Therefore, adequate preoperative training and exercises are absolutely essential before surgery. Postoperatively, re-education of the transplanted muscle is equally important.

- Begin with guided passive full-range movement in the exact groove of the expected arc of movement. Gradually progress to assisted movement by encouraging the patient to actively contract the transplanted muscle.

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- Electrical stimulation synchronized with the patient's effort is extremely useful in re-education. Biofeedback also provides an excellent means of re-education.

The sessions of muscle re-education and strengthening should be continued and progressed till strong and controlled movements by the transplanted muscle are achieved. Guided functional training hastens the recovery.

Dynamic orthosis may sometimes become necessary to provide assistance and to avoid unwanted movements.

Arthrodesis: This is a joint stabilizing procedure where immobilization is usually done for a long period.

Preoperative training

The patient is taught the procedures of functionally using the limb effectively, e.g., non–weight-bearing crutch walking. Exercises are given to strengthen the movements of the joints adjacent to the joint to be arthrodesed.

Mobilization of the shoulder girdle and pelvic girdle are given when the arthrodesis is planned for shoulder and hip, respectively. It helps in the functional use of the limb following stabilization.

During immobilization: Vigorous exercises are given to the joints free from immobilization.

Gait training is started as soon as the pain recedes.

Mobilization: The exercise programme is made vigorous, emphasizing endurance training. As the initial weight bearing is painful, weight transfers to the limb; single leg balance and ambulation are done in a graduated manner. Adequate walking aid may be necessary initially, but it should be waned gradually.

Functional use of the operated joint is emphasized by teaching compensatory mechanisms by using adjacent

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joints.

Correction of the limb length disparity: Like arthrodesis, the period of immobilization is long and therefore strengthening and endurance exercises are emphasized to all the free joints.

Proper positioning of the limb is ensured in the external fixator. Isometrics to the glutei and quadriceps are given on removal of the external fixator or POP. Gradual training in weight bearing, weight transfers, balance and gait is initiated and progressed to normal use.

Rehabilitative surgery

Orthopaedic surgery plays a crucial role in patients after 18 months to 2 years when the period of neuronal recovery comes to a standstill.

Objectives

- To correct or minimize the influences of soft tissue contractures
- Reconstructive surgery in the form of tendon transfers to
- Compensate for a loss of function due to the paralysis affecting the prime movers of a particular movement
- To eliminate the deforming forces
- To improve muscle imbalances, giving rise to marked instability while performing functional activities

Joint arthrodesis

To permanently stabilize a flail joint not allowing functions of the distal nonparalysed muscle groups, e.g., hand grip in flail wrist.

Osteotomy – correcting bony deformities hindering the function.

Examples

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1. Correction of deformity due to soft tissue contractures

Joint	Contracture	Surgical Procedure
Hip	Flexion contracture	Soutter's release
Knee	Flexion contracture	Mild degree – division of iliotibial tractModerate degree – lengthening of hamstrings Severe degree – Hamstrings release coupled with posterior capsuloctomy of the knee joint
Ankle	Contracture of tendoachilles	Z-plasty, release of a tight tendoachilles (Fig. 28.6)
Foot	Tight plantor fascia	Surgical release
	Cavus deformity	Steindler's procedure

2. Tendon transfer procedure

Muscles used for transfer	To compensate for a paralysed muscle
Shoulder: trapezius	To the neck of the humerus to compensate for the paralysis of deltoid muscle for shoulder abduction
Elbow: common origin of elbow flexors	Transferring common flexor origin at the medial epicondyle to the anterior aspect of the lower end of the humerus (Fig. 28-3)
Hand: FDS tendon from the middle phalanx of the middle finger to the thumb (Fig. 28-5)	Transferred to the abductor pollicis brevis to act as thumb abductor To facilitate opposition at the carpometacarpal and metacarpophalangeal opposition and flexion, and extension at the IP joint of thumb
• Iliopsoas and erector spinae	• Transferred to paralysed gluteus maximus to compensate for paralysed hip extensors
Tensor fascia lata	Transferred to paralysed gluteus medius to act as hip abductor
Hamstrings	Transferred into patella to act as knee extensors (quadriceps)
Tibialis	Tibialis tendon to the cuboid bone to act as ankle and foot eversion (peroneal muscle) to compensate for talipes varus due to paralysed peronei
Peronei	Talipes valgus due to paralysis of tibialis anterior – peroneal muscles are transferred to the cuboid bone to control talipes valgus
Extensor hallucis	Transfer of the tendon of the extensor hallucis into the neck of the first metatarsal bone with fusion of the IP joint of a great toe, to reduce the dropping of the head of the 1st metatarsal bone

3. Joint arthrodesis: fusion

Joint	Purpose
Wrist	To stabilize the wrist joint in 15 degree extension to improve grip by facilitating stronger finger flexion improving grip strength

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Spine	Fusion to provide stability to the spine (with or without instrumentation)
Talipes calcaneus (due to paralysis of gastrosoleus)	Stage I: Correction of cavus by the fusion of talonavicular joint with Steindler's release
	Stage II: Transfer of tibialis posterior, or peronei or the long toe flexors into tendoachilles
Talipes equinus	Triple arthrodesis (Fig. 28-7, B and C; Fig. 28-8)

4. Osteotomy – to correct bony malalignments and deformities like genu varum.

5. To correct the disparity in the leg length like shortening of the affected lower extremity by Ilizarov technique, Wagner's technique (Figs. 28-8 and 28-9).

Prevention of late effects of poliomyelitis

Recent studies on the follow-up observations of the polio epidemics of 1935–1955 have highlighted certain late complications.

Late complications

1. Joint pains and degenerative joint disease

2. Myofascial pains

3. Gradually decreasing endurance

4. Gradually decreasing strength in the affected as well as unaffected muscles

5. High incidence of fractures

6. Increasing respiratory insufficiency (in bulbar poliomyelitis patients)

7. Compressive neuropathy

8. Decreased ability to ambulate and in performing ADLs (Agre et al.,

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1998; Halstead & Rossi, 1985; Perry et al., 1988)

All these complications arise due to the following factors:

1. Lack of regular checkup

2. Discontinuance of exercises

3. Discontinuing supportive aids

4. Deconditioning from injury or immobilization

5. Disregarding the advice to avoid sustenance of posture and activities causing excessive stretch or joint compressions

6. Lack of exercises, excessive sedentary lifestyle with increased body weight

Physiotherapeutic management

The major factor of increasing age in these patients cannot be overlooked. However, certain measures and advice will definitely prevent these complications or reduce the intensity of ill-effects due to them.

Physiotherapeutic advice cannot be generalized as the expected complications depend upon the degree and the area involved in an individual patient. It has to be planned on an individual basis. At discharge, the patient should be fully assessed for the expected complications and given a suitable programme to prevent them. The following measures should be taken:

1. Identification of the susceptible areas and thorough education to prevent them.

2. Insist on follow-up visits at regular intervals so that any faulty attitude can be rectified at the earliest.

3. Complications like articular pains, due to joint generation and pains

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of muscular origin are all related to the modern, physically overdemanding lifestyle. Therefore, proper advice on controlling daily activity by proper energy consumption or energy conservation by the use of wheelchair or motorized scooter or other assistive aids may be necessary. Postural requirements of job or work also need to be critically analysed and corrected, along with other activities of daily routine.

4. Exercise programme should be directed to improve strength, endurance and flexibility of the specific muscle groups that are functionally important. At the same time, it should not result in the overuse of weak muscles. The regime of exercise as reported by Perry et al. (1987) has proved to be beneficial. It consists of moderate intensity exercise with low rate of repetition. 60–70% of the maximum resistance is applied for 5–10 repetitions to each functionally important muscle group, done once a day. This has resulted in increased endurance, agility and the functional ability (walking) of postpolio patients.

Study conducted by Perry et al. (1988) indicated that the instances of overuse were present in the following muscle groups:

- The biceps femoris (82%)
- The quadriceps (53%)
- The soleus (34%)
- The gluteus maximus (34%)

Therefore, these muscle groups should be given regular strengthening exercises, but at the same time, the activities putting extra strain on these muscle groups should be prevented. To prevent contractures, simple techniques of

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sustained stretching should be taught to the common susceptible musculotendinous complexes.

5. Regular use of aid and appliances: The ambulatory aids and orthoses prescribed at the time of discharge should be continued to avoid undue strain. Patients should not discard them unless advised to do so.

6. For the patient with respiratory insufficiency, the emphasis should be on respiratory exercises to improve vital capacity.

7. Compressive neuropathy: Carpal tunnel syndrome and ulnar neuropathy at the cubital tunnel may result from overuse and compressive forces from the incorrect use of cane, crutch and wheelchair. The patient using assisting devices should be educated on the proper use of these aids and to report immediately if any symptoms occur, so that they can be controlled at the earliest.

8. Control of body weight: Patients with sedentary life-style should be strictly warned against the possible ill effects of overweight.

9. Properly controlled programme of aerobics may be helpful in improving the overall physical fitness.

10. Susceptibility to injury and fractures can be avoided by advising against continuation of strenuous activities after muscle fatigue.

Reconstructive surgery and tendon transfers may be necessary to correct deformity and its ill effects. Joint stabilization procedures may be necessary to offer stability to the unstable joint. A stable joint will prevent undue stresses in the related joints, e.g., triple arthodesis will prevent strains on the hip and knee. Thus, regular monitoring of these factors is necessary to prevent or to reduce the gravity of such late effects.

Summary

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Anterior poliomyelitis is an infective viral disease transmitted through the droplets infection or by oral ingestion.

The virus is resistant to antibiotics, enters through the tonsilopharyngeal route, multiplies and disseminates in the CNS. It has a specific affinity to the anterior horn cells of the spinal cord causing their destruction and permanent damage. Affects mainly children within 1 year age but may affect children up to 5 years. The phases of the disease are as follows:

Acute phase: During the acute inflammatory phase of (first 2–3 weeks), the virus multiplies and spreads to the CNS. It is associated with fever and tenderness in the affected limb muscles; restlessness may be present.

Subacute phase (3–6 weeks to 6 months): A phase of maximum recovery and a phase of maximum physiotherapeutic efforts to strengthen the paretic muscle.

Chronic phase: When there are no chances of further muscular recovery.

More than 18 months of the onset: The treatment is mainly concentrated on functional re-education of the affected limb or limbs by providing aids, appliances, reconstructive surgical procedures and compensatory techniques to assist ADRs.

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Chapter 29

Arthritides

Outline

■ Classification of arthritis

■ Osteoarthritis (general)

■ Osteoarthritis of the hip

■ Osteoarthritis of the knee

■ Osteoarthritis of the ankle

■ Osteoarthritis of the foot

■ Osteoarthritis of the wrist and hand

■ Osteoarthritis of the shoulder

■ Osteoarthritis of the elbow

■ Osteoarthritis of the wrist

■ Osteoarthritis of the trapeziometacarpal joint of the thumb

■ Osteoarthritis of the temporomandibular joint

■ Osteoarthritis of the sacroiliac joint

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- Rheumatoid arthritis
- Juvenile rheumatoid arthritis
- Seronegative spondyloarthritis
- Still disease
- Haemophilia (haemophilic arthritis)
- Ankylosing spondylitis
- Other forms of seronegative arthropathies
- Metabolic arthritis
- Connective tissue diseases
- Charcot joint
- Miscellaneous conditions

Arthritis

Inflammation of a joint is called arthritis. Affections of the joint may be generalized, as a part of a systemic disease; or may be localized with the involvement of a particular joint due to some local problem.

Classification of arthritis

Arthritis is classified into several categories as listed in Table 29.1.

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Table 29-1

Classification of Arthritis

1. Osteoarthritis (degenerative)	(a) Primary (b) Secondary
2. Rheumatoid arthritis	(a) Seropositive • Rheumatoid arthritis • Juvenile rheumatoid arthritis (b) Seronegative • Ankylosing spondylitis • Reiter disease • Psoriatic arthritis • Enteropathic arthritis
3. Neuropathic arthropathy	
4. Metabolic arthritis	(a) Gout (b) Pseudogout

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	(c) Alkaptonuric arthritis
5. Arthritis in systemic disease	Haemophilia
6. Miscellaneous	(a) Villonodular synovitis (b) Synovial chondromatosis

Osteoarthritis

Osteoarthritis is a noninflammatory degenerative disorder of the joints characterized by progressive deterioration of the articular cartilage and formation of new bone (osteophytes) at the joint surfaces. It is called (a) *primary* when the aetiology is natural wear and tear with aging, overuse or obesity and (b) *secondary* when it follows some known primary cause, e.g., trauma, infection and rheumatoid arthritis (RA).

It is more common in weight-bearing joints such as the hip and the knee. It is also seen in the spine, carpometacarpal joint of the thumb and distal interphalangeal (DIP) joints of fingers. The concept of 'wear' and 'tear' is generally attributed as a cause of osteoarthritis. It holds true as osteoarthritis is seen commonly in weight-bearing joints, predominantly in the middle and older age groups. Various other factors such as obesity and hormonal and genetic factors have been found as a pathology to predispose to

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idiopathic osteoarthritis.

Common sites of osteoarthritis

■ Weight-bearing joints: Hip, knee, ankle and spine

■ Overused joints: wrist joints, carpometacarpal joint of thumb, distal metacarpophalangeal joints, etc.

■ Most common site: knee joints

In osteoarthritis, there occurs loss of the ground substances of the cartilage, which results in disturbance of dissipation of the stresses. The collagen fibres are, therefore, subjected to excessive stresses and strains leading to their rupture. The cartilage develops fissures, gets eroded and exposes the underlying subchondral bone. Microfractures of the trabeculae develop in the subchondral bone. Resorption of these microfractures results in subchondral cyst formation, a characteristic radiographic feature of osteoarthritis. Inflammatory synovitis, may occur; the new bone and cartilage outgrowths developed at the margins of the articular cartilage are seen as osteophytes on radiographs (Fig. 29-1A and B).

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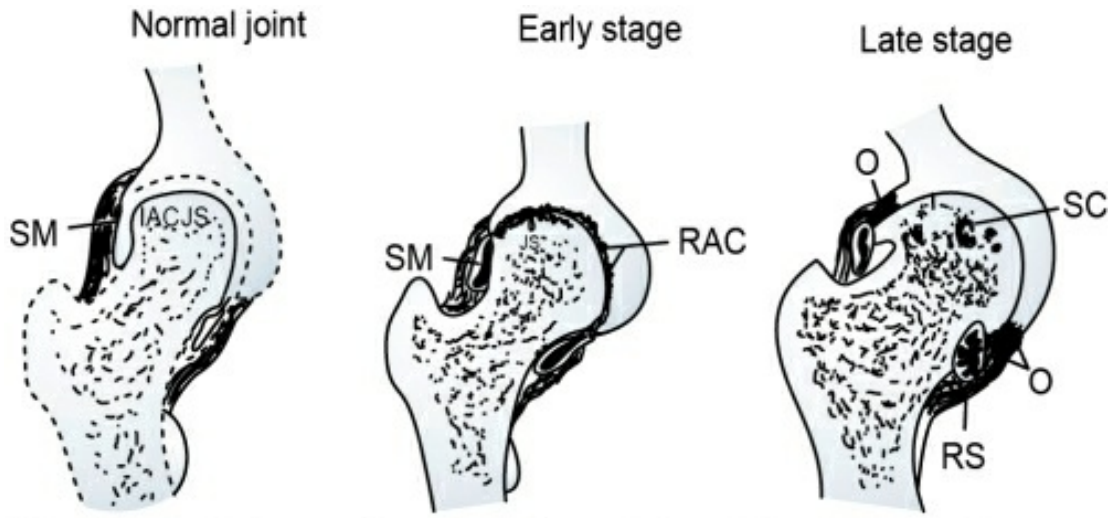

IAC = Intact articular cartilage
JS = Normal joint space
SM = Synovial membrane

JS = Narrowing of the joint space with fibrillation and roughening of articular cartilage (RAC)

JS = Loss of joint space
O = Remodelling osteophytes (Lipping)
RS = Reactive synovitis
SC = Subchondral cyst

(A)

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(B)

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(C)

FIG. 29-1**(A)** Course of osteoarthritis of hip – diagrammatic representation. **(B)** Preoperative radiograph. **(C)** Postoperative radiograph after noncemented total hip arthroplasty done on both sides.

Clinical features

Pain is the main presenting symptom. Initially, the pain occurs usually during or after weight-bearing activity, or at the end of the day. Later on, it becomes continuous, occurring even at rest. The joint becomes swollen due to synovitis. Stiffness gradually sets in, following severe pain and capsular contractures. In the late stages of the disease, the joint becomes deformed. A common example is genu

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varum deformity at the knee (see Fig. 29.4). It may be caused by ligamentous instability, capsular contractures or muscle imbalance at the later stage of the disease.

On examination, there is swelling due to synovial thickening and/or effusion, muscle wasting and prominence of the articular margins due to osteophytes. Movements are painful and restricted. Crepitus is felt on passive joint movement. In the late stages of the disease, loose bodies may develop in the joint, causing recurrent joint effusion, pain, swelling and locking of the joint.

Radiographic examination reveals the following main features (Fig. 29-2):

- Narrowing of the joint space
- Osteophytes at the margins of articular cartilages
- Sclerosis and cysts in the subchondral bone

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FIG. 29-2Osteoarthritis of both hip joints. Note the reduction in joint space, osteophyte formation and subchondral cysts. There is also deformation and collapse of the femoral head.

Treatment

Conservative treatment

Reduction in the quantum of load on the joints is an important aspect of the treatment of osteoarthritis. An obese patient should be advised to reduce weight and minimize compressive forces on the affected joint by proper body mechanics and the use of ambulatory aids. Analgesics and anti-inflammatory drugs are used to control pain with

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correct pain-relieving physiotherapeutic modality.

Excessive jerks and strenuous movements should be avoided to protect the joint from injury. Joint deformity should be prevented as it alters the biomechanics and puts uneven strain on the joint. Physical therapy is the mainstay of the treatment and should be started early.

Surgical treatment

In osteoarthritis, surgery is indicated in progressively increasing pain that is not relieved by conservative treatment. The surgical treatment is discussed in the following pages in connection with the disease of individual joints.

Principles of physiotherapeutic management (general) in osteoarthritis

Osteoarthritis is neither a condition of relentless progression nor a disease. It is the result of imbalance between the mechanical stresses on the joint and the ability of the tissues to withstand them (Radin, 1987).

General principles of treatment

1. Prevention

2. Control of pain

3. Prevention of further damage

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4. Improvement in range of motion (ROM)

5. Improvement in strength, endurance and muscle functions of muscle groups passing over the involved joints

6. Improvement in the functional status of the involved joint and the whole body – with correct ergonomic control

The methods of management vary with each joint, its functions and the degree of its involvement.

To plan an appropriate physiotherapeutic programme, it is essential to conduct a thorough physical examination and correlate it with other clinical investigations.

The physiotherapist should be able to detect the altered joint kinematics, through joint play movements, at the early stage. The therapy is concentrated not only on improving the muscle strength, endurance and mobility, but also on restoring normal movements and muscle action at the joint.

Assessment

1. ***Assessment of pain:*** Pain is an index of the degree of joint irritability. The site of pain, its nature and duration are noted. The factors that precipitate pain-like jarring and compression (weight bearing), sustained stress, specific movement, rest and posture should be recorded since prevention of further damage is directly related to these factors. Similarly, factors providing relief of pain are also recorded. These factors are modified and are made more effective by providing guidance to the patient. Rest or

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particular movement or postural adjustment may relieve pain. First evaluate the intra-articular factors causing pain. Pain may be the result of the following:

(a) Destruction of the cartilage exposing the subchondral bone to compressive forces

(b) Osteophytes that may encroach upon the synovial lining of the joint – The osteophytes may directly exert compression on the soft tissues of the joint as loose bodies; overall pain can be reliably assessed by the visual analogue scale (VAS)

(c) Imbalanced stretch that may occur on the weight-bearing joint surfaces due to wear and tear of the cartilage.

2. ***Assessment of function:*** The impact of the disease on the functional performance of the patient is examined and recorded on a functional evaluation chart.

3. ***Assessment of joint stiffness:*** Accurate evaluation of the passive ROM with its end feel is an important index of stiffness. The type of joint restriction, whether capsular or noncapsular, should be noted. The capsular type is indicated by the loss of mobility of the entire joint capsule. A firm and leathery end feel without effusion indicates capsular fibrosis, while an abrupt locking end feel without any apparent stretching of the antagonists indicates bony ankylosis. The range at which pain or discomfort sets in is also recorded along with the overall basic and accessory movements.

4. *Assessment of strength, endurance, tone and volume* of the muscle groups related to the involved joints are

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systematically recorded.

5. ***Assessment of tenderness:*** The degree and the area of tenderness, effusion and crepitus are carefully examined by palpation, volumetric measures or measuring tape and relaxed passive ROM, respectively.

6. ***Assessment of deformity:*** It is extremely important to measure the degree of deformity accurately. The deformity may be fixed or dynamic when exposed to compression. The assessment should, therefore, be done in the position of maximum compression, e.g., weight bearing on the affected leg alone.

Prevention: Physiotherapy can play a vital role in the prevention of the painful symptoms of osteoarthritis. Understanding the following factors in the pathogenesis of osteoarthritis facilitates the planning of a prevention programme.

1. ***History of trauma:*** A single episode of trauma causing excessive compression of the cartilage is enough to initiate the degenerative changes. Therefore, individuals with a definite history of trauma to the knee are susceptible to develop osteoarthritis.

2. ***Characteristics of joint cartilage:*** The joint cartilage is avascular and aneural, with the absence of pain receptors. Therefore, it is susceptible to fatigue. It also lacks the normal inflammation and repair response. These factors lead to the advancement of degeneration with microfractures without any symptoms. The symptoms of pain, stiffness,

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inflammation occur only in the advanced stage of degeneration, when the synovial effusion stretches the joint capsule and the pain sensitive receptors are fired. Initiation of appropriate physiotherapy is advisable at the early stage (may also result in acute synovitis).

3. ***Effects of immobilization:*** Prolonged immobilization results in irreversible osteoarthritic changes. Knee immobilization for 4 weeks produces compression between the articular surfaces, which is approximately three times its initial level. This is accompanied by shrinkage of periarticular soft tissues with marked increase in the synthesis of collagen and glycosaminoglycans (Eronen, Videman, Friman & Michelson, 1978). Increased fibrosis of periarticular tissues, cartilage proliferation at the joint edges, atrophy in the weight-bearing areas, regional bony eburnation, sclerosis and resorption can occur even after 2 weeks of immobilization (Langenskiold, Michelsson & Videman, 1979). This proves the importance of early mobilization.

4. ***Weight bearing:*** Early and unprotected weight bearing also leads to unequal stresses on the joint. The presence of a deformity, even of a mild nature, increases the susceptibility of the imbalanced compressive forces on the joint. Early measures should be taken to detect and check the disposition of weight-bearing axis, especially in relation to the lower extremity joints.

5. ***Full ROM exercises:*** It has been observed that osteoarthritis of the hip is rare in the population where the hip joint is frequently subjected to full ROM. This

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observation proves the importance of full ROM as a preventive factor. In floor squatting, the total area of the articular cartilage is intermittently subjected to compression due to weight bearing and should be encouraged.

Measures of prevention

1. Early identification of individuals at risk, e.g., with a history of trauma to the joint, those with obesity and deformities at the related joints, those with a stressful overuse joint tendency, should be done.

2. Critical examination of the joint kinematics in weight-bearing and non–weight-bearing positions should be done as well as examination of the end feel and joint play movements, and excursion of the axis of weight bearing. Radiographic findings can also help in early detection.

3. Guided measures are to be taken depending on the findings of the examination to prevent or control further deterioration of degeneration like:

(a) Strengthening, improving flexibility and endurance of concerned muscle groups

(b) Corrective measures to compensate the influence of altered stresses on the joints by using viscoelastic inserts, avoiding undue strain

(c) Exercises to be directed to lower the impact of excessive force across the involved joint: This is achieved either by decreasing the contractile force of the muscles or by making

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muscles more efficient so that they do not contract as strongly to produce the same effect; thus, controlled activity of the muscle group can prevent compression of the joint due to excessive contraction

(d) Guidance on avoiding various postures and activities causing excessive compression of the susceptible joints, e.g., repetitive sitting and standing, long standing, step climbing

(e) Nutritional guidance for obese individuals

(f) Inhibition of degenerative changes during immobilization by providing safe and limited ROM devices like non–weight-bearing functional orthosis – Traction or continuous passive motion (CPM) are also useful (Videmann, 1987) and strong repetitive isometrics

(g) Early management of congenital anomalies (congenital hip dislocation and acetabular dysplasia), infective conditions of joints and intra-articular fractures

(h) Graduated resistance to the full arc of movement or controlled loading through full ROM: It is necessary to expose the maximum area of cartilage to the stimulus of weight bearing; public awareness of these facts can prevent progression of osteoarthritis

Treatment

The treatment is planned by giving due considerations to the patient's lifestyle, physical requirements, body weight and the reports of evaluation. It is difficult to generalize the

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treatment for all patients of osteoarthritis. The basic approaches can be enumerated as follows:

1. ***Pain control***

(a) To control pain, suitable electrotherapeutic modality should be used. In the acute phase, pain relief is achieved better by superficial heat modalities or cryotherapy. Ultrasound therapy, transcutaneous electrical nerve stimulation (TENS), diapulse, pulsed diathermy and stimulation are also effective. Short-wave diathermy (SWD) may be used in the later phase when the tissue oedema is less.

(b) Hydrotherapy is particularly useful when the weight-bearing joints are affected.

(c) The compressive forces on the joint can be reduced by resting in a proper position, splints or joint distraction by manual or mechanical traction, CPM or functional bracing.

2. ***Improvement of muscle power, endurance and tone:*** Graduated exercise programme is initiated, which consists of progressive resistive exercises (PRE), strong and sustained repeated sessions of isometrics (5 min every hour) holding or sustaining muscle contractions in static midrange position of the isotonics.

3. ***Improvement in ROM***

(a) Active free relaxed rhythmic movements improve the range as well as promote relaxation of the joint.

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(b) Relaxed passive movements should be started first to mobilize stiff joints. Hydrotherapy and proprioceptive neuromuscular facilitation (PNF) techniques are useful in improving ROM. When mechanical dysfunction blocks the movement, manipulation and mobilization and manual therapy techniques are effective.

4. ***Improvement of functional independence:*** Function of the whole body in relation to the degenerated joint can be improved by the following:

(a) Proper guidance to relieve compression over the affected joints

(b) Providing assistive aids, modified supports, corrective orthoses, adaptations and ergonomic advice on the performance of ADLs, and special shoes with inserts.

Osteoarthritis of the hip

Primary osteoarthritis of the hip joint is rare in India but commonly seen in Western countries. Secondary osteoarthritis, however, is seen more frequently following old trauma, Perthes disease and avascular necrosis of the femoral head. Traumatic conditions that may develop secondary osteoarthritis include fracture of the neck of femur, dislocation of the hip and fractures of the acetabulum.

Clinical features

The presenting features are progressively increasing pain

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and limitation of movements. Gradually, all the movements of the hip are restricted except in some cases; a good range of flexion may be preserved for quite some time. This may be because flexion is required in the movement of squatting – a movement required so often in the Indian setting.

Treatment

Conservative treatment

It is treated initially by conservative treatment in the form of deep healing modality, body ergonomics exercises, analgesics, etc. Weight reduction may be helpful in obese persons. Use of a walking stick in the opposite hand should be encouraged as it reduces the load on the affected hip joint and minimizes pain and a limp.

Common sites of osteoarthritis:

1. Hip

2. Knee

3. Hand

Surgical treatment

Any of the following surgical procedures may be performed:

1. Osteotomy – to centralize weight-bearing axis

2. Arthrodesis – only at a late stage, just to provide a stable

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hip

3. Pauwell's varus osteotomy in patients with coxa valga

4. McMurray's displacement is performed in patients with coxa vara

5. Arthroplasty (total hip joint replacement [THR]) – to provide mobility

Osteotomy: Displacement or McMurray's osteotomy is performed in relatively early cases to relieve pain. However, the relief in pain is temporary and, therefore, this operation is rarely performed for osteoarthritis of the hip. It is still occasionally performed for the treatment of intracapsular fracture of the neck of femur. It is discussed in detail in Chapter 5.

Arthrodesis: It gives a pain-free but a fixed joint. It is ideal for young adults, particularly heavy manual labourers. It is discussed in a separate chapter devoted to these three surgical procedures.

Arthroplasty: THR is the most commonly performed operation for osteoarthritis of the hip. It is also discussed in detail in a separate chapter.

Physiotherapeutic management

The objective of physiotherapy is to provide pain-free and functionally acceptable hip joints.

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Control of pain

1. In the acute phase, the painful muscle spasm can be relieved by ice massage, ice packs in resting positions.

2. Gentle intermittent traction may be effective as it relieves compression of the affected joint surfaces. However, it may not suit every patient. Sustained low-grade traction is another alternative. Even minimal force of traction may be helpful as it provides rest, relaxation and prevents deformity.

3. Deep heating modalities like ultrasound, pulsed SWD, TENS, interferential currents or any other suitable pain-relieving modality may be used.

Joint mobilization

Various methods of joint mobilization can be applied. They should progress gradually according to the patient's response.

1. Initially, relaxed ROM swinging exercises are ideal. The physiotherapist carries the total weight of the limb without involving any voluntary muscular contractions in the muscles that are in spasm. The ROM should be progressed in gradual steps with stretching modes with holds.

2. Progress to small-range assisted free active movements by using ped-o-cycle, stationary bicycle or roller skates in a restricted range. Sling suspensions to mobilize the range of abduction are ideal but should be done for both hips

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simultaneously to prevent the compensatory pelvic tilt due to stiffness of the affected hip joint.

3. Maitland techniques of low-grade mobilization, gradually progressed to higher grades, provide early mobility, which is pain free.

4. Hydrotherapy with correct guidance in the form of pool therapy promotes relaxation, improves mobility, strength and confidence.

5. PNF techniques can be used provided they are not painful (possible only in the middle ROM).

Muscle strengthening

Improving strength and endurance of the important muscle groups that offer stability to the hip and the body in weight bearing and weight transfers, like gluteal muscles, should be initiated. Controlled isometrics done repeatedly but not strong enough to cause pain are ideal. Strengthening the knee extensors, flexors as well as ankle dorsi and plantar flexors is also important.

There may be abnormal reflex activity in the absence of normal arthrokinematics. Strengthening of the muscles alone may have a deleterious effect on the joint. The plan should be, therefore, to restore the normal accessory and component movements at the involved joint on a biomechanical basis because the joint problem in osteoarthritis is that of mechanical dysfunction.

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Isometrics should be progressed, in graded steps, to PRE for the ultimate strengthening of these muscle groups.

Exercise should preferably be self-performed with correct guidance and emphasis with self-generated internal resistance.

Gait re-education

1. The correct methods of weight transfers and the stages of gait cycle need to be educated to provide near normalcy in gait.

2. If any limb length disparity exists, it should be adequately compensated before gait re-education.

3. Necessary walking aid may be given to assist weight transfers, along with other functional aids. The general tendency among patients is to discard the walking aid. This should be discouraged by properly explaining to them the ill effects of joint compressive forces due to weight bearing.

4. Other ambulatory activities like stair climbing and descending, back- and sidewalks should be taught in the proper sequence (e.g., going up the steps with the good leg leading and coming down with the affected leg leading).

Floor squatting and cross-leg sitting may not be possible for tense patients because of the limited ROM. However, the patient should be trained to perform ADLs with guided assistance.

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Secondary osteoarthritis of the hip

Causes

■ Unstable hip joint, e.g., subluxation

■ Angular pressure load, e.g., anteversion, coxa vara

■ Old direct trauma or infective disease

■ Constitutional factors, e.g., hyperthyroidism and obesity.

■ Loss of incongruity of the joint surface, e.g., Perthes disease

Progression of disease

■ The progress is relentless.

■ As it occurs in the younger age group, surgical intervention at the earliest helps in maximum resolution.

Postoperative procedure

The same pattern is followed as that in other hip joint osteoarthritis surgeries.

Osteoarthritis of the knee

In Indians, primary osteoarthritis of the knee joint is more common than the secondary osteoarthritis. It is perhaps due

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to the frequent need of squatting and sitting cross-legged. It is commonly seen in middle-aged obese females; however, males are not exempted.

Causes of primary and secondary osteoarthritis (knee)

Primary osteoarthritis

- Repetitive weight bearing or prolonged weight bearing on the susceptible joints
- Competitive sports with inadequate rest periods
- Excessive sedentary attitude and obesity
- Multiple endocrinal disorders
- Multiple metabolic disorders

Secondary osteoarthritis

- Obesity, varus or valgus deformity at the knee
- Intra-articular injury or fracture
- RA infection or TB
- Hyperparathyroidism
- Haemophilia
- DM

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- Excessive steroid therapy

The presenting complaints are pain, stiffness, limitation of movements and swelling occasionally with clicking sounds. There may be instances of locking of the joint in some advanced cases.

On examination, there will be synovial thickening as indicated by a joint line tenderness with effusion, crepitations are felt on movement. There may be some flexion deformity of the knee joint with limitations of movement. In advanced cases, advanced genu varum deformity causes ligamentous laxity on the lateral side of the knee with unusual opening of the lateral joint space as seen on X-rays (Fig. 29-3).

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FIG. 29-3 X-ray of the knee joint shows genu varum along with unusual opening of the lateral joint space.

There may be involvement of one or more compartments of the knee joint, i.e., medial, lateral or patellofemoral compartments. When the medial compartment of the knee joint is predominantly involved, genu varum deformity results (Fig. 29-4 A–C).

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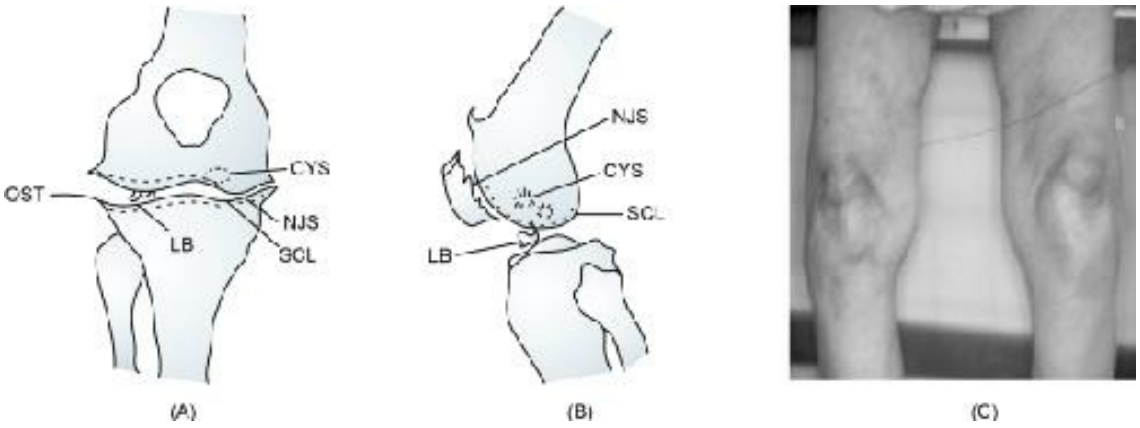

FIG. 29-4Osteoarthritis of the knee – radiographic features: involvement of the medial tibiofemoral. **(A)** Patellofemoral compartments. **(B)** Anteroposterior view (AP). NJS: narrowing of the joint space at the medial tibiofemoral compartment with genu varum. OST: osteophytes at the joint margins (lipping). SCL: sclerosis at the joint margins. CYS: cystic changes. LB: loose body in the joint. B: lateral view. NJS: narrowing of the patellofemoral joint space with lipping at the superior margin of patella. SCL: sclerosis at the joint margin. CVS: cystic changes. LB: loose body in the joint. **(C)** Genu varum deformity in osteoarthritis of knee.

Treatment

Conservative treatment

The conservative treatment includes anti-inflammatory drugs and electrotherapy for relief of pain, and exercises to strengthen the quadriceps muscles and to restore or maintain full mobility of the knee joint. Early use of cane and proper ambulatory training with special modified footwear should

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be done whenever applicable. Nowadays, offloading braces are available which are used to shift the weight-bearing stresses from one compartment of the knee (usually the medial) to the other which causes relief of pain.

Surgical treatment

Any one of the following surgical procedures may be performed depending upon the occupation and the functional needs of the patient.

1. **Osteotomy:** This is the most commonly performed operation for osteoarthritis of the knee joint. It is ideally indicated in a unicompartmental disease (medial or lateral) with marked varus, or less commonly, valgus deformity. The high tibial osteotomy is performed 2 cm distal to the tibial articular surface but proximal to the tibial tubercle, i.e., proximal to the insertion of the ligamentum patellae. The genu varum deformity, which is more common, is treated either by a closed wedge osteotomy (Fig. 29-5) or by an open wedge osteotomy with internal fixation. Femoral (supracondyler) osteotomy may be performed for the deformity of genu valgum (Fig. 29-5B).

The osteotomy may be fixed internally by staples or special plates or immobilized in an above-knee or cylinder plaster cast.

By doing an osteotomy, the deformity (varus or valgus) is corrected, thereby redistributing the load from the medial compartment of the knee. It helps in relief of pain in majority of the patients.

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Postoperatively, the knee is immobilized in a plaster cast for a period of 3 weeks where staples have been used for internal fixation, or for 6 weeks where no staples are used. Weight bearing in the plaster may be allowed at the end of 4–6 weeks in the latter case. After removal of the plaster, knee mobilization is initiated. Full weight bearing is permitted after 8–10 weeks.

2. **Arthrodesis:** It provides a pain-free stable but stiff knee joint. It is, however, not performed generally for osteoarthritis of the knee joint where alternatives of providing a mobile joint, such as an arthroplasty, are available.

3. **Arthroplasty:** Total knee joint replacement is indicated in elderly patients with marked disorganization of the joint due to osteoarthritis. It is discussed in detail elsewhere.

4. **Arthroscopic surgery:** Arthroscopic surgery is employed more often in the treatment of mild-to-moderate degree of osteoarthritis of the knee joint. The arthroscopic procedures include lavage of the joint with removal of osteochondral loose bodies, shaving of the osteophytes, and the removal of degenerated and frayed or torn menisci. These procedures, however, provide temporary relief from pain.

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(A)

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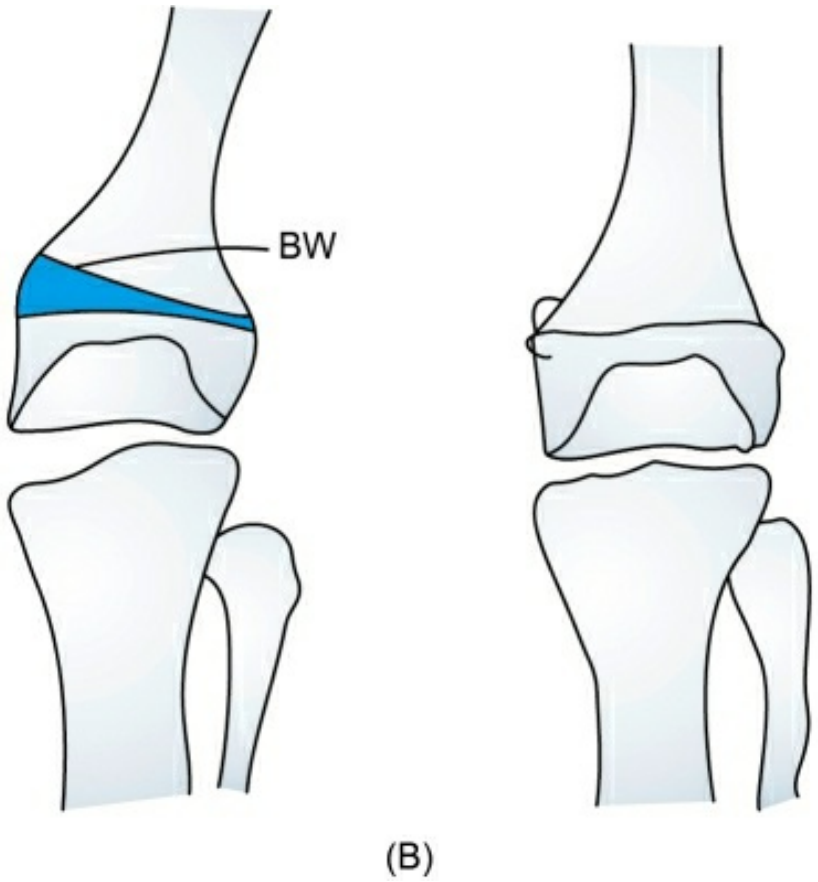

FIG. 29-5**(A)** High tibial osteotomy for genu varum. Postosteotomy position of correction of genu varum. **(B)** Femoral supracondylar corrective osteotomy for genu valgum osteotomy. BW: outline of bony wedge to be resected from supracondylar region of femur.

Physiotherapeutic management

In osteoarthritis of the knee, the major problems are pain, stiffness, joint instability, deformity and functional inadequacy at the later or chronic stage.

Pain: Pain is assessed for its character, degree, posture and duration. Pain is usually noticed when the degenerated joint

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is exposed to compressive forces. In some patients, pain at rest may be present due to the hypervascularization of the neighbouring bone.

Tenderness and effusion: The sites and degree are recorded.

Range of movement: Passive ROM including the end feel is recorded.

Deformity: Its nature and extent are assessed at hip, knee, ankle and foot during total weight bearing on the affected leg alone.

Stability: The stability of the joint is assessed in supine position and with weight bearing on the affected knee alone.

Strength, endurance and flexibility of the quadriceps, hamstrings and glutei should be recorded. Wasting should also be measured.

Efficacy of performing functional activities and the pattern of gait and other ambulatory parameters are evaluated. Knee rating scale (Table 29-2) is ideal to assess pain and functional status.

The duration of the ability to stand on the affected leg alone is also noted.

Physical demands: Physical demands of the patient's daily routine need to be evaluated in relation to the degree of involvement.

Table 29-2

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Knee Rating Scale for Pain and Functions (50 Points)

Pain-free standing and long walk	50
Mild pain, painless walking up to 1 km	40
Considerable pain on long standing/walking	20
Pain free up to less than 0.5 km	10
Severe pain on standing/walking or even at rest	5
Unable to walk	0

After physical examination, it is necessary to confirm the site and extent of degeneration by radiographic investigations.

RADIOGRAPHIC CLASSIFICATION

Stage I	Bony spurs only
Stage II	Narrowing of joint space, less than half of the normal joint space
Stage III	Narrowing of the joint space, more than half of the normal joint space
Stage IV	Obliteration of joint space or bone attrition under 1 cm
Stage V	Major bone attrition, more than 1 cm, subluxation or secondary lateral arthrosis

Stages I and II can be managed conservatively. The

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osteoarthritic changes are usually confined to one of the following three arbitrary sites:

1. Retropatellar or patellofemoral compartment

2. Medial tibiofemoral compartment

3. Lateral tibiofemoral compartment

Medial tibiofemoral compartment with genu varum is the most common site of degenerative changes.

Early diagnostic signs

■ Common in middle-aged women with tendency for obesity

■ Tendency to lead easy, nonexerting lifestyle

■ Mild joint pain on bearing body weight while assuming certain posture or positions, floor squats, ambulatory advances such as stair climbing; usually the pain and discomfort is relieved on sitting or lying

■ Tenderness over the joint line

■ Tendency for gluteus medius limp (trunk side bending)

Treatment

Self-care and self-help: The most important aspect of physiotherapeutic management is to educate the patient on

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self-care or self-help methods of treatment by simple procedures that reduce the compressive forces on the knee joint. These avoid repetitive impulse loading and compressive forces on the knee joint, e.g., frequent standing and sitting.

■ Level walking: The maximum compressive force is as much as three times the body weight (Morrison, 1969).

■ Climbing up the steps: The compressive force is to the tune of 4.25 times the body weight (Morrison, 1969).

■ Raising from a normal chair without arm supports: The compressive forces on the knee joint are as high as up to 7 times the body weight, whereas during rising from a chair with the help of arm supports, the forces are reduced to less than half the body weight (Ellis, 1981).

The first objective of the treatment is to reduce the degree of compressive forces on the knee to the maximum.

This can be achieved by avoiding the following:

1. Prolonged standing and repetitive sit–stand activity

2. Long walk

3. Unsupported climbing, or climbing with the affected leg leading

4. Unarmed chairs

5. Unsupported squatting or getting up from squatting

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6. Positions like kneeling, squatting

7. Sustained positions of knee flexion like cross-leg sitting

8. Walking without walking aids or prescribed orthosis

9. Walking carrying heavy weights

10. Heavy exercises like half squats

11. Long immobile sitting e.g., during travelling, watching TV, a movie or a stage performance without moving the knees

Pain: During the acute phase of exacerbation, pain can be managed effectively by cryotherapy, hydropack, TENS, ultrasound therapy, pulsed diathermy and maximum care to prevent compressive forces on the knee. Chronic pain can be adequately relieved by deep thermotherapy. Various trials conducted to prove the efficacy of a particular modality have not conclusively proved the superiority of any modality over the other. However, exercise has proved to be a single common factor as regards therapeutic effectiveness (Chamberline, Care & Harfield, 1982; Clarke, Willis, Stenners & Nichols 1974; Quirk, 1985).

Therefore, the role of any electrotherapeutic modality is limited to offering some relief of pain and hence acts mainly as an adjunct to facilitate the exercise programme.

Exercise programme

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The exercise programme should be simple but specific according to the physiological changes in the joint. It should be developed on the basis of the normal kinematics, to regain the correct mechanics of the knee joint.

1. *Isometrics:* In the presence of effusion, speedy isometrics to the quadriceps and hamstrings are useful. It should be repeated every hour with the limb in elevation. The slow and sustained isometrics help in reducing pain and improving strength.

Quantitative progressive exercise (QPE) programme with emphasis on maximum isometrics to quadriceps and hamstrings at various hip and knee angles, isotonics with and without resistance and speedy contractions have proved extremely effective (Fisher, Gresham & Pendergast, 1988).

2. *Speedy active relaxed free movements:* Active relaxed free movements, within the limits of pain, are useful in improving the ROM and inducing relaxation. They are easy to perform, too. They also improve the free mobility of the joint, maintaining the lubrication. Repeated relaxed knee swinging in supine or sitting posture are also useful (see Fig. 1-2) to further relaxation and mobility.

3. *Isokinetic exercises:* Isokinetics are a mode of exercise with a capacity to adjust the resistance according to the varying muscular strength. This effect, to a certain extent, can also be obtained by the therapist manually applying resistance. Another substitute to isokinetics is by the patient himself, applying resistance by the other leg. These exercises are self-controlled and hence are better accepted by the patient (Fig.

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29-6). They can be repeated frequently.

4. *Straight leg raising (SLR):* SLR is made effective by simultaneous isometrics to the quadriceps with the foot held in dorsiflexion. It can be made resistive by adding weight or resistance by the other leg. It improves stability to the knee during weight bearing.

Suggested progressive self-resistive SLR

Slow and continuous SLR with simultaneous *isometro–isotonic* exercise mode to the level of muscle fatigue (Figs 29-7 and 29-8).

(a) Begin with strong isometric holds to quadriceps and the ankle and foot dorsiflexors.

(b) Now perform SLR at a slow speed as much as possible using the time to generate more intramuscular isometric tension.

(c) After SLR to a certain angle (which may vary according to the strength), slowly bring the leg down.

(d) Before the heel touches the bed, raise straight leg up again.

(e) Continue repeating to the level of fatigue or pain.

Advantages

■ It improves strength, endurance as well as power at one go.

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■ Performing SLR at a slow speed induces early fatigue in all the participating muscle groups.

■ It provides advantages of maximum exercise to all the participating muscle groups in a shorter period.

■ Along with these major benefits, it will also improve the movement control for the whole limb.

5. *Hamstrings stretching:* Stretching of the hamstrings is important to prevent knee flexion deformity. Short sessions of toe touching in long sitting are useful (Fig. 29-9).

Isometric co-contractions of the hamstrings along with quadriceps should be encouraged during the acute (painful) stage. It helps to prevent the adaptive shortening of the hamstrings which usually begins during this stage.

The exercise programme should be simple, brief yet specific and should be repeated several times.

6. *Posture, gait and simple modifications in the assistive devices:* Correct posture, near-normal pattern of gait and adequate assistive aids like cane, crutch and orthoses have an important role in reducing the compressive forces on the knee.

Modifications to ease pain and functional activities

■ Special chair with higher sit and double arm support should be used.

■ Ambulatory training should be provided with proper

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assistance which reduces the discomfort during weight bearing.

■ No still standing; if compelled to, then the body weight should be well balanced by placing the feet with at least 12-inch wide base.

■ Never use Indian toilet; opt for a commode sit.

■ Toilet and bathroom should be fitted with a hand rail and toilet seat with a handle to take the body weight on the hands.

■ Use slow and steady steps on stairs which are provided with a bilateral hand rail.

■ If using a cane for walking, height of the walking assistive device should be at the wrist level with elbow held in extension.

■ Adopt sustained lying repetitively to prevent developing hip flexion attitude (e.g., playing carrom, reading)

7. *Wedge insole:* Properly measured wedge insole provides relief by reducing the compressive forces on the affected compartment on bearing body weight. It also reduces the excessive tensile force on the opposite compartment (Sisaki and Kazunori, 1987). It has been reported to be clinically effective up to three radiographic stages of osteoarthritis (but not in stages IV and V). Therefore, wedge insole with an exterior height of 7–12 mm should be tried, so that the sagittal axis of the posterior part of calcaneus is tilted laterally at an angle of 5 degrees to the floor. The period of

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using insole should be increased gradually to allow adaptation and continued in spite of setting in of early fatigue and discomfort.

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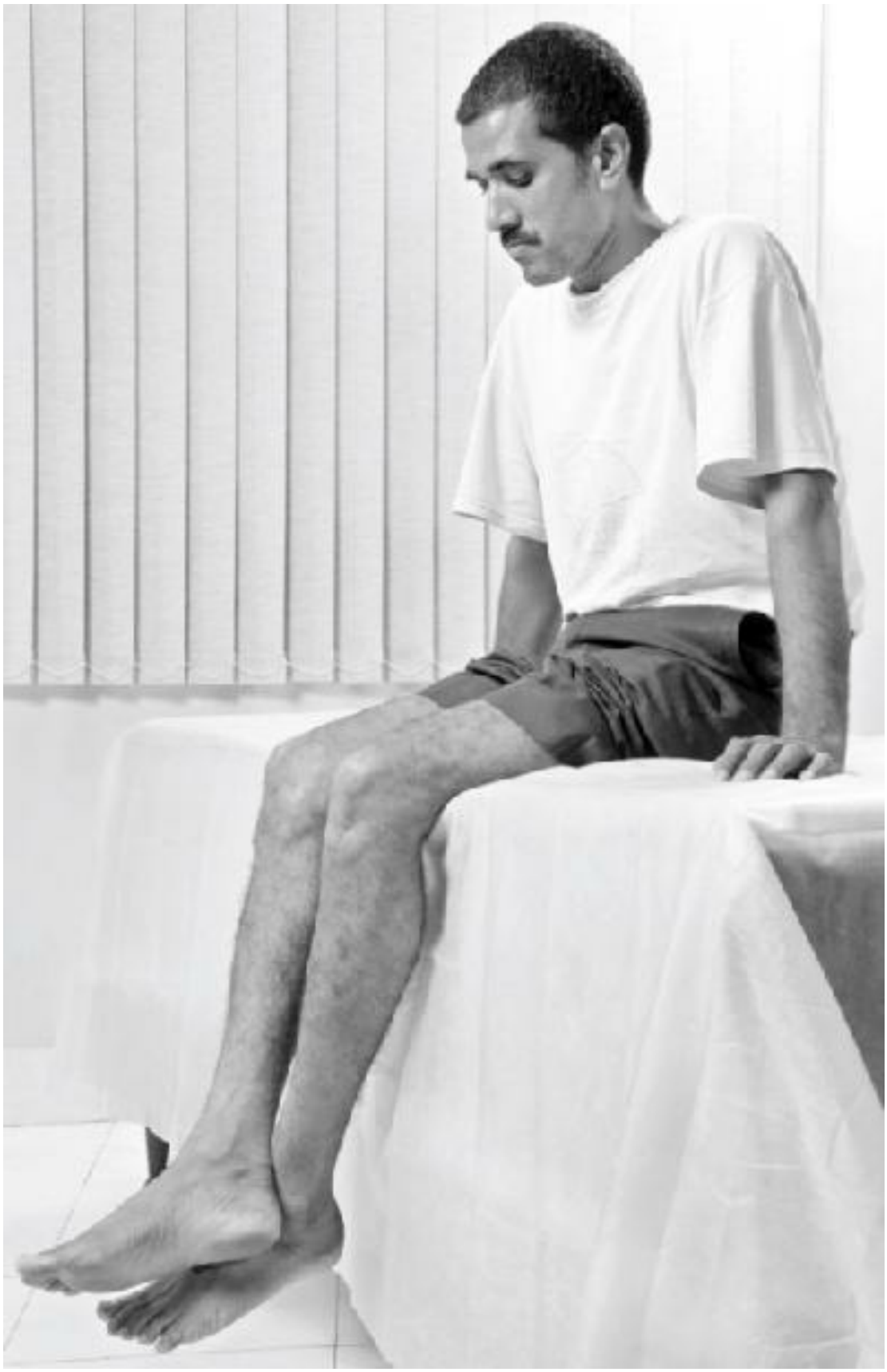

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FIG. 29-6Self-resisted exercise using contralateral leg to perform isokinetic-type exercises.

FIG. 29-7Isometric contraction of quadriceps.

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FIG. 29-8Straight leg raising.

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FIG. 29-9Toe touching to stretch hamstrings.

The proper control of exercises, rest and self-care are the most important measures to limit imbalances between mechanical stresses and improvement in the ability of tissues to adequately withstand such stresses.

Dos and don'ts for OA joints is presented in Table 29-3.

Table 29-3

Don'ts and Dos for Osteoarthritic Joints

Don'ts	Dos
Hip, Knee and Ankle	Always Begin Exercise with
• **Exposing the joint to a sustained load (e.g., remaining in one posture for a longer duration, such as sitting and standing)**	• Performing pain-free relaxed rhythmic free active movements to full or maximum ROM
• Repetitive joint compressive stress (e.g., frequent position changes like sitting to standing, stair, inclined or rough surfaces with ups and downs)	• Mobilize the joint with relaxed free active movements before bearing weight (e.g., standing after long duration sitting)

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• Sudden stressful rotatory activity (e.g., spontaneous turning with feet firmly grounded)	• Perform self-resistive pain-free and endurance exercises at every possible opportunity (e.g., while sitting and talking, watching TV)
• Unsupported ambulation in spite of pain and limp (a very common situation, invariably unacceptable to the majority of population)	• Correct use of assistive aids to ensure transference of body weight from the affected joint to the walking aid (e.g., using cane)
Wrist and Hand	Always Begin Exercise with
• Avoid repeatedly performing stressful movements. (e.g., activities of daily routine including lifting weight objects, purposed less passive compression of MCPs, PIPs and DIPs with other hand or sustained tight grip)	• Wrapping hot water rubber bag in a wet Turkish towel and securing it properly around the painful joint for 20 min three times a day. Besides giving a soothing warmth, it also provides compulsive rest. During intermittent episodes of pain, use a simple technique of applying hot pack and perform relaxed free active movements in a pain-free ROM • Dynamic orthosis immobilizing

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	the CMC joint of the thumb • Restrict using distal IP joints of fingers. • Carry out full ROM passive flexion at the DIPs of fingers to prevent organization of a flexion deformity

Osteoarthritis of the hand

Osteoarthritis affects the interphalangeal joints of the hand. The DIP joints are commonly involved initially but proximal interphalangeal (PIP) joints may get involved later on. In rare instances, metacarpophalangeal joints may also be involved. Osteophyte formation at the margins of these joints gives rise to hard prominences known as Heberden nodes at the DIP joint and Bouchard nodes in the PIP joint (Fig. 29-10). The occurrence of these nodes in the dominant hand, particularly in women, indicates excessive use as one of the aetiological factors.

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FIG. 29-10Chronic degenerative changes with formation of nodules at the IP joints.

Initially, pain in these nodes is minimal. However, further constant use precipitates inflammatory reaction with

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increase in pain and decreased function of the hand. Inflammation may lead to a cystic swelling containing gelatinous material which is extremely painful and may even burst.

Treatment

1. Rest should be provided in a splint with elevation.

2. Relaxed passive ROM exercises should be done once a day to maintain ROM.

3. Small-range active movements with maximum relaxation without exerting any stress on the involved joints are important.

4. Cryotherapy, TENS, ultrasound, etc. could be tried for pain relief; however, using repetitive hot packs is ideal.

Osteoarthritis of the trapeziometacarpal joint of the thumb

The carpometacarpal (trapeziometacarpal) joint of the thumb may be involved (Fig. 29-11).This involvement results in pain and limitation of function as the thumb plays a dominant role in the hand function. It may give a squarish appearance to the base of the thumb, causing further difficulty in grasp.

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FIG. 29-11Osteoarthritis of the trapeziometacarpal joint (thumb).

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Physiotherapeutic measures have limited scope and therefore surgical intervention in the form of excision of the trapezium or a silastic implant may be required.

Physiotherapeutic assessment

Accurate recording of the following is done:

1. ROM of individual joints of the involved hand is measured either by finger goniometer or by a malleable wire. It is important to record passive as well as active ranges.

2. Grading of individual muscles is done after proper stabilization without causing pain.

3. Sensory status, especially at the fingertips, should be recorded.

4. Functional use of the hand: Each type of grasp involving individual fingers and thumb should be assessed along with the status of hand functions on the whole.

5. Grip strength and efficacy of grasps should be evaluated objectively.

Treatment

The following should be done during acute phase or exacerbations:

1. Rest should be provided in a splint with elevation.

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2. Gentle, relaxed passive ROM exercises should be done at least once a day to maintain the range of joint motion.

3. Small-range active free movements should be given without causing extra strain to the involved joints.

4. Suitable form of cryotherapy or TENS may be used for the relief of pain preceding movements.

Mobilization phase

When symptoms of acute inflammation subside, a phase of vigorous mobilization to improve ROM, strength and endurance of the hand function is initiated. Use of corrective splint should be continued till adequate control of the hand function is returned.

Exercises causing pain and excessive stress on the affected joints should be avoided.

Assisted individual joint movements with axial traction and proper stabilization in the correct groove of movement are effective.

Exercises designed to incorporate various hand functions should be guided and encouraged.

Besides hip, knee and hand, osteoarthritis may involve shoulder, elbow, wrist and temporomandibular or sacroiliac joints.

Osteoarthritis of the shoulder

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Osteoarthritis of the shoulder is rare and usually needs conservative treatment in the form of anti-inflammatory drugs and physiotherapy. However, the role of total shoulder joint replacement in osteoarthritis of shoulder is discussed elsewhere.

Physiotherapeutic management

Objective: The objective is to maintain functional independence of the upper extremity with minimal discomfort.

■ Pain during movements and occasionally during rest is the main cause of disability. The correct choice of therapeutic modality is necessary. Deep heat, cryotherapy, ultrasound therapy, interferential currents and TENS are some of the common modalities used. The choice of a particular modality depends upon the patient's response.

■ Hydrotherapy, which promotes relaxation and at the same time facilitates movements, is the treatment of choice.

■ Exercises are aimed at improving ROM of shoulder which many times is prevented by protective muscular spasm. Therefore, relaxed passive movements are taken to reduce pain, prevent spasm as well as promote further ROM at the glenohumeral joint.

■ Active resistive movements or PNF techniques are useful in improving strength and endurance of the shoulder muscles besides assistance in gaining ROM.

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■ Maintenance of functional ROM and strength is greatly facilitated by providing guidance in the use of the whole arm.

■ Use of axial traction relieves pressure on the sensitive intra-articular structures and is useful in relieving pain and muscular spasm.

Osteoarthritis of the elbow

Osteoarthritis of the elbow joint is usually secondary and leads to a stiff joint.

Treatment

Arthroplasty (excisional or total joint replacement) may be indicated in selective patients.

Therapeutic modality is employed to induce relaxation and to reduce pain to the maximum.

Functional use is encouraged and guided within the limits of pain and discomfort as early as possible.

Self-resistive controlled active movements are encouraged without causing excessive compression and pain at the elbow joint.

Self-assistive exercises like roller skates and wand are beneficial to improve joint mobility.

Maintaining a pain-free maximum angle of elbow flexion for

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sustained periods is ideal.

Osteoarthritis of the wrist and hand

Osteoarthritis of the wrist is usually secondary to trauma (fracture of the scaphoid or fracture/dislocation of other carpal bones) or avascular necrosis of the lunate.

Pain and stiffness of the wrist are the presenting symptoms. If not relieved by physiotherapy, arthrodesis of the wrist in a position of slight extension is performed (Fig. 29-12).

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FIG. 29-12Arthrodesis of the wrist joint.

In the hand, osteoarthritis of the carpometacarpal joint of the thumb is common (Fig. 29-13). It is usually treated conservatively by analgesics and physical therapy. Severe painful cases are treated by excisional arthroplasty of the carpometacarpal joint and in rare cases by arthrodesis (Fig. 29-14).

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FIG. 29-13Osteoarthritis of the CMC joint of thumb.

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FIG. 29-14Excisional arthroplasty of the CMC joint performed for OA. Note that the trapezium has been excised, creating a space in the joint.

DIP joints of the fingers are usually affected by osteoarthritis. Clinically, it presents as mild deviation of the digit at the DIP joints with Heberden nodes (see Fig. 29-10). They require no specific treatment.

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In addition to the measures to control pain, induce relaxation and improve strength, the patient may be provided with a splint. A cock-up splint maintaining the wrist in extension not only provides rest to the arthritic joint, but also facilitates hand function without causing much discomfort.

Maintaining optimal pain-free function of the hand and functional re-education are the basis of the therapy.

Osteoarthritis of the ankle and foot

Osteoarthritis of the ankle joint is rare and is usually secondary to some old trauma or disease.

The surgical treatment includes either arthrodesis or total joint replacement (Figs 29-15 and 29-16).

(A)

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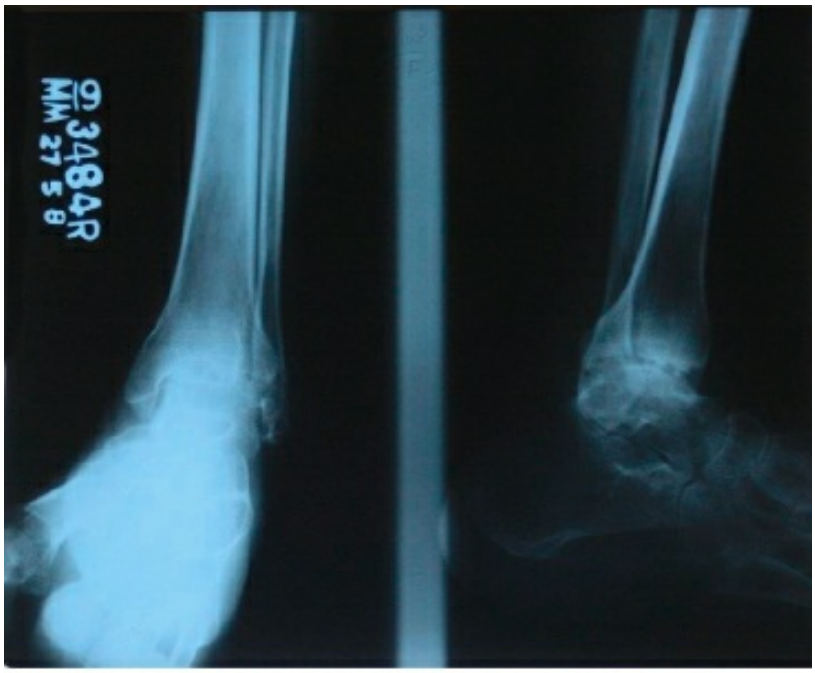
(B)

FIG. 29-15**(A)** Ankle arthritis. **(B)** Arthrodesis of the ankle done using Ilizarov fixator.



(A)

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(B)

FIG. 29-16Total ankle joint replacement: **(A)** Preoperative X-ray showing osteoarthritis. **(B)** After total ankle joint replacement.

Osteoarthritis of the joints of the big toe is seen occasionally and is discussed under hallux valgus and hallux rigidus.

Osteoarthritis of the subtalar (i.e., talocalcaneal) joint is secondary to an old fracture of the calcaneum. A severely disorganized, painful joint may need arthrodesis of the subtalar joint for relief of pain (Fig. 29-17).

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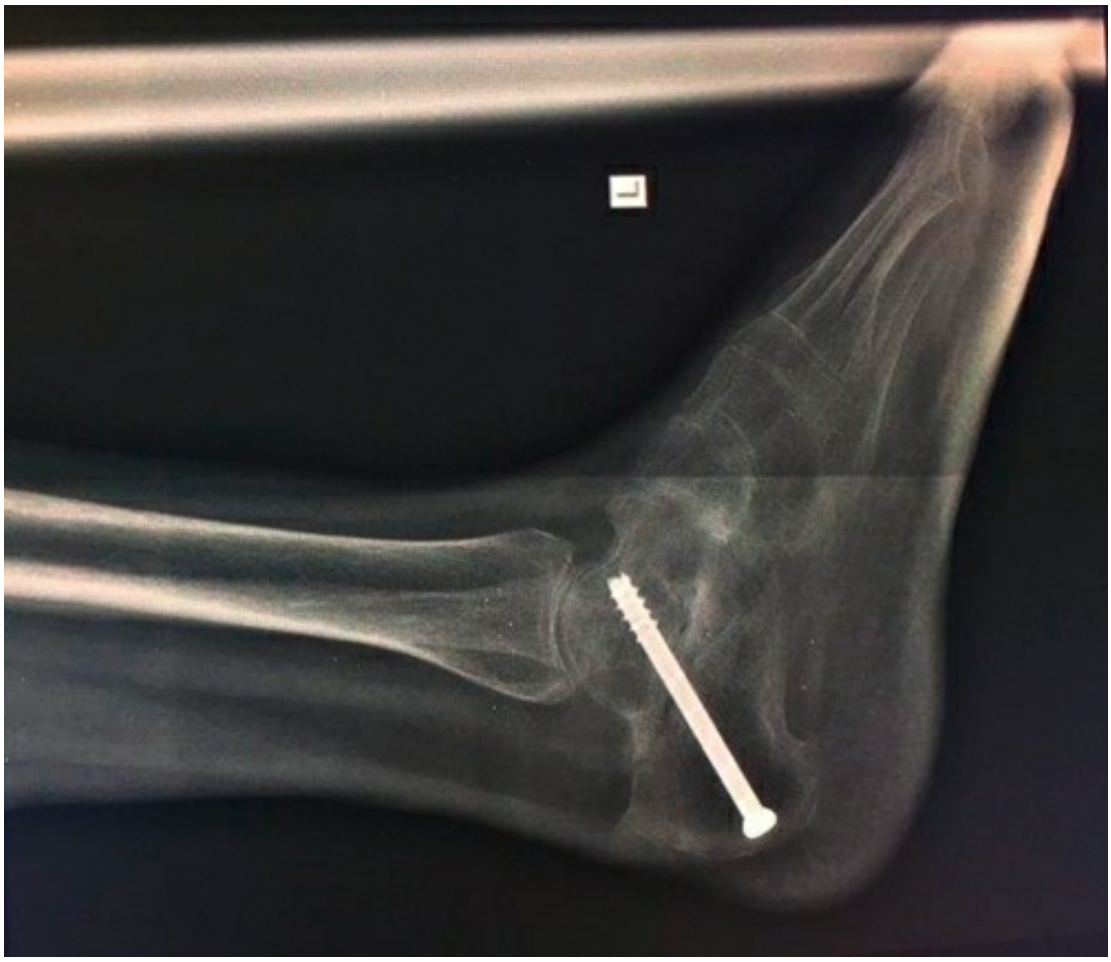

FIG. 29-17Subtalar arthrodesis.

Physiotherapeutic management

Very rare and needs measures to reduce bearing body weight on the affected joints, rest and hot packs. Operated cases are treated with graduated mobilization of the ankle and foot joints.

Restoring ROM of ankle to the plantigrade position must be achieved. Soft padded footwear helps in reducing pain during ambulation; correct gait training is inescapable.

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Osteoarthritis of the temporomandibular joint

Anti-inflammatory drugs and analgesics combined with ultrasonic therapy are useful in relieving pain. Movements of the jaw are encouraged to avoid ankylosis.

Osteoarthritis of the spine (lumber spondylosis)

Degenrative changes like reduction of disc space, sclerosis and osteophyte formation is commonly seen at the lumbar spine.

Both weight bearing and overuse are the precipitating factors, as the highest incidence of spondylosis is evident at the L5-S1 segment of the lumbar spine (Fig. 29-18). These degenerative changes may progress and compress the nerve roots at their exit at the intervertebral foramen and could result in neurological compression syndrome.

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FIG. 29-18Lumbar spondylosis.

Conservative treatment by physiotherapy is the initial relieving modality, but surgery may have to be carried out if the symptoms are progressive in nature.

Osteoarthritis of the sacroiliac joint (lumber spondylosis)

Low back pain, tenderness over the involved sacroiliac joint

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and stiffness following rest are the common features. It is often unilateral and can be detected by radiographic evidence of degenerative changes in the joint.

Appropriate therapeutic modality like ultrasonic therapy and ergonomic advice to prevent excessive stress on the sacroiliac joint provide relief of pain and facilitate pain-free function.

Physiotherapeutic management following surgical procedures is described under respective headings:

■ Other rare forms of osteoarthritis

■ Osteoarthritis of the acromioclavicular joints

■ Hereditary severe erosive osteoarthritis of PIPs and DIPs, with fixed deformities resulting in joint ankylosis

■ Bunion – a combination of osteoarthritis along with a deformity of the first metatarsophalangeal joint

■ Mucinous cysts – the cyst contains degenerative myxomatus fibrous tissue at the DIP or PIP joints

Rheumatoid arthritis

Rheumatoid arthritis (RA) is a systemic disease which results in chronic inflammation and destruction of synovial joints. It is an autoimmune disease that involves systems/organs other than the bones and joints alone.

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Aetiology

The aetiology is unclear; however, various factors like climate, race, diet, psychosomatic disorders, trauma, endocrine dysfunction, biochemical disorders, hereditary influences, disturbances in the autoimmunity and infection have been found to initiate the rheumatoid process. Environmental conditions precipitate the disease in genetically predisposed individuals. It is possible that genetic factors predispose certain individuals to tissue damage by infection; even viral infections may predispose RA.

Diagnosis

The diagnosis of RA is based more on clinical criteria than on laboratory tests alone.

The criteria for diagnosis as formulated by the American Rheumatism Association are shown in Table 29-4. It enumerates the features of RA.

Table 29-4

Criteria for the Diagnosis of Rheumatoid Arthritis (American Rheumatism Association)

1.	Morning stiffness (>6 weeks)
2.	Pain on motion or tenderness in at least one joint (>6 weeks)
	Swelling of one joint either due to soft tissues or effusion

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3.	or both
4.	Swelling of at least one other joint with an interval free of symptoms no longer than 3 months
5.	Symmetrical joint swelling (same joint)
6.	Typical radiographic changes that must include demineralization in periarticular bone as an index of inflammation with subcutaneous nodules
7.	Positive test for rheumatoid factor (Rh factor) in serum
8.	Synovial fluid showing poor mucin clot formation when added to dilute acetic acid
9.	Histopathology of synovium consistent with rheumatoid arthritis
10.	Characteristic histopathology of rheumatoid nodules

Note: Presence of >5 criteria concludes diagnosis of RA.

Detection of the abnormal protein, known as *rheumatoid serum factor* (Rh factor), forms one of the bases of diagnosis.

Laboratory tests:

1. Rheumatoid factor and anti-CCP (anti-cyclic citrullinated peptide) tests are positive.

2. *Abnormalities occur in the serum proteins:* The erythrocyte sedimentation rate (ESR) is raised. There is an increase in the serum fibrinogen with reduction in albumin and marked increase in the immunoglobulins.

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3. The CRP (C-reactive protein) is also elevated.

4. *Examination of the synovial fluid:* The clarity, colour and viscosity of the synovial fluid can assist in the diagnosis as well as differential diagnosis from other traumatic and degenerative conditions. Predominance of polymorphonuclear leukocytes in the synovial fluid is peculiar to RA (Table 29-5).

Table 29-5

Synovial Fluid Analysis

	Colour	Clarity	Viscosity	White Cells	Special Features
Normal	Straw	Clear	High	±200 (25% polys)	Nil
Traumatic	Yellow or red	Clear or Cloudy	Moderately high	2000 ±	Red cells + to +++
Degenerative arthritis	Straw	Clear	High	700 ±	Cartilage fibrils
Rheumatoid	Yellow or green	Cloudy	Low	5000–40,000 (75% polys)	Phagocytes +Rose–Waaler test +

Clinical features

The onset of the disease is common between the age groups of 35 and 55 years, and women are affected more than men

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in a ratio of 3:1.

The disease involves several organs and tissues, with various systemic manifestations.

Involvement of the synovial tissue is present in a majority of the cases. Involvement of the synovial lining of tendon sheaths, bursae and ligaments gives rise to pain, swelling, increased redness and warmth and stiffness. Tense synovial effusion and thickening may provoke capsular ruptures or joint herniation. When the extruded synovial fluid irritates the soft tissues of the calf, it may result in phlebitis.

Involvement of ligaments in the cervical region may produce subluxation with pain and neurological signs. The other nonarticular features are enumerated in Table 29-6.

Table 29-6

Nonarticular Features of Rheumatoid Arthritis

1.	*Systemic illness:* Malaise, weakness, loss of weight, fever
2.	*Blood disorders:* Anaemia, increase or decrease in white blood cell count
3.	*Vascular:* Involvement of small arteries, arterioles, veins, mono-or polyneuritis
4.	*Cardiac:* Myocarditis, pericarditis, valve lesions
5.	*Respiratory:* Pharyngitis, laryngitis, pleuritis, diffuse pulmonary fibrosis
6.	*Reticuloendothelial:* Lymph node enlargement, splenomegaly, hepatomegaly, overall increased liability

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	to infections
7.	*Skin:* Ulcerative lesions, purpura, erythema, pigmentary disorders, leucoderma
8.	*Eyes:* Conjunctivitis, keratitis, keratopathy, uveitis
9.	*Serological:* Dysproteinaemia with increase in fibrinogen and immunoglobulins; raised ESR and C-reactive protein
10.	Renal, hepatic and gastrointestinal lesions occur frequently and often silently

The involvement of articular surfaces of the joints and their surrounding soft tissue produces cardinal joint symptoms that eventually are responsible for the crippling disorganization of the concerned joint. The extent of physical disability is directly proportional to these changes. They begin with pain, tenderness, warmth, erythema and effusion. If not controlled, they progress to stiffness, cartilage wear and tear, and osteoporosis resulting in joint subluxation and dislocation. Progressive weakness of the muscle groups further complicates the situation. In the majority of patients, the wrist, metacarpophalangeal and knee joints are involved early compared to the other joints. Joint changes progress through the following three stages (Fig. 29-19):

Stage I: Inflammation of the synovial membrane spreads to the articular cartilage and other soft tissues. There occurs limitation of joint movements with pain and muscle spasm.

Stage II: Formations of granulation tissue occurs within the synovial membrane and spreads to periarticular tissues. The cartilage starts disintegrating and the joint is filled with

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granulation tissue. There occurs thickening of the joint capsule, tendons and their sheaths impairing the joint movement permanently.

Stage III: The granulation tissue gets organized into fibrous tissue with adhesion formation between tendons, joint capsule and the articular surfaces. The articular surfaces get partly covered by cartilage and partly by fibrous tissue. They may give rise to contractures and even ankylosis of the joint, or secondary osteoarthritis.

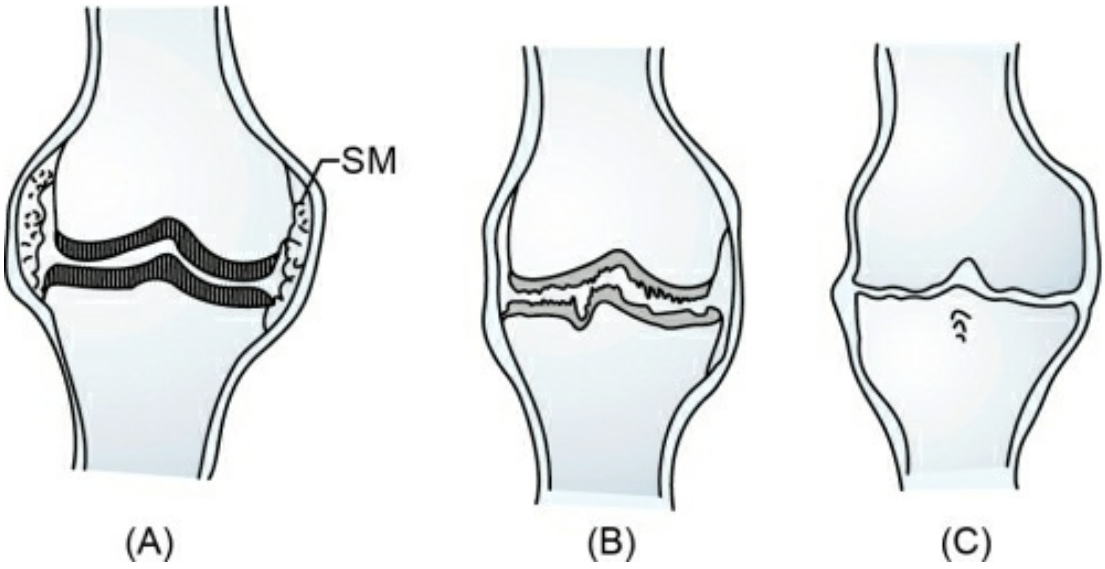

FIG. 29-19Stagewise joint changes in rheumatoid arthritis (knee). **(A)** Stage I: inflammation and thickening of the synovial membrane (SM). **(B)** Stage II: disintegration and erosion of cartilage. **(C)** Stage III: secondary osteoarthritis.

Individual joint involvements

1. *Cervical spine*: Subluxation is common at the atlantoaxial joint. It may produce root symptoms, upper motor neuron

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symptoms, visual disturbances, transient hemiparesis and vertigo.

2. *Temporomandibular joint*: Pain and limitation of movements.

3. *Cricoarytenoid joint*: It may progress from hoarseness of voice to stridor and as such needs careful watch.

4. *Shoulder joint*: Glenohumeral joint and rotator cuff involvement are common.

5. *Elbow*: Limitation of extension is common. It may affect forearm movements also. Occasionally, compression of the ulnar nerve may be present.

6. *Wrists*: Subluxation of the distal end of the ulna may result in stiffness, deformity and pain. This may also cause rupture of the extensor tendons of the third, fourth and fifth fingers, ulnar deviation deformity at the wrist and occasionally carpal tunnel syndrome.

7. *Hands*: Palmar subluxation and ulnar deviation are the common deformities due to the involvement of metacarpophalangeal and PIP joints. A typical swan-neck deformity and boutonniere deformity also may occur (Fig. 29-20).

8. *Hip*: Erosion of the head of femur occurs with its protrusion into the acetabulum (protrusio acetabuli). Trochanteric bursitis may also occur. Eventually, the hip may become stiff.

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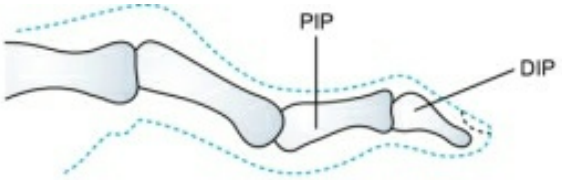
9. *Knee*: Beginning with synovial swelling, it may lead to severe destructive changes resulting in deformity (flexion deformity or wind-swept deformity – flexion with valgus on one side and varus on the other). Marked instability and secondary degenerative changes occur in the late stage.

10. *Ankle and foot*: Ankle joint may be spared but the distal joints may usually be involved leading to valgus foot.

11. *Metatarsophalangeal joints*: Subluxation may occur at these joints with hallux valgus and toe fanning.



(A)

'Swan-neck deformity'
Hyperextension of PIP with flexion of DIP

'Boutonniere deformity' caused by rupture of the central slip of the extensor tendon flexion of PIP; hyperextension of DIP

(B)

(C)

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FIG. 29-20**(A)** Swan-neck deformity. **(B)** Boutonniere deformity. **(C)** A rheumatoid hand showing both types of deformities.

The basic aim of physiotherapy is to make the patient self-reliant.

Treatment

Conservative treatment

- Anti-inflammatory and immunosuppressive drugs
- Appropriate static splints
- Intralesional injections of corticosteroids
- Physiotherapy

Surgical treatment

Common procedures

1. Synovectomy: Excision of the inflamed synovium when the articular cartilage is not eroded

2. Osteotomy: To correct varus or valgus deformity at the hip or knee

3. Arthroplasty: In the advanced stage of the disease when the joint is destroyed beyond salvage

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4. Arthrodesis: To stabilize the joint

5. Reconstructive surgery of the hand, e.g., tendon transfers and soft tissue release

Physiotherapeutic management

Principles of physiotherapy

1. Relief of pain and inflammation

2. Prevention of deformity

3. Correction of deformity

4. Restoration and maintenance of joint motion

5. Improvement of muscle strength and endurance

6. Guidance and training to achieve optimum function

7. Education on the management of recurrence

As the course of the disease is unpredictable, accurate assessment of the condition is a must at the time of reporting as well as at regular intervals.

Objective evaluation of the patient is carried out as follows:

1. *Pain*: Body image pain chart and VAS

2. *Swelling*: Volumetric measures

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3. *Skin*: Erythema, temperature, skin lesion, presence of nodules, texture of nails and hair

4. *Deformity*: Exact degree of deformity

5. *Joint range*: By goniometry

6. *Muscle strength and endurance* of the muscles of the joints involved and the related joints

7. *Respiratory functions*: Vital capacity (VC), forced expiratory volume (FEV1) and thoracic excursion to be evaluated

8. *Postural deviation*: Measurement

9. *Hand function*: Measurement of various grip strengths

10. *Gait analysis*

11. *Efficiency of performing activities* of daily living (ADLs)

12. *Physical requirements* of the vocation

13. *General psychological status*

The type of measures adopted depends on the clinical status of the disease.

The clinical course of RA is divided into two phases:

1. Acute phase or active phase

2. Chronic phase

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The treatment differs radically in both these phases of the disease. There may be remissions and exacerbations during the course of the disease.

Any form of active exercise is contraindicated during the acute phase or the acute-on-chronic phase (exacerbations). However, the tendency for developing tightness or contractures should be avoided.

During the chronic phase, various forms of vigorous exercises are given as the pain is less. Functional training should also be intensified.

Acute phase (3–4 weeks)

During the acute or active phase of the disease, the acute symptoms – pain, erythema, tenderness and swelling – are present.

1. Properly supported positioning of the involved joints and correct bed posture are important. The use of firm mattress or occasional back support minimizes the effects of malpositioning and thereby preserves the integrity of the affected joints. The limb is placed in a position of minimal discomfort; however, contracture should be avoided.

2. Splints and sandbags may provide additional support to the limb. Special attention is needed for the knee and elbow joints as they are prone to develop flexion contractures. The use of casts should be kept to the minimum. Splints or casts should be checked regularly to avoid complications due to them.

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3. Deep breathing exercises are important to improve the VC.

4. Joints and muscles free from immobilization and the active disease need to be put through the full ROM and PRE.

5. Functional mobility should be encouraged and maintained within the pain-free limits.

6. Postural guidance and methods of performing activities without putting extra strain on the affected joints are taught.

7. In cases where weight-bearing joints are involved, the upper extremities should be prepared for future crutch walking.

8. *Isometrics*: Isometric exercises do not involve movements of the joints and are therefore relatively painless. They should be started early. Muscles like quadriceps and deltoid are susceptible to disuse atrophy and hence need repeated sessions of isometrics. Other functional muscles concerned with weight bearing and body balance need strengthening and improved endurance and thus require repetitive isometrics.

9. Speedy isometrics to the affected limb in elevation reduce swelling and effusion (especially of the knee). No heat therapy should be given to the joints that are already warm.

10. TENS, pulsed ultrasound, ice massage or ice packs for longer periods offer reduction in the muscle spasm and pain. Interferential current of 90–100 Hz reduces the accommodation of nerves, whereas a frequency of 50–100 Hz improves healing, blood supply and membrane permeability

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by improving absorption.

11. Properly guided pool therapy for the whole body provides an ideal medium for exercises.

Chronic phase

It is a phase of vigorous activity to train the patient to use the involved joints to the greatest extent for physical independence. By 4–5 weeks of the onset, independent sitting by the use of hands can be started. If pain permits, active and functional therapeutic programmes should be initiated. This will include standing and walking. However, weight bearing should be deferred till pain and discomfort subside.

Before allowing weight bearing, it is absolutely essential to provide the necessary orthotic support or walking aid to relieve compressive forces on the affected joints. This should be done between the parallel bars to judge the effects of weight bearing on the diseased joints.

Sustained or intermittent stretching procedures may be necessary for the joints that have developed tightness or contractures during the acute phase. Deep heat (if acceptable), ultrasonics, TENS and other adjuncts may be used to relieve pain.

Efforts should be made to improve the strength and endurance of the muscles related to the affected joints.

Education and assistance are provided in adopting

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functional positions, speed and proper gait.

Job-oriented performance should be imparted in the exercise regime.

Relapse

Relapse is common in RA. It should be treated on the same lines as detailed for the acute phase.

Caution

Since it is a systemic disease, it is usually accompanied by early fatigue. Therefore, exercise sessions should be brief.

Usual sites of contractures and their prevention

1. *Back*: There is a generalized tendency for flexion attitude of the spine, which gives rise to an exaggerated kyphosis and obliteration of the lumbar lordosis. Therefore, stooping posture should be avoided at rest as well as during activity. Repeated prone posture should be encouraged.

2. *Hip joints*: Tendency for developing hip flexion contracture is common in the acute phase due to prolonged recumbency. Therefore, use of a firm mattress, no pillow under the knee as well as prone postures can effectively avoid flexion contractures at the hip joint. Once contractures develop, they are very difficult to correct and they adversely affect the weight-bearing activities.

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Prognosis of the disease: The prognosis of the disease is very unpredictable.

(a) There may be partial or total remission.

(b) It may remain as a mild disease.

(c) It may be insidiously progressive in nature.

(d) It may be progressive, but the progress of the disease may be (i) rapid, (ii) slow or (iii) intermediate.

The time factor is variable, so also is the response of a patient to drugs. However, poor prognosis can be predicted by the presence of ocular involvement, nodules, vasculitis and other complications. Tissue typing also provides a clue to the prognosis. Patients with an acute attack show better improvement than those in which the onset is insidious.

Considering the complexities involved in the disease, it is essential to individualize the treatment plan after critical overall assessment of a patient and the response to a particular therapeutic measure.

3. *Knee joints*: The knee joints are more prone to develop flexion contractures than any other joint. Relaxing flexion attitude during the acute phase of the disease is the main cause. Taking adequate measures to prevent the flexion deformity, or to keep it to the minimum, is the first priority. The patient's own active or assisted efforts play an important role. Holding the position of maximum stretching in extension is more effective than applying repeated stretches. Resisted early movement through full range is important.

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Unsupported early weight bearing should be discouraged to avoid valgus and varus deformities.

4. *Ankle and foot*: Maintenance of neutral position and full ROM exercises to the intrinsic muscles are important to reduce the expected deformities of valgus foot and metatarsus valgus. Tendency for the deformity should be detected early and checked by varus pad in the shoe or a splint.

5. *Shoulder joint*: Limitation of the range of terminal shoulder abduction in elevation should be repeatedly checked as the limitation usually begins in this range. Extreme range of abduction and external rotation should be concentrated next. Full ROM to the shoulder with cuff and collar in the initial stage is important. Strenuous abduction should be prevented to avoid injury to the rotator cuff, by exercising in supine position.

6. *Elbow joint*: Limitation of extension or tendency to develop flexion contracture is the common deformity next only to flexion deformity of the knee.

Immobilization of the elbow in extension during active phase prevents this deformity. Gravity-assisted elbow extension enforced subsequently with low-grade resistance by weight belt within the limits of pain provides an ideal method of applying effective stretch. Signs of ulnar nerve compression syndrome should be looked for.

7. *Wrist and hand*: Tendency to develop flexion contracture with ulnar deviation has to be controlled by simple self-

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assisted passive stretching movements, positioning and splints. Swan-neck deformity – flexion at the metacarpophalangeal joint, hyperextension at the PIP joint with flexion at the DIP joint – should be watched for and controlled.

Role of splints

There are two classes of splints:

1. Static splints: To provide rest, support and prevent deformity

2. Dynamic splints: To re-educate and strengthen weak muscles and to carry out functional tasks

Characteristics of an ideal splint

The splint should have the following features:

1. Inexpensive

2. Easy and quick to make

3. Comfortable

4. Light and neat

5. Strong

6. Functionally accurate

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7. Fitting optimally

8. Cosmetically acceptable

Splints provide an excellent means of immobilization and rest. They are essential during the acute phase of the disease, particularly with polyarticular involvement. However, the following disadvantages restrict the use of rigid splints occasionally.

Disadvantages

1. Possibility of muscular weakness and wasting (disuse atrophy)

2. Loss of mobility

3. Tendency for the joint to get fixed in the position of splinting

4. Fabrication, trials and application of splints are painful

Advantages

1. Corrects the deformity (serial splinting)

2. Provides support and rest (acute phase)

3. Easy application and removal: It prevents static deformity unlike rigid immobilization

4. Prevents dynamic instability due to the imbalanced

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muscular forces

5. Provides stability to the weak or deformed unstable joints, acting as an alternative to surgery

6. Offers functional efficiency to the ADLs as an adjunct to surgery

7. Reduces the impact of unwanted and harmful forces acting on the body due to the structural changes in the joints (inserts and wedges in shoes, knee cage, etc.)

8. Provides means of strengthening re-educative and assistive aids: Ambulatory devices like canes, crutches, walkers and wheelchairs may also provide stability of weight bearing during ambulation

Dynamic splints are elaborated in Chapter 34.

Juvenile rheumatoid arthritis

A seropositive autoimmune connective tissue disease commonly affects female adolescents, mainly affecting connective tissues. It follows the course of RA mostly affecting small joints of the hand and feet.

1. Systemic onset (Still disease): Rashes, high fever, lymphadenopathy, splenomegaly, carditis and arthritis

2. Pauciarticular onset: Involving less than four joints

3. Polyarticular onset: Involving four or more joints

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4. Iridocyclitis: Leading to blindness

Seronegative spondyloarthritis

The conditions under this category are similar to RA but without the presence of the rheumatoid factor in the serum. The disorders include:

1. Ankylosing spondylitis

2. Reiter syndrome

3. Psoriatic arthropathy

4. Reactive arthropathy

Still disease

This is a juvenile chronic polyarthritis, which could be any of the following:

1. Systemic

2. Polyarticular

3. Oligoarticular

In the systemic disease, malaise, weight loss and evening rise of temperature are present with enlargement of spleen and lymph glands. Rashes appear with fever or following the use of external heat. Polyarticular involvement develops into chronic arthritis. The disease has a better prognosis when it

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affects fewer joints (oligoarticular). An accompanying eye disease (iridocyclitis) may lead to blindness, especially if there are positive antinuclear antibodies (ANAs).

Treatment

Drug treatment is the same as for adult RA except that corticosteroids are used with precision.

Physiotherapy

A thorough assessment of the patient is carried out. The general approach of the treatment remains the same as for RA. However, protection of the optimal functional alignments of the involved joints is important. These children are more prone to develop contractures and deformities. Lack of movements may lead to overall growth retardation. Therefore, concentrate on the following:

1. Prevention of deformities

2. Early splints in functional positions

3. Vigorous exercises to uninvolved joints and muscles

4. Maintenance of functional activities with adequate splints and adaptations

5. Gait training and guidance to avoid limp – the most important aspect being the active participation of parents in home treatment programmes.

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Factors complicating the management

1. *Neurological problems*: Nerve root compressions, upper motor neuron lesions, transient cerebral and cerebellar lesions may occur as a sequela to disease in the cervical region. Mononeuritis, carpal tunnel syndrome or peripheral neuropathy may be associated with vasculitis.

2. *Cardiac lesions*: Pericarditis, constrictive pericarditis and incompetence of the aortic valve may occur.

3. *Pulmonary complications*: Pleural effusion, pulmonary nodules, interstitial fibrosis or fibrosing alveolitis may occur.

4. *Alimentary problems*: Drug therapy often causes gastric ulcers, haematemesis and melaena leading to anaemia.

5. *Vascular complications*: Vasculitis leads to sensory peripheral neuropathy in feet, purpura, leg ulcers and gangrenous digits.

6. *Nodule formations*: Subcutaneous nodules over pressure points overlying bony prominences may develop. They are common over the extensor aspect of the forearm.

7. *Renal complications*: Frequent urinary tract infections may occur. Drugs like analgesics, after prolonged use, may lead to renal impairment.

8. *Muscle*: Muscular atrophy, weakness as well as shortening (contractures) commonly occur in the vicinity of the inflamed joints.

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9. *Bone*: Periarticular osteoporosis of the involved joints occurs as a result of steroid therapy and lack of movements.

10. *Oedema*: Lack of pumping action of muscles, immobility or anaemia may precipitate oedema.

11. *Ocular complications*: Cataract, retinal changes and corneal deposits may occur as a complication of drugs.

12. *Amyloidosis*: Deposition of a cheese-like material in the reticuloendothelial system, liver, spleen and kidneys may occur due to prolonged inflammation leading to nephrotic syndrome.

13. *Septic arthritis*: It leads to exacerbation of symptoms in the involved joint. It is associated with fever, leucocytosis and low blood pressure.

14. *Iatrogenic diseases,* e.g. Cushing syndrome may be seen due to the overuse of corticosteroids.

Surgery

The objectives of surgery:

1. Improvement mobility

2. Providing adequate stability

3. Correction of deformity

4. Increase in control of muscles

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5. Relief from pain

6. Early return to normal domestic tasks

Indications for surgery

1. Failure of medical treatment

2. Disturbing pain

3. Persistent synovitis

4. Tenosynovitis, bursitis

5. Tendon rupture

6. Nodule formation causing pressure syndromes

7. Faulty alignment of the joint

8. Nerve compression

9. Joint ankylosis

10. Cosmesis

Contraindications for surgery

1. Progressive or active disease

2. Poor medical control

3. Widespread disease in aged patient

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4. Adequate functional status

5. Adaptation of the body to the deformity

6. Lack of cooperation

7. Apathy and depressed patient

8. Severe amyloid disease

9. Arteritis

Timing of surgery

Lower limb surgery should be performed first. Upper extremity surgery should be performed in proximal-to-distal direction (Savili, 1964).

Stages of the disease and the type of surgery

Barron (1969) adequately described the type of surgical procedures to be adopted during various stages of the disease.

Stage I: An early stage of proliferation.

Synovectomy for pain relief and to protect articular cartilage, tendon and nerve from continued damage.

Stage II: An intermediate stage of soft tissue destruction.

1. Deformities like boutonniere, swan-neck and ulnar drift,

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which are in their earlier stage, are corrected by reconstructive surgery.

2. Tendon ruptures and trigger fingers could be managed effectively by reconstructive procedures.

Stage III: This late stage of skeletal collapse results in ankylosed or unstable joints. Joint reconstructive procedures like arthroplasty and arthrodesis are performed. Joint reconstruction can be successful only when the tendon mechanism is intact. Therefore, tendon repair has to be performed before reconstruction of a damaged joint.

Common surgical procedures in rheumatoid arthritis

1. ***Synovectomy:*** It is a commonly performed surgical procedure. It consists of excision of the thickened and inflamed synovial membrane of the joint or tendon sheath. It is indicated in the joints where the articular cartilage is not eroded. Synovectomy relieves pain, possibly by retarding the disease process and thereby preserving the articular cartilage. It can be performed on the knee, wrist and small joints of the hand and occasionally foot and tendon sheaths of the hands.

Postoperative regime (knee joint): The limb is immobilized in a Thomas splint with Pearson knee attachment. Flexion exercises at the knee, in the splint, are started as soon as the pain permits. CPM may be initiated within 48 h. The stitches and splint are removed after 2 weeks and mobilization is started because of the tendency of the knee joint to get stiff following synovectomy. Isometrics to the quadriceps should

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be initiated at the earliest to prevent its disuse atrophy.

If satisfactory ROM at the knee joint is not regained by the end of 3 weeks, the knee joints should be manipulated under general anaesthesia. This should be followed by an intensive mobilization programme.

Partial weight-bearing ambulation should be started after 3–4 weeks. Full weight bearing can be resumed by the end of 4–6 weeks. However, full weight bearing with cane can safely be started earlier provided the pain permits and the quadriceps mechanism is adequate.

Synovectomy of the other joints: Following synovectomy of the wrist and small joints, rigid immobilization in a cast is not always necessary. A pressure bandage is given for the initial 3–4 days. This facilitates early mobilization of these joints. Light weight functional activities of the wrist and hand should be started as early as possible.

2. ***Osteotomy:*** It is done in the upper tibia or upper femur, in that order. It is performed mainly to correct the valgus or varus deformity at the knee and hip.

3. ***Arthroplasty:*** It is performed in the advanced stage of the disease where the joint is destroyed beyond salvage. Two types of arthroplasty procedures are commonly performed.

(a) *Excisional arthroplasty*: It is done in the hip, small joints of the hands and feet and elbow joint. In this, the diseased portion of the joint is excised and a gap is thus created between two adjacent bones of the joint. This provides better

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mobility with relief from pain.

(b) *Total joint replacements*: This is an advancement over excisional arthroplasty. In this, the joint is replaced totally, thus providing a stable, pain-free and mobile joint. This operation can be performed for hip, knee, small joints of hand and less commonly for shoulder, elbow and wrist.

4. ***Arthrodesis:*** It is also performed in the later stages of the disease in the joints of the spine, shoulder, elbow, knee, wrist and ankle. Though it provides a stable and pain-free joint, it is not a procedure of choice as it results in a fused joint. The total joint replacement is, therefore, preferred wherever possible.

5. ***Tendon reconstruction (reconstructive surgery of the hand):*** Reconstructive procedures are necessary for tendon ruptures and deformities in the hand (Table 29-7).

Table 29-7

Reconstructive Surgical Procedures for the Hand

Involvement of	**Surgery**
1. Wrist joint	• Excision of lower end of ulna • Dorsal synovectomy • Arthrodesis • Extensor tendon repair

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2. Metacarpophalangeal joint	• Synovectomy • Correction of ulnar deviation • Arthroplasty
3. Proximal interphalangeal joint	• Synovectomy • Correction of boutonniere deformity • Correction of swan-neck deformity • Arthrodesis
4. Distal interphalangeal joint	• Correction of mallet finger • Arthrodesis
5. Thumb (a) Carpometacarpal joint (b) Metacarpophalangeal joint (c) Interphalangeal joint	• Interposition arthroplasty • Replacement arthroplasty • Synovectomy • Arthrodesis • Synovectomy • Arthrodesis

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6. Flexor tendon	• Synovectomy • Tendon repair
7. Nerves	• Repair • Grafting

Physiotherapy following surgery

The physiotherapeutic management proceeds on the same lines as described under the various headings in this chapter.

Hand surgery and stabilizing reconstructive surgery form the basis of the management of RA. While planning physiotherapy, one must remember the overall impact of the disease and its involvement.

Early mobilization is the key to success. The period of immobilization should be the shortest (Wynn Parry, 1982). Physiotherapy to the other parts free of immobilization needs regular exercises performed personally and not by just instructions.

The ultimate goal should be to regain adequate functional independence for domestic tasks and employment.

Haemophilia (haemophilic arthritis)

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Haemophilia is a systemic arthritis as a result of a bleeding disorder that is caused by deficiency of an antihaemophilic globulin (factor VIII) resulting in insufficient coagulation. The coagulation time may be increased up to 60 min, as against the normal range of 4–10 min. This disease is transmitted as a sex-linked character by females but manifested only in males. Another bleeding disorder, known as Christmas disease, results from deficiency of plasma thromboplastin component (factor IX).

Pathology

Bleeding occurs into (i) joint and (ii) muscles.

1. *Haemarthrosis* or bleeding into the joints is the most common manifestation of this disease. The commonly involved joints are knee, elbow and ankles, whereas hip, shoulder, wrist, hand and foot are less frequently involved. Haemophilic arthropathy results from repeated attacks of bleeding into the joints. The synovium gets thickened and hypertrophic, organization of the exudate causes joint adhesions with subsequent reduction in the joint space. The late sequelae are subchondral bone resorption with collapse, osteoporosis, osteoarthritis and even ankylosis of the involved joint (Fig. 29-21).

2. *Bleeding* may occur into the muscle following a trivial trauma or even an intramuscular injection. The muscles of buttock and thigh are the usual targets of bleeding.

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FIG. 29-21Ankylosis of the knee resulting in fixed flexion deformity as a late sequela of haemophilia.

Initially, there occurs a clot formation with protective muscle spasm resulting in a flexion deformity of the hip or equinus at the ankle (depending on the site of bleeding). This is later on followed by fibrosis and features of compartmental syndrome.

Intramuscular bleeding may also cause compression over peripheral nerves. The most common example is

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involvement of the femoral nerve in a thigh bleeding. Similarly, median, sciatic and posterior tibial nerves may get involved.

Symptoms

1. Pain

2. Haemorrhage

3. Swelling

4. Muscle atrophy (in late stage)

5. Crepitus

6. Limitation of ROM of the affected joint

7. Flexion contracture

8. Joint instability (late stage)

Treatment

Treatment consists of (i) correction of the factor VIII deficiency and (ii) treatment of the musculoskeletal manifestations.

1. *Correction of the factor deficiency* is achieved by transfusing fresh frozen plasma or cryoprecipitate, or human or animal AHG.

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2. *Treatment of the musculoskeletal manifestations* depends on the degree of involvement of a joint, muscle and/or nerve.

Acute haemarthrosis: Fresh bleeding is stopped by replacement of the factor. The pain and swelling of the joint can be reduced by a compression bandage or POP cast. Physical therapy is initiated, as soon as the pain and swelling permit, by removing the splint/cast intermittently under the cover of factor VIII. The main goal is to prevent residual joint deformity.

Chronic haemarthrosis: The treatment is directed towards development of good muscle power and prevention of any contracture/deformity. Braces and plaster splints may be used for this purpose. Surgery may be done for release of contractures and correction of deformities, at specialized centres.

Muscle bleeding: The treatment of a muscle bleeding is complete rest using splints. Physiotherapy is started gradually after factor replacement.

Nerve involvement: The treatment is the same as described for muscle bleeding. Splintage is necessary to prevent joint contractures.

Haemophilic arthropathy: An established arthritis may require surgery in the form of patellectomy, meniscectomy, synovectomy, or total joint replacement. Any surgical procedure needs a careful monitoring of factor VIII or IX assessment and its adequate replacement throughout the period of surgery and postoperative phase.

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Physiotherapeutic management

The basic objectives of treatment:

1. Alleviating pain

2. Preventing further haemarthrosis that results from weakness or joint instability by encouraging normal activity

3. Reducing periods of immobilization following joint or soft tissue haemorrhage

4. Reducing deformity and crippling by restoring muscular strength and ROM

5. Emphasizing strengthening of the muscles around the affected joint to provide joint protection

Therefore, clinical assessment of all these symptoms is the basis of planning a physiotherapy programme. Classification and grading proposed by the World Federation of Haemophilia provide a useful means of assessment (Table 29-8).

Table 29-8

Classification and Grading Proposed by the World Federation of Haemophilia (Used to Assess the Shoulder, Elbow and Wrists)

Pain		
Grade	0	No pain No functional

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		deficit
Grade	1	Mild pain Does not interfere with normal use Occasional analgesia
Grade	2	Moderate pain Some interference with normal use Occasional analgesia
Grade	3	Severe pain Interference with normal use Frequent analgesia (narcotic)
Haemorrhage (Incidence in Any 1 Year)[a]		
Grade	0	No haemorrhages
Grade	1	No major haemorrhages

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		1–3 minor haemorrhages
Grade	2	1–2 major haemorrhages 4–6 minor haemorrhages
Grade	3	3 or more major haemorrhages 7 or more minor haemorrhages
Clinical Features		Score
Swelling	Nil Present	0 2
Muscle atrophy	Nil Present	0 1
Joint crepitus	Nil Present	0 1
Range of movement	<10% loss of total range 10–30% loss	0 1

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	>30% loss	2
Flexion contracture	<15°	0
	>15°	2
Instability	Nil	0
	Present – function unaffected	1
	Present – interferes with function and may require bracing	2

[a]A minor haemorrhage lasts less than 24 h.

Besides these, functional analysis of the involved upper and lower extremities in relation to the whole body functions should be done.

Acute phase

First day:

1. The patient is given the replacement therapy. The joint is in a state of acute bleeding. No active physiotherapy is given. The limb is rested in an optimal position of comfort with posterior POP slab or moulded thermoplastic splint for the resolution of haemarthrosis.

2. Hyaluronidase iontophoresis can be given to promote

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haemorrhagic reabsorption (Magistro, 1964).

Second and third days:

1. Gentle isometrics can be started to the quadriceps and hamstrings in a splint if there is decrease in pain and effusion. The common bleeding sites should be checked thoroughly following the exercise.

2. Resistive exercises to the unaffected limbs can be started.

Fourth day onwards:

Gradual mobility exercises as well as strengthening procedures can be started. Isometrics should be made more vigorous as they increase strength and elasticity of the ligaments, muscular strength and bone mineralization. Isometric exercises can improve strength to the tune of 40–70% (Pelletier, Findley & Gemma, 1987).

If pain and swelling are well controlled, partial weight bearing on two axillary crutches may be started.

The tightness in the joint is corrected by serial POP casts. Sessions of graduated stretching are continued till the prebleeding status of the joint is attained. PNF techniques of rhythmic stabilization and hold–relax movements within the limits of pain are useful at this stage.

Full weight bearing, with correct transfers of the body weight and gait training are initiated in stages.

Hydrotherapy

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Hydrotherapy provides an ideal medium of exercise after surgery.

Pulsed short-wave diathermy

Pulsed short-wave diathermy (SWD) has been reported to be an effective modality in both muscle and joint bleeds. It promotes the resolution of bleeding along with pain relief. It can be used in acute and subacute stages as well as in joints where surgical procedures with metal implants have been done (Buzzard and Jones, 1988).

Tens

This pain relieving modality has been safely used even in the acute joint bleeding stage(Martinowicz, Heim, Beeton, Tuddenham & Krnoff, 1986).

Ultrasonics and interferential currents are useful in relieving pain and preventing adhesions.

Functional training

The patient should be educated on safer but progressive techniques of self-care activities, ambulation and functional positions, depending on the site of involvement. The patient should be educated to detect symptoms of bleeding.

Caution

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Overstretching of the affected joint, active or passive, and injury should be avoided as these may cause recurrence of bleeding.

Chronic stage including arthropathy

The physiotherapeutic measures are aimed at (i) prevention and maintenance of correction of the deformities, (ii) improving the power and endurance of the affected muscles and (iii) proper use of assistive aids and appliances.

In cases where surgical procedures like synovectomy, arthrodesis or joint replacement have been performed, the physiotherapeutic regime follows the same pattern as for the nonhaemophilia patients. However, a gentle and graduated approach is necessary to prevent secondary haemorrhage.

Ankylosing spondylitis

It is a seronegative chronic inflammatory (perhaps autoimmune) disorder affecting primarily the spine and sacroiliac joints, and secondly the other major joints (hip, knee, shoulder, etc.) in the body. It is more common in males (male/female ratio 9:1), the age of onset being 15–20 years.

The exact cause of this disease is not known. However, genetic predisposition has been observed. It is sometimes associated with urethritis, ulcerative colitis and conjunctivitis.

The disease has an insidious start with intermittent backache.

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The patient has stiffness of the back that is worst in the morning initially, and progresses the whole day. Occasionally, the pain may radiate to the lower limbs simulating a disc lesion. The stiffness of back increases progressively, affecting the whole of the spine. The other peripheral joints also become stiff gradually.

On examination, initially there is vague tenderness over the lumbosacral spine and the sacroiliac joints. The chest expansion decreases, usually being less than 2 inches initially, and gradually progresses to a mere half inch. This is due to the involvement of the costochondral joints. The spinal mobility is decreased considerably. The gait in these patients is very characteristic – the patient walks with a stiff spine swinging his arms in an arc.

The mobility of other joints will also be diminished in advanced cases.

The radiographs of the sacroiliac joints show involvement of the joints gradually leading to fusion. Similarly, the whole spine may get fused eventually; it is then called 'bamboo spine' (Fig. 29-22).

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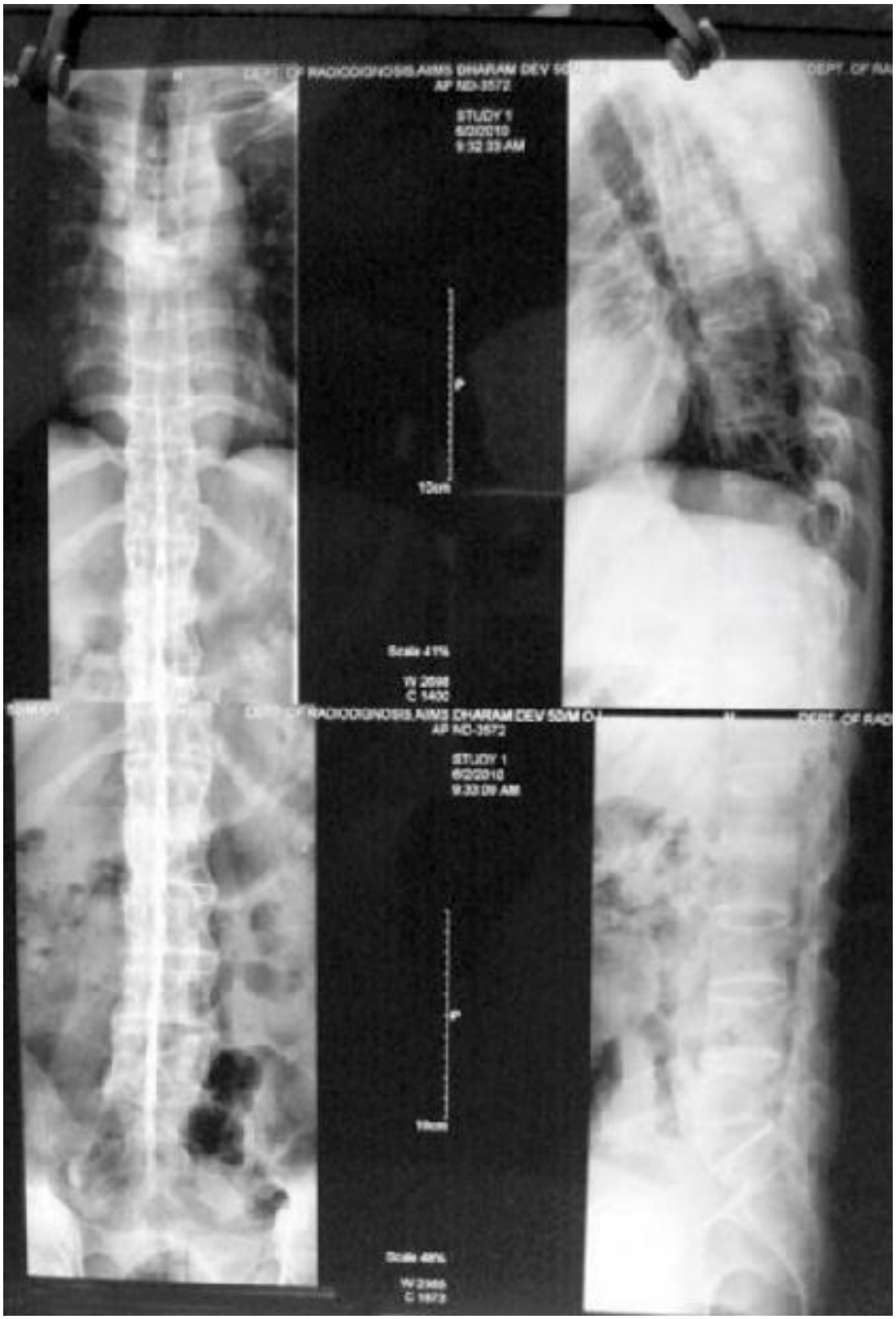

FIG. 29-22A typical ‘bamboo spine’ deformity due to

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fusion of the intervertebral joints in ankylosing spondylitis.

Treatment

Physical therapy plays an important role in the management of this disease throughout its whole course, more so in the initial stages. A general exercise programme is prescribed to maintain the mobility of the spine as well as other joints after critical musculoskeletal evaluation, as a baseline assessment, as much as possible. Breathing exercises are important to maintain chest mobility and expansion.

Analgesics and anti-inflammatory drugs are given for symptomatic pain relief.

Surgery

The following surgical procedures may be undertaken in the advanced cases.

(a) *Total joint replacements*: For ankylosed hip and knee joints, THR and total knee replacement are done respectively.

(b) *Excisional (Girdlestone) arthroplasty of the hip*: Rarely, excisional (Girdlestone) arthroplasty is done for an ankylosed hip to regain movements. An early and vigorous exercise programme is instituted after the for-mentioned surgical procedures, as these patients have a tendency for stiffness and re-ankylosis, due to ectopic bone formation.

(c) *Osteotomy of the spine*: In advanced cases of ankylosing

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spondylitis, ankylosis of the spine leads to a fixed flexion deformity of the spine, restricting the field of vision and the respiratory function.

In such cases, spinal osteotomy is indicated and is performed at the lumbar region, usually at the level of the L2 vertebra. The spinous processes are osteotomized and cut into small strips to be used as bone grafts later. Oblique osteotomy is performed through both the superior articular facets of the vertebra below and the inferior articular facets of the vertebra above. The spine is then extended by raising the head and the foot of the operating table. The flaps of the bone from the laminae adjacent to the osteotomy are raised and the defect is bridged with the bony strips obtained from osteotomy of the spinous processes (Fig. 29-23). By this procedure, the exaggerated dorsal kyphosis remains uncorrected; however it improves the posture. Postoperatively a plaster cast, a combination of spinal jacket and short hip spica, is given for a period of 6–12 weeks.

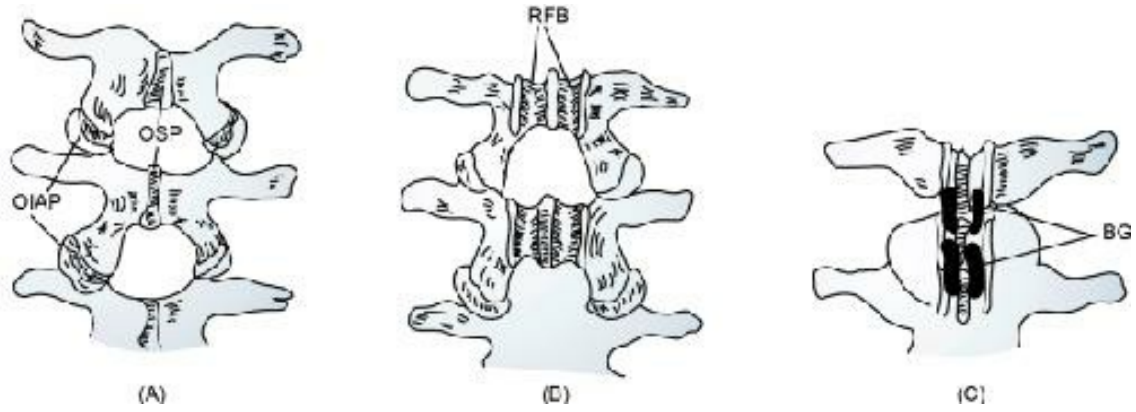

FIG. 29-23Spinal osteotomy to reduce kyphosis following ankylosing spondylitis. **(A)** Osteotomy of the spinous processes (OSP) and oblique osteotomy through the superior and inferior articular facets of the

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adjacent vertebral joints (OIAP). **(B)** Raising the flaps of bone from the laminae adjacent to the osteotomized spinous processes (RFB). **(C)** Bridging the defect by bone grafts (BG) obtained from the osteotomized spinous processes.

Physiotherapy

Physiotherapy for the total joint replacement and excisional arthroplasty is described in Chapters 13 and 24. Following osteotomy of the spine, immobilization is done by a combination of spinal jacket and short hip spica for 6 weeks. Thus, deep breathing, resistive arm, knee, ankle and toe movements are done vigorously during this period.

Following removal of the immobilization, vigorous mobilization is done for the hip joints. However, graduated mobilization of the patient from turning to sitting up and standing is done. Postural guidance based on ergonomic principles is emphasized to maintain the correction during daily activities.

Physiotherapeutic management of the patients treated conservatively: Ankylosing spondylitis is one of the most disabling chronic inflammatory affections of the joints of the spine. The inflammatory process initially affects the sacroiliac joints in a young adult and gradually progresses to the whole spine and other major joints of the body. Although the natural course of the disease leads to a typical 'poker back' or 'bamboo spine', the physiotherapy is directed to retain the functional mobility through compensatory

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movements of the joints.

Physiotherapeutic management depends on the stage of the disease. Before planning the therapeutic regime, the patient is carefully assessed as follows:

A. ***General posture:*** The patient is observed from anterior, posterior as well as from both the sides to detect the overall postural deviations.

Initially the whole spine assumes a stiff posture. Later on, it may get totally fused. The spinal fusion gives rise to a stiff and deformed posture where the cervical spine is fixed in flexion with atlantoaxial hyperextension. Thoracic spine is fused in marked kyphosis leading to a rounded back. The hips and the knees tend to assume compensatory attitude of flexion. Accurate measurements of the posture are taken at regular intervals with the help of spondylographs and/or clinical photographs.

B. ***Assessment:*** Passive as well as active ROM is measured separately for:

1. *Cervical spine*: By goniometry (Joshi, Singh, Kanta & Verma, 1978) – The extent of cervical flexion deformity is evaluated by measuring the distance from wall to tragus (Figs 29-24 and 29-25).

2. *Thoracolumbar flexion and extension*: The distance between the prominent seventh cervical vertebra and the sacrococcygeal junction is measured in the erect posture in full flexion and in full extension.

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3. *Lumbar flexion and extension*: On the patient's back, two points are taken as landmarks: one midway between the spinous processes of the fourth and fifth lumbar vertebrae and another 10 cm above this. The difference between the two points measured in full flexion and extension provides the range of flexion–extension.

4. *Lateral flexion*: The distance between the fingertip and the floor with the patient in maximum side flexion is measured.

5. *Rotation*: The pelvis is rotated with the patient in supine position, with hips and knees flexed. The movement is then recorded.

6. *Spinal flexion with hip flexion*: From erect posture, patient bends forward without flexing the knees. The distance between the fingertip and the floor provides a combined measure of hip and spinal flexion. Major arc of movement is contributed by hip joints. However, this assessment is important from the point of view of functional activities.

7. *Examination of the peripheral joints*: Commonly involved peripheral joints like temporomandibular, shoulder, hip and knee should be examined for active and passive ROM.

8. *Respiratory function*: An early involvement of costovertebral joints results in gradual restriction of the movement of ribs, which reduces the respiratory capacity. The chest expansion is markedly reduced, often less than 2.5 cm (average normal chest expansion: 7.5 cm). Chest expansion should be recorded at two levels: at the xiphoid process (seventh rib) and at the nipple (fourth rib). The VC,

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peak flow and FEV should also be recorded.

9. *Functional status*: Functional status of the patient in relation to the disability and the type of daily work is evaluated. This will help to provide the necessary guidance and adaptations to plan work-related therapy.

(A)

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(B)

(C)

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FIG. 29-24Cervical goniometry to evaluate ROM at cervical spine. **(A)** For measuring flexion and extension. **(B)** For measuring lateral flexion. **(C)** For measuring rotation.

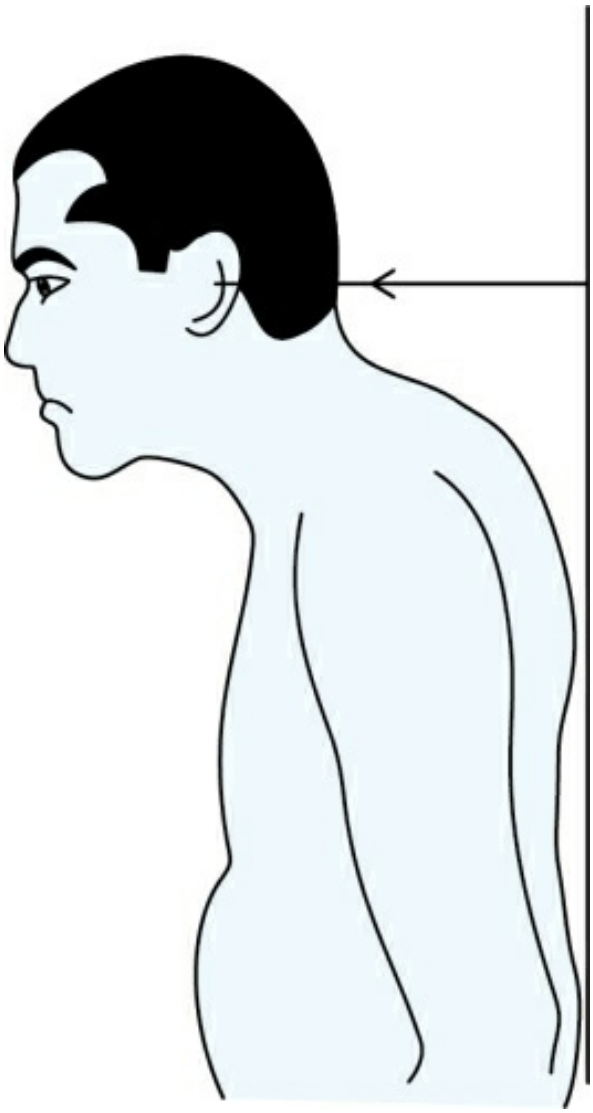

FIG. 29-25Measurement of tragus-to-wall distance in ankylosing spondylitis to assess fixed flexion deformity at cervical spine.

Treatment: Mobility of the whole body and spine in particular is the area of maximum emphasis.

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1. *Pain*: The pain and muscular spasm in the acute stage are controlled by superficial modalities such as hydrocollator packs or cryotherapy. Deep heating is effective in the chronic stage.

Steam bath preceding the exercise controls pain and induces relaxation.

2. *Mobility*: The objective is to maintain mobility of the spinal intervertebral joints by various procedures. Mobilization of the facet joints by specialized techniques as described by Maitland (1977) is effective.

The most important technique is the repeated small-range mobilization of the spine incorporated in the activities of daily routine. The patient should be educated on the correct procedure and the feel of segmental mobilization.

Pool therapy is an excellent means of providing pain relief. It also improves mobility and gives a feeling of fitness as the whole body is exercised.

3. *Respiration*: Free active exercises with deep breathing maintain the mobility and improve respiratory capacity.

Localized thoracic breathing without back support improves the breathing capacity.

4. *Body ergonomics*: Body attitudes promoting deformities should be discouraged. Maximum emphasis needs to be given to static as well as dynamic postural attitudes, e.g., keeping the chin tucked in, repeated prone lying with hyperextension at the dorsal spine on forearm supports, hip

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hyperextension in prone and trunk lateral bending with deep breathing.

The usual tendency to stoop should be strictly discouraged. Instead, the chest should be held up and forward with the shoulders retracted. Repetitions of isometric shoulder bracing are valuable and should be made a part of daily routine.

5. *Improvement of muscle power and endurance*: Muscles that are strong and capable of maintaining contractions will provide the necessary force to sustain correct posture. To induce relaxation and to improve mobility, active free movement plays an important role.

The progression of the disease usually stops after 10–15 years leaving a permanent residual deformity. In a majority of patients, total functional independence returns except for the fused spine.

Surgery may be necessary when there is ankylosis of the joints with severe fixed deformity. Hip ankylosis may need excisional or replacement arthroplasty. Severe flexion deformity of the spine may need wedge osteotomy. Appropriate physiotherapeutic measures will be necessary as per the type of surgery.

Due to rigidity, the whole spine develops an attitude towards flexion. Flexed and rigid spine discourages attitude towards lying prone, which in turn results in FFD at the hips, occasionally hip joints get ankylosed – with inability even to stand, they may need THR.

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Other forms of seronegative arthropathies

1. Psoriatic arthritis

2. Reiter syndrome

3. Reactive arthritis and postdysenteric Reiter syndrome

4. Enteropathic arthritis

Psoriatic arthritis is associated with skin lesions. Reiter syndrome may have urethritis, balanitis, skin lesions, conjunctivitis and oral ulcerations. Ulcerative colitis and Crohn disease (regional ileitis) – the inflammatory bowel conditions are present in enteropathic arthritis.

Besides all their characteristic symptoms, arthritis is common to all these conditions. Arthritis presents in two forms: (i) **peripheral** when there is an involvement of peripheral joints – it may be monoarthritis – and (ii) **axial arthritis** resembling ankylosing spondylitis.

Physiotherapeutic management is basically on the same lines as for RA and ankylosing spondylitis.

Physiotherapeutic modality like ultraviolet radiations may be used to treat the skin lesions of psoriasis. Advice on the proper care of skin and prevention from further damage due to trauma needs to be provided to patients. Footwear adaptations and modifications may be necessary, along with assistive walking aids. Maintenance of joint range, improvement of muscle power, and prevention of

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deformities are the basic therapeutic objectives. Repeated sessions of guided functional activities are of primary importance in all types of spondyloarthropathies.

The patient who is depressed due to the complexities of the disease needs to be assured to get his or her active cooperation.

Metabolic arthritis

Gout

Excessive concentrations of uric acid and some purine bodies in blood precipitate gout. The kidney is unable to separate this combination of uric acid and purine bodies. The uric acid salts accumulate in the blood. It mainly affects the joints, but other constitutional disturbances may also accompany. The disease is commonly seen in the first metatarsophalangeal and metacarpophalangeal joints in men older than 40 years. Deposits of biurate of soda occur around the affected joint (Fig. 29-26). The joint changes include subchondral cysts, osteophyte formation and in the late stages, reduction in joint space.

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FIG. 29-26Gout.

During an acute phase, the involved joint has signs and symptoms of acute inflammation with a hard and tender nodule known as ‘chalk stones’ or ‘tophi’. Fever often accompanies excruciating night pain, but the involved joint is comparatively pain free during the day.

Treatment

Acute stage: Colchicine, probenecid, indomethacin 75–200 mg. In addition, anti-inflammatory analgesic drugs are prescribed along with colchicine.

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Lithium ionization is sometimes done in between the acute attacks. This iontophoresis forms soluble lithium urate in place of insoluble sodium urate.

Cryotherapy in the form of crushed ice-packs and other nonthermal modalities may be tried to reduce inflammation and pain.

Pseudogout

Pseudogout is usually present in the older age group and affects knee and wrist joints. It can be polyarticular with an evidence of calcification of the cartilage (chondrocalcinosis). There is deposition of calcium pyrophosphate crystals. The signs and symptoms resemble acute arthritis.

Treatment

The treatment is the same as for gout.

Alkaptoneuric arthritis (syn: Ochronosis)

It is due to the absence of homogentisic acid oxidase – which appears in the body fluids and urine.

Clinical features

Normal colour urine of a child turns black on exposure to air – later the pigment gets deposited in various connective tissue matrices – leading to painful stiffness in the spine and large appendicular joints with calcification of the

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intervertebral discs.

Treatment

Treatment is mainly symptomatic.

Physiotherapy is mainly directed to maintain or improve the mobility to control stiffening of the affected joint, besides encouraging self-sufficiency in the ADRs.

Connective tissue diseases

The major connective tissue diseases include:

1. Systemic lupus erythematosus (SLE)

2. Systemic sclerosis (scleroderma)

3. Dermatomyositis: (polymyositis)

4. Mixed connective tissue disease (MCTD)

Anti-inflammatory drugs and corticosteroids are necessary to combat the acute inflammatory phase. Necessary physiotherapy also needs to be planned according to the symptoms and involvement.

Systemic lupus erythematosus

It has a complicated symptomatology. Various antibodies like ANA may be present. Usually, young females are affected.

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Skin lesions are widespread including the butterfly rash.

Joint changes like RA may occur.

The lesions may affect lungs, pleura, CNS and may accompany Raynaud phenomenon.

Treatment

Nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroids may be necessary in nonresponding cases.

Physiotherapeutic management

Physiotherapeutic measures are taken to control acute joint problems, to improve muscular weakness and to prevent deformities. As the acute symptoms recede, the programme of exercises and activities is increased. Prolonged sessions of exercises or activities should be avoided as a precaution.

The approach of physiotherapy varies according to the involved body systems. Repeated sessions of deep breathing exercises are important to maintain the VC.

Encourage patients to remain active and actively participate socially.

Systemic sclerosis (scleroderma)

Raynaud phenomenon with skin adherence (sclerodactyly) over the dorsum of the fingers is a distinguishing feature.

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Tightening of the skin around eyes, nose and diminished oral aperture may result. The kidneys may be involved resulting in hypertension.

Treatment

Drugs like penicillamine with colchicine may be given.

Physiotherapeutic management

Sclerodactyly may give rise to limitation of flexion of the affected fingers. All the physiotherapeutic measures are directed to retain the mobility at least to the functional level. Relaxed graded passive movements and self-assisted stretching of the finger flexion is to be repeated several times. Friction massage and ultrasound is advisable to promote mobility of these joints.

Dermatomyositis: Polymyositis

Skin rashes resembling SLE may occur, but are often associated with oedema over the eyelids. Erythema may occur over knuckles and nail folds.

Inflammatory changes occur in muscles with weakness of proximal limb muscle groups. Calcific lesions may occur in skin, muscles, tongue and even brain.

Treatment

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Corticosteroids are effective.

Physiotherapeutic management

During the acute stage, proper positioning of the limbs is of vital importance to avoid deformities.

As pain is reduced, early active movements should be initiated to the weaker proximal group of muscles. Recording and monitoring of the muscle power in the initial stage and subsequently are important to judge the progress.

Mixed connective tissue disease

The symptoms of all the first three varieties of connective tissue disease are present in MCTD.

Polyarteritis nodosum (PAN): Inflammation occurs in the arteries. This results in ischaemia of the end organ. Skin lesions (vasculitis) and renal complications may be present.

Polymyalgia rheumatica: Pain and stiffness of the neck and shoulder in the morning with tenderness are common. Synovitis may occur in hands and knees. Arteritis involving temporal arteries may be present.

Corticosteroids are effective in combating the disease.

Erythema nodosum: In this disease, erythematous raised lesions are present on the anterior aspect of the skin. The symptoms of arthritis may occur.

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Corticosteroid therapy is effective.

Sjogren syndrome: Dryness of eyes and mouth with peripheral arthropathy are present. RA, thyroid, hepatic or renal diseases may accompany.

Charcot joint

It is a neuropathic joint that occurs in syphilis (acquired or inherited) and is characterized by gross disorganization of major joints of the body. The knee, ankle, hip or shoulder joints are commonly affected. However, in rare instances, other smaller joints may also be affected.

There occurs rapidly progressive painless disorganization of the affected joint, without associated muscular atrophy. There may be signs of ataxia (locomotor incoordination, as in tabes dorsalis) and trophic (nonhealing) ulcers over the sole of foot.

Treatment

The treatment is unsatisfactory and disappointing. Splinting is impractical and the results of surgery (arthrodesis) are unpredictable.

Physiotherapeutic management

It is not possible to outline the definite therapeutic measures to be adopted to treat Charcot joint. They vary according to the demands of the involved joint, existing pathology and

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the symptoms of the disease.

Preventive measures like education on proper foot care to avoid trophic changes are taken. Splints or braces may be used to stabilize the disorganized joints. Graduated stretching of the joint is necessary to avoid contractures.

Maintenance of the optimal function of the muscles and joints free from the disease, and guidance on safe continuation of functional performance are important.

Miscella neous conditions

Synovial chondromatosis

Cartilaginous loose bodies are formed from the surface of a synovium. These get detached as loose bodies.

Treatment

Treatment is done by synovectomy and lavage of loose bodies.

Physiotherapy

Graduated ROM mobility exercises and exercises to improve muscle functions are performed.

Table 29-9 depicts distinguishing characteristics of RA, ankylosing spondylitis and osteoarthritis.

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Table 29-9

Characteristics of Rheumatoid Arthritis (RA), Ankylosing Spondylitis (AS) and Osteoarthritis (OA)

Rheumatoid Arthritis (RH)	Ankylosing Spondylitis (SA)	Osteoarthritis (OA)
• Inflammatory joint disease	• Chronic inflammatory disease	• Noninflammatory degenerative disease
• Autoimmune disease	–	• Due to wear and tear of the reticular cartilage
• Presence of RA (rheumatic factor) with absence of rheumatic factor	• Absence of rheumatic factor but presence of HLA-B_{27}	–
• More common in females between the age group of 30 and 50 years	• More common in males (M/F ratio 9:1) between the age group of <40 years, the age of onset being 15–20 years	• Common in females older than 40 years

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• Mostly bilateral joint affection	• Involves SI and later on – spinal joints (intervertebral joints)	• Usually single joint affection, later on may involve other side
• Signs of inflammation at the affected joint (e.g., redness, warmth, effusion)	• Causes localized tenderness and vague pain at the site of involvement and low back pain; sleep-disturbing acute pain at night or during rest	• Causes localized tenderness and pain with stressful movements
• Morning stiffness which prolongs longer	• Morning stiffness localized to back, relieved with movement	• Morning stiffness as well as stiffness following prolonged rest, reduced with movement
• Multijoint affection common at small joints of hands and feet	• Involves SI, intervertebral joints and may involve joints like hip	• Commonly involves weight bearing, overused joints (e.g., hips, knees)

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• Systemic involvement with feeling of sickness, early fatigue, loss of body weight	• Gradual setting in of spinal stiffness, loss of lumbar lordosis	• Pain, stiffness, localized to the involved joints only
• Extra-articular lesions like vasculitis, subcutaneous nodules, osteoporosis, heart, lung, neuromuscular and reticuloendothelial system affections may be seen	• Extra-articular lesions like uveitis, CNS disturbances, pulmonary complications, conduction defects in heart may occur	• No extra-articular lesions are generally seen
• Prognosis: Controllable, but unpredictable with chances of recurrence	• Prognosis: Controllable, spinal stiffness remains a permanent feature	• Prognosis: Good

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Chapter 30

Deformity

Outline

■ Congenital deformities

■ Radioulnar synostosis

■ Madelung deformity

■ Radial club hand

■ Contracted fingers

■ Other congenital deformities (syndactyly, polydactyly and ectrodactyly)

■ Congenital pseudoarthrosis of the tibia

■ Klippel–Feil syndrome (short neck)

■ Congenital dislocation of the hip (CDH)

■ Acquired deformities

■ Developmental disorders of the bone

■ Osteogenesis imperfecta (syn: fragile ossium)

■ Fibrous dysplasia

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- **Paget's disease (osteitis deformans)**
- **Congenital multiple exostosis (diaphyseal aclasis)**
- **Cerebral palsy**
- **Muscular dystrophy**

Introduction

Deformity

Deformity is an alteration in the shape of the basic normal structure of a body anywhere from head to toe. It has a great association with orthopaedic science. In fact, the word orthopaedics itself is derived from two Greek words 'orthos' meaning to straighten and 'pedios' meaning a child. Therefore, orthopaedic specialty began with the correction of deformities in children. Besides cosmetic disfigurement, deformity may lead to impairment or even a loss of function. Deformity may occur following any orthopaedic disorder irrespective of its basic pathology or after a muscle injury, posing a major challenge to the orthopaedic surgeon as well as the physiotherapist.

Commonly, a deformity can be classified as follows:

1. Congenital

2. Acquired

Congenital deformity

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Incorrect position in the uterus, failure to develop normally, and abnormal development of the neuromusculoskeletal tissues due to a combination of genetic and/or environmental factors are the main causes of congenital deformity. The congenital deformity may or may not be hereditary.

Acquired deformity

Acquired deformity develops after birth. It can be produced as a result of the following causes:

1. Bone disease: Diseases like tuberculosis, carcinoma, and rickets may produce bony deformity by affecting the composition of the bone. Chronic infections like osteomyelitis can also cause deformity.

2. Joint diseases: Like arthritis and gout.

3. Muscular causes include the following:

(a) Deformity can be caused due to muscular imbalance resulting from paralysis. Continuation of this muscular imbalance may eventually produce articular changes which further aggravate the deformity.

(b) Muscle spasticity leading to malpositioning in the direction of spastic muscle groups may become organized into deformity (a classical example is equinus deformity at the ankle and foot due to spastic gastroc-soleus).

(c) Muscular disease like muscular dystrophy produces deformity in due course.

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(d) Shortening of musculotendinous complex or contracture of the muscle due to various causes may result in a deformity.

4. Trauma: Malunited fractures can result in a deformity. Epiphyseal injuries in children may lead to premature closure of the growth plates and cause deformity or shortening. Scar formation following burns or soft tissue injuries can develop soft tissue contractures, resulting in a deformity.

5. Postural causes: Long periods of bad habitual postures, lack of correct postural reflex, altered joint mechanics could be the precipitating factors for a deformity.

6. Nerve lesions: Gross sensory and/or imbalanced motor impairment following injury or neuronal diseases may result in the loss of sensations and joint sense. This, in turn, causes uncontrolled perception to pressures resulting in a deformity or even loss of a segment of the limb, as occurs in Hansen disease.

Classification of the degree of deformity

A deformity is classified into the following three grades:

1. First degree: The deformity is mild and can be corrected completely by passive stretching.

2. Second degree: Shortening in the soft tissues prevents full passive correction of the deformity. Attempted passive correction results in pain. Minimal bony changes may be

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present.

3. Third degree: The deformity is rigid and cannot be corrected by passive stretching or manipulation. It may be associated with bony changes.

Methods of management

Assessment

The first principle of management is accurate assessment of the deformity.

■ The extent of the deformity is evaluated objectively by goniometric measurement.

■ Passive correction, if possible, should be recorded.

■ Related body segments should be examined for any effect sequelae of the deformity.

■ The causative factor of the deformity should be ascertained.

■ The overall impact of the deformity, functionally as well as cosmetically, should be assessed.

Depending upon the evaluation, the therapeutic approach should be planned, keeping in mind the patients' or the parents' cooperation, since the treatment is tedious and time consuming.

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Principles of management

1. Treat the causative factor, i.e., muscular imbalance/biomechanical shifts because of habitual posture or any underlying disease by corrective measures.

2. Correct the deformity to the maximum.

3. Passive maintenance of the correction by rigid support (e.g., plaster of Paris [POP] cast).

4. Re-education to actively maintain the correction or reduction by dynamic orthosis (e.g., toe-pick up orthosis).

5. Control the factors which may produce secondary deformity.

6. Avoid recurrence of the deformity.

Methodology to correct the deformity depends upon the degree of deformity and its overall functional impairment.

Management of first- and second-degree deformities

It can be corrected by measures like:

1. Graduated passive stretching.

2. Exercises to correct the muscular imbalance.

3. Strapping by kinesiology tape helps to strap the deformity in slightly overcorrected position, and still allows movement.

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4. Maintenance of correction by adequate immobilization.

5. Regular check-up of the correction during immobilization.

6. Re-education exercises.

7. Corrective splinting to maintain the correction.

8. Appropriate orthosis – its care and maintenance.

9. Functional re-education with the orthosis.

10. Emphasis on reporting for regular check-up and advice to avoid recurrence.

Management of third-degree deformities

In the presence of third-degree deformities, the management is difficult, time consuming with unpredictable results. The treatment involves a series of corrective manipulations and/or surgical procedures on soft tissues and bones.

Congenital deformities

Sprengel shoulder

Sprengel shoulder, also called *congenital* high scapula, is characterized by an abnormally raised small scapula, on one or both the sides (Fig. 30-1). The aetiology is unknown.

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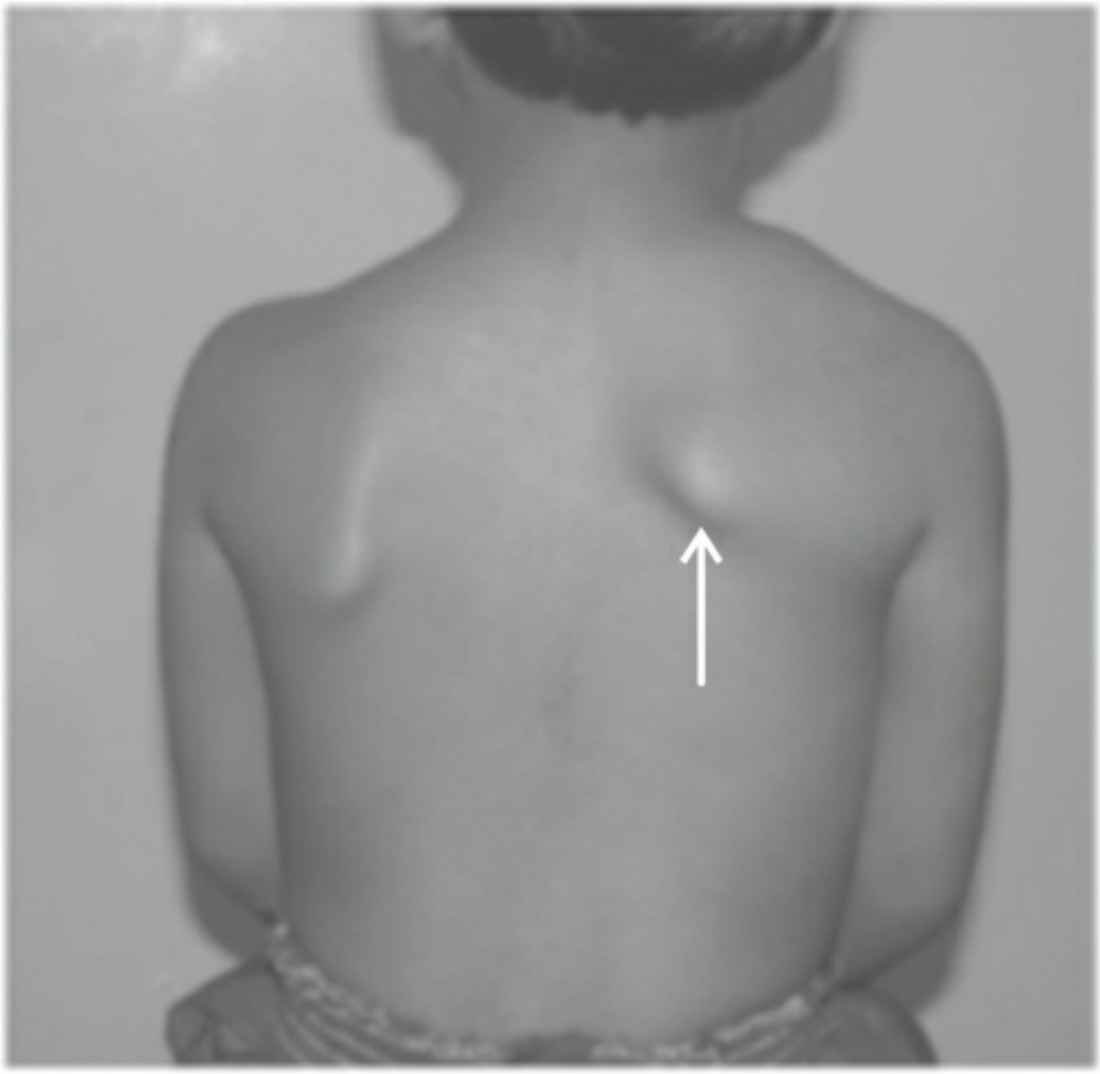

FIG. 30-1Sprengel shoulder. Note that the right scapula is at a higher level (arrow).

The scapular muscles are poorly developed and may be represented by fibrous bands. It may be accompanied by scoliosis (thoracic curve) with convexity on the involved side. The movement of scapula is markedly limited due to the fibrous bands or a bony bar resulting in limitation of shoulder abduction and elevation. However, the functional disability is usually minimal. Very little improvement can be offered by way of corrective exercises.

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Surgical treatment

It consists of excision of the fibrous band or bony bar and bringing the scapula down to its normal position.

Physiotherapy after surgery

1. Gradual relaxed passive mobilization of the shoulder and scapula.

2. Suitable pain reducing modality.

3. Special attention is given to achieve early mobility of the scapula and shoulder abduction and elevation.

4. Overall mobilization of the shoulder girdle muscles.

5. Strengthening of all the groups of muscles.

6. Maximum possible correction of the posture and its maintenance is important. This will help in learning habitual correction of the posture.

Radioulnar synostosis

In this deformity, the radius and ulna are fused at the proximal radioulnar joint (Fig. 30-2). There is restriction of the movements of rotation of the radius over the ulna (i.e., pronation and supination of the forearm). This results in functional impairment of the arm.

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FIG. 30-2Congenital radioulnar synostosis.

When the forearm is fixed in the near range to mid-position of the forearm or pronation, the arm can be effectively used for functional activities by manoeuvring movement at the shoulder, elbow and wrist joints.

However, when the forearm is fixed in an abnormal position, osteotomy may be indicated.

In conservatively managed patients, guidance is given to strengthen the compensatory muscle groups and joints.

Operative treatment: If the rotational deformity is unacceptable, an osteotomy of the radius and ulna is done to fix the forearm in an acceptable rotation position for optimum functional result. No pronation/supination movement, however, is possible.

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Madelung deformity

It is a congenital anomaly associated with defective development of the medial part of the lower radial epiphysis. This results in growth disorders of the medial side of the radius, while the outer part of the radius and the ulna continues to grow at a normal pace. Subsequently, the radial shaft bows backwards and the lower end of the ulna subluxates backwards (Fig. 30-3A and B).

(A)

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(B)

FIG. 30-3**(A and B)** Madelung deformity.

The deformity is usually bilateral, commonly seen in adolescent females and presents with weakness of the hand and wrist. The movement of dorsiflexion at the wrist is limited; occasionally, in severe cases, supination and pronation are also limited.

Treatment

The treatment consists of shortening the distal fourth of the ulna and corrective osteotomy of the radius. The plaster cast is required to be maintained for 6–8 weeks.

Radial club hand (fig. 30-4)

There is partial or complete absence of the radius, associated with hypoplastic or absent thumb. This results in radial deviation of the hand and wrist with bowing of the ulna. The

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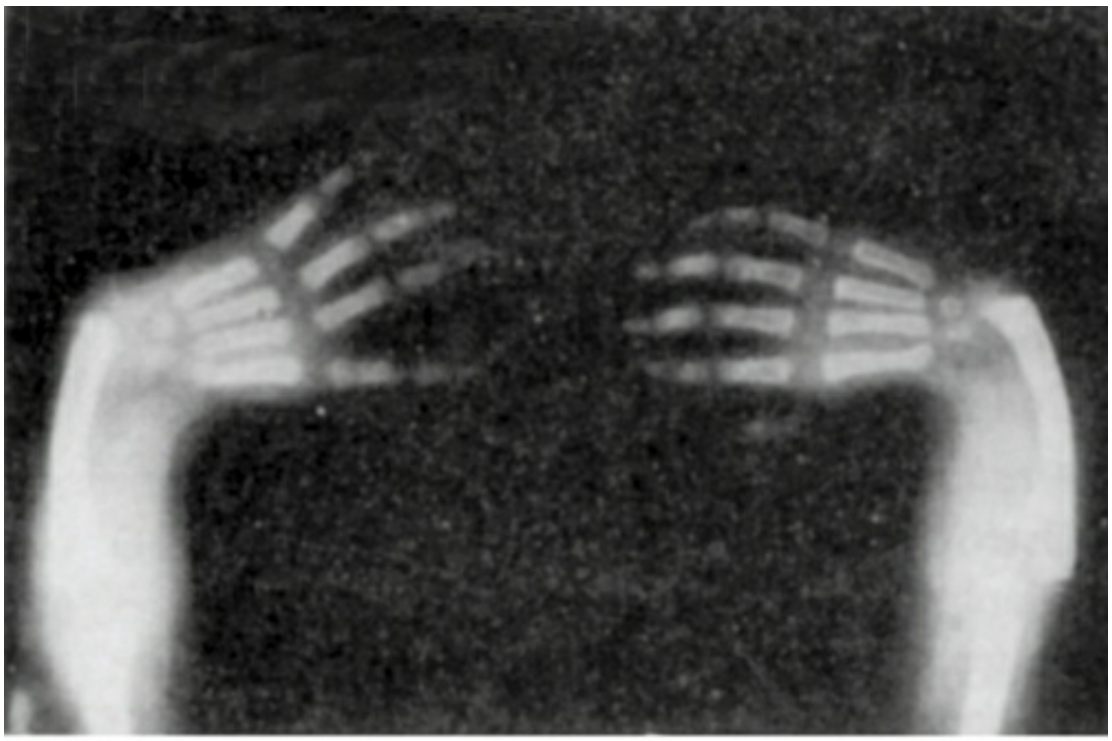
thumb may be hypoplastic, floating (Fig. 30-4B), or completely absent. The muscles on the radial side of the forearm are also abnormal or underdeveloped.



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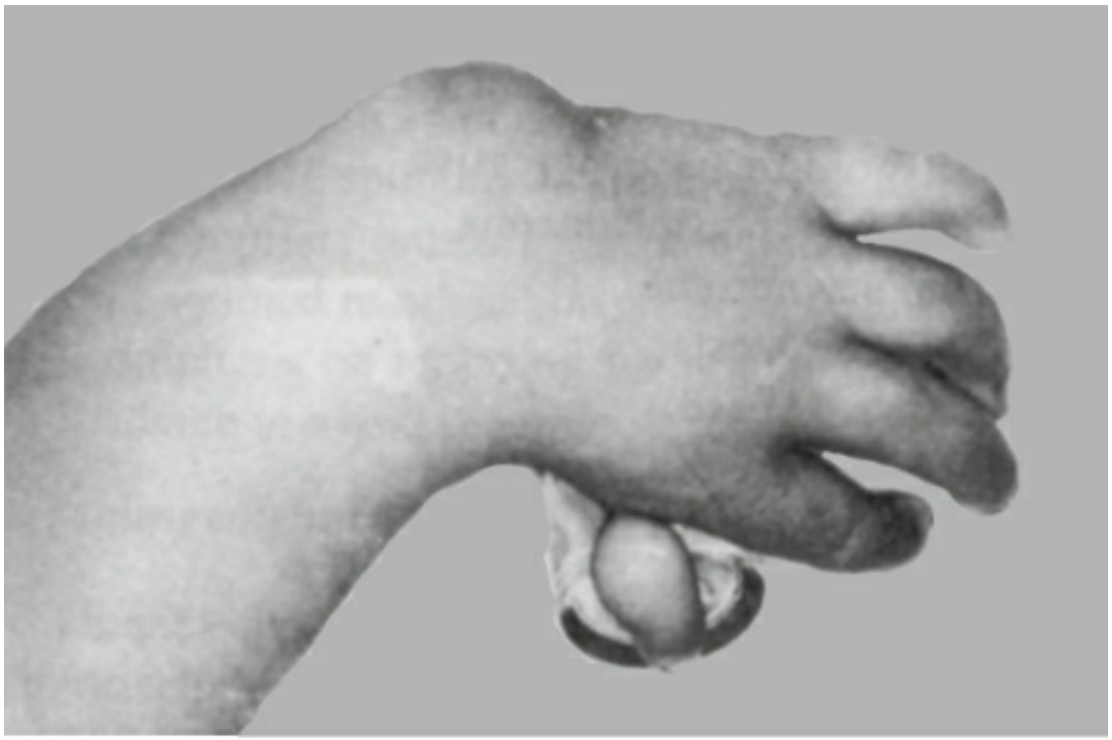

(B)

FIG. 30-4Radial club hand. Excessive radial deviation of wrist due to the absence of radius. **(A)** X-ray and **(B)** photograph.

X-rays: X-ray of the forearm and wrist shows the following features (Fig. 30-5):

■ Strong, stout and curved ulna.

■ Absent radius; radius may be present in proximal half and may be rudimentary.

■ Thumb may be absent or hypoplastic.

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FIG. 30-5Radial club hand. Note the strong, stout ulna along with rudimentary radius.

Treatment

Initially, the contracted soft tissues are stretched by serial plaster casts until a full passive correction of the deformity is obtained. Subsequently, carpus of the hand is (surgically) centralized over the ulna. The ulna is aligned with the third metacarpal (Fig. 30-6).

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(A)

(B)

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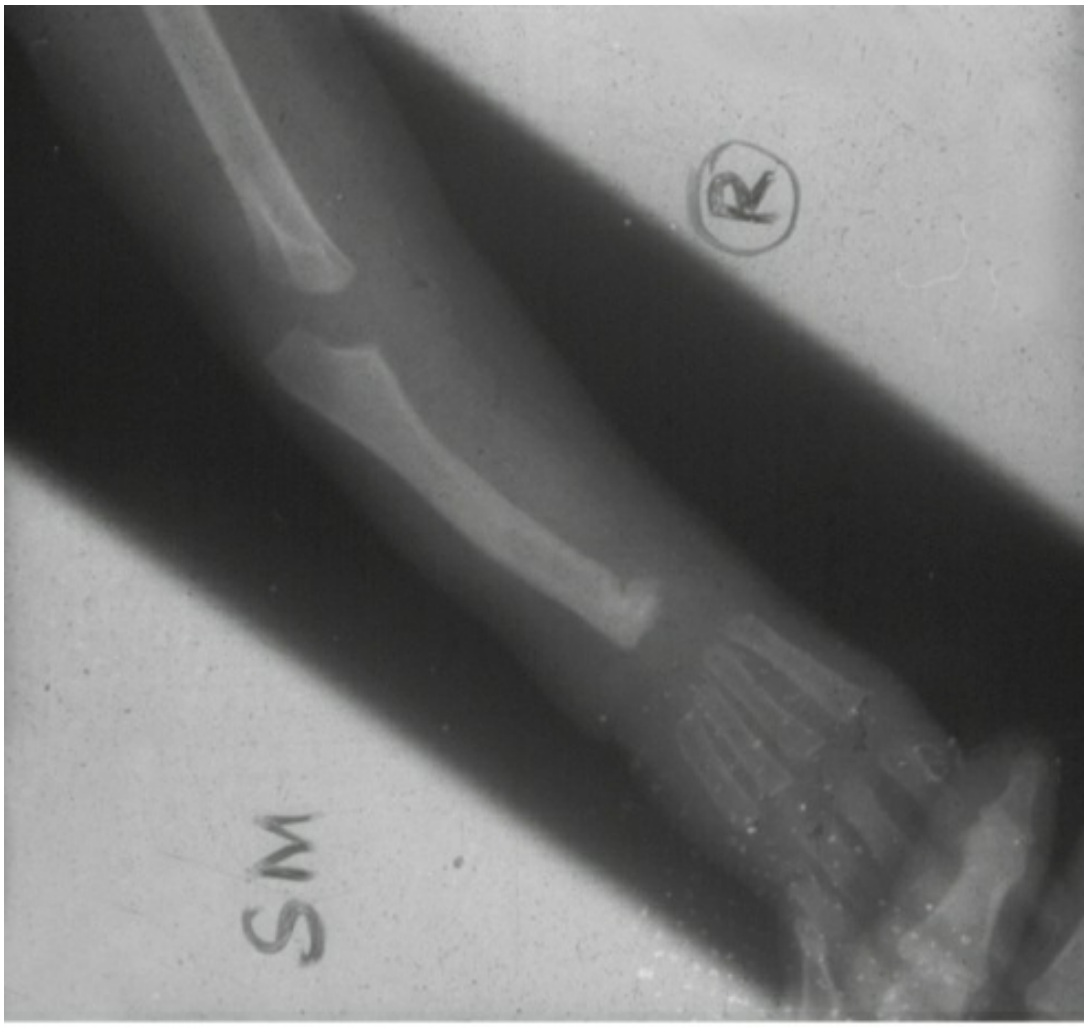

(C)

FIG. 30-6**(A)** Radial club hand deformity. **(B)** Centralization procedure done – distal end of the ulna is aligned with the third metacarpal. Note that the radius is absent. **(C)** Result – after correction of the deformity.

When the thumb is absent, the index finger is reconstructed into a thumb, a surgical procedure called pollicization – this is done subsequently as a secondary procedure (Fig. 30-7).

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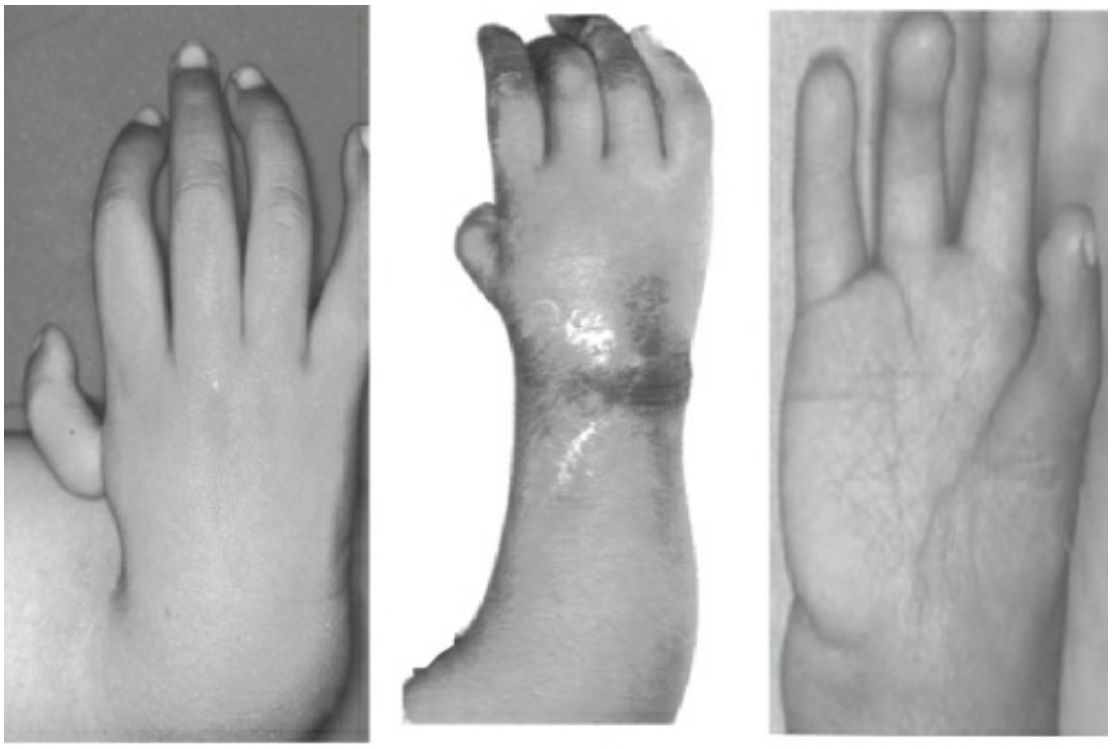

FIG. 30-7**(A)** Radial club hand with hypoplastic thumb, **(B)** deformity corrected by surgery and **(C)** pollicization done. Index finger converted into thumb.

Postoperative mobilization

1. Maintenance of proper positioning of the wrist in overcorrected position has to be strictly observed. Ideally the splint should be prepared before surgery, leaving the minor adjustments to be done during the actual fitting.

2. Sessions of gentle relaxed passive movements towards overcorrection as well as wrist extension should be concentrated.

3. Strengthening procedures for the muscle group

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antagonistic to the side of the deformity need special attention.

4. The functional use of the hand with splint needs to be educated and repeated several times.

5. The splint is gradually weaned off if the correction achieved is maintained voluntarily.

6. Regular follow-up to be emphasized to prevent recurrence.

Contracted fingers

Congenital contractures in the ring and little fingers are seen due to the tightness in the fascia and skin of the fingers. It usually presents as a flexion deformity at the proximal interphalangeal joint with extension at the metacarpophalangeal and distal interphalangeal joints.

In mild cases, if detected early, the deformity can be corrected by applying finger splints which keep the fingers straight. The proximal interphalangeal (PIP) joint can easily be stretched to extension by relaxed passive movement. This passive manipulation needs to be done several times and the splint to be applied immediately to retain the correction. Neglected cases need surgical correction where the fascia is divided.

Postoperatively, application of splint and the regular regime of relaxed passive stretching along with strengthening exercises and functional use should be encouraged. As with any other hand surgery, strict vigil is needed to avoid

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recurrence.

Other finger deformities (syndactyly, polydactyly and ectrodactyly)

Syndactyly: There is webbing of two or more digits (Fig. 30-8). The fingers are separated by surgery only (Fig. 30-9).

Polydactyly: The digits are more than five in number (Fig. 30-10). The extra digits are excised surgically.

Ectrodactyly: Lobster-claw appearance of hand with pincer grip. The lobster-claw hand is corrected by reconstructive surgery (Fig. 30-11).

FIG. 30-8Syndactyly in both hands. The middle and ring fingers are fused.

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FIG. 30-9Syndactyly release—result.

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FIG. 30-10Polydactyly.

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(A)

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(B)

FIG. 30-11Lobster claw hand: **(A)** Preoperative picture. **(B)** Postoperative result.

Congenital pseudoarthrosis of the tibia

It is a rare familial condition where nonossified tissue is present at the junction of the middle and distal third of the tibia. It may remain ununited or result in a pathological fracture following a trivial trauma.

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There may be anterior bowing of the tibia or there may be abnormal mobility at the site of nonossification (Fig. 30-12).

FIG. 30-12Congenital pseudoarthrosis of the tibia.

Treatment

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The union is difficult to achieve in this type of nonunion of the tibia. Many treatment methods have been described; a few of them are as follows:

1. Excision of the abnormal bone mass, internal fixation of the nonunion and bone grafting.

2. Ilizarov fixator treatment.

3. Excision of the abnormal bone mass/segment of the tibia and vascularized fibular grafting and internal fixation. The vascularized fibula is placed in the gap in the tibia using microvascular technique (Fig. 30-13).

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(A)

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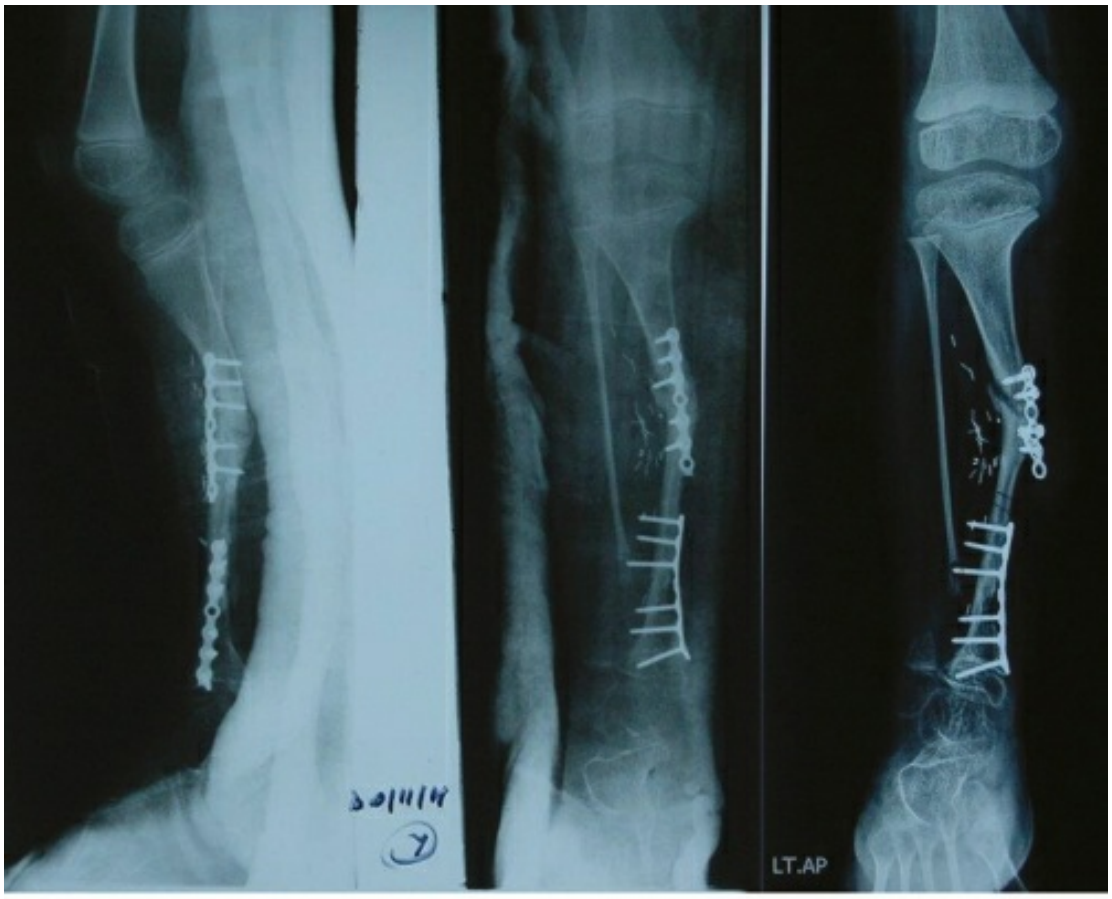

(B)

FIG. 30-13Congenital pseudoarthrodesis tibia: **(A)** Preoperative X-ray. **(B)** Postoperative result.

Physiotherapy is directed mainly to keep a regular check on immobilization–correct positioning of the limb. On the removal of POP, carefully graduated weight-bearing and ambulatory training are instituted.

Torticollis

A developmental defect in one sternomastoid muscle or malposition of the neck in the uterus can give rise to this deformity. The shortening of the sternomastoid is the

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principal causative factor. There may be an associated shortening of the scalene, platysma, splenius or trapezius muscles. Incidence is more common in girls, and the side affected is usually left. Occasionally, it may be bilateral. The affected sternomastoid may get atrophied and facial asymmetry may occur in untreated cases.

Nature of the deformity

The head is fixed in side flexion to the same side (i.e., on the side of the affected muscle), while it is rotated to the opposite side. The shoulder on the affected side is raised. Scoliosis with convexity to the sound side may be present in the cervical region. Facial asymmetry with smaller eye and lowering of the corners of the mouth and eye with deviation of nose on the affected side may be present (Fig. 30-14).

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FIG. 30-14Torticollis. Note the contracted sternocleidomastoid muscle on the right side and the facial asymmetry.

In rare bilateral affections, both the sternomastoids are contracted. The head is protruded forward with associated kyphosis.

Treatment

The basic objectives:

1. To correct the deformity by release of the contracted soft tissues

2. To maintain the correction by suitable exercise regime, avoiding recurrence

Early mild cases: Children with mild degree of deformity reporting early for treatment can be managed with physiotherapy. The following physiotherapy procedures are employed:

1. Evaluation: Careful evaluation of range of motion (ROM) and the degree of deformity.

2. Massage: Massage can relax the muscle preceding the stretching manoeuvres.

3. Carefully administered thermotherapy modality induces relaxation.

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4. Passive movements: The child is placed in supine position with head beyond the edge of a table with neck in extension by positioning a pillow under the thoracic region. Shoulders are stabilized by an assistant.

(a) To attain relaxation, all the movements of the cervical spine are done in a form of slow relaxed passive movements.

(b) This should be followed by sustained passive stretching to the affected sternomastoid, e.g., when the right sternomastoid is involved, the head should be gradually bent in side flexion to the left, held there for a while and then rotated gradually to the right. Try to gain as much overcorrection as possible by applying gradual traction to gain further stretching.

(c) Maintenance of correction: Once the correction is achieved, it has to be maintained by passively holding or keeping a sand bag.

(d) The same manoeuvre can be repeated during subsequent visits.

(e) Active correction: Active correction is best achieved by assisting the child's head to follow an object moved in the proper arc of correction. A bright coloured sound-producing object is ideal to attract the child's attention.

(f) PNF: Patterns of neck extension can be used at an advantage with emphasis on stretch and traction.

(g) Home treatment programme: This assumes an important role as these manipulations need to be repeated. The mother

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should be trained properly for this. The best method is to put the child in a prone position and teach the mother to carefully move the head towards the affected side; the child is encouraged to look back over the right shoulder.

(h) Positioning: Exact positioning of the head during sleep is important. The child should be made to sleep on the opposite side of the lesion and the position of head adjusted by pillow or sand bag in a maximally corrected posture. This positioning has two advantages. First, there is natural relaxation of the muscle and secondly, whatever correction is achieved, it is maintained for a longer period during sleep. However, the mother should intermittently check the correction.

Older children and adults: With advancing age, the deformity gets organized and does not get corrected by conservative management.

Surgical

The sternal and the clavicular heads of the sternomastoid are divided close to the origin along with release of the tight fascia. The head is then immobilized in a plaster cast in an overcorrected position for 2–4 weeks. Mobilization is begun as soon as the cast is removed.

Physiotherapeutic management following surgery

Since the contracture is released surgically, passive sustained stretching is not necessary. However, the following measures

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are undertaken:

1. Control of pain: Pain at the surgical incision may persist, particularly during exercises. Pain relieving modality like hot pack or infrared should be given before exercises.

2. Active movements: Emphasis should be on active movements, especially for the sternomastoid which becomes weak following surgery. Initially, free active movements are encouraged. Then specific exercise for the sternomastoid in a correct groove to attain lateral flexion to the opposite side and rotation to the same side is encouraged. Whenever possible, this movement combination should be made resistive.

3. Self-correction: Methods of self-correction in front of a mirror and its maintenance by active efforts should be well educated.

4. Collar: Specially moulded cervical collar should be used during the rest of the period and proper posture should be checked and maintained during sleep. The collar should be removed for exercises and discarded only after maximum correction is achieved.

5. Working posture: Guidance on the proper posture while working or during the activities of daily life forms an important part of the treatment to avoid recurrence.

Klippel—feil syndrome (short neck)

There is fusion of two or more cervical vertebrae. There is

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characteristically a low hairline with variable restriction of movements of the neck. The neck is unusually short. There is n specific treatment.

Cervical rib (fig. 30-15)

Cervical rib is the presence of an extra rib or a fibrous band, the extension of the costal process of the seventh cervical vertebra. It may give rise to vascular symptoms when it exerts pressure on the axillary artery. It may press on the lower part of the brachial plexus giving rise to neurological symptoms like paraesthesia in the hand, hypothenar wasting, atonia in the shoulder girdle muscles with drooping of shoulder or lower trunk paresis. Sympathetic disturbance with increased sweating in the hand may be present.

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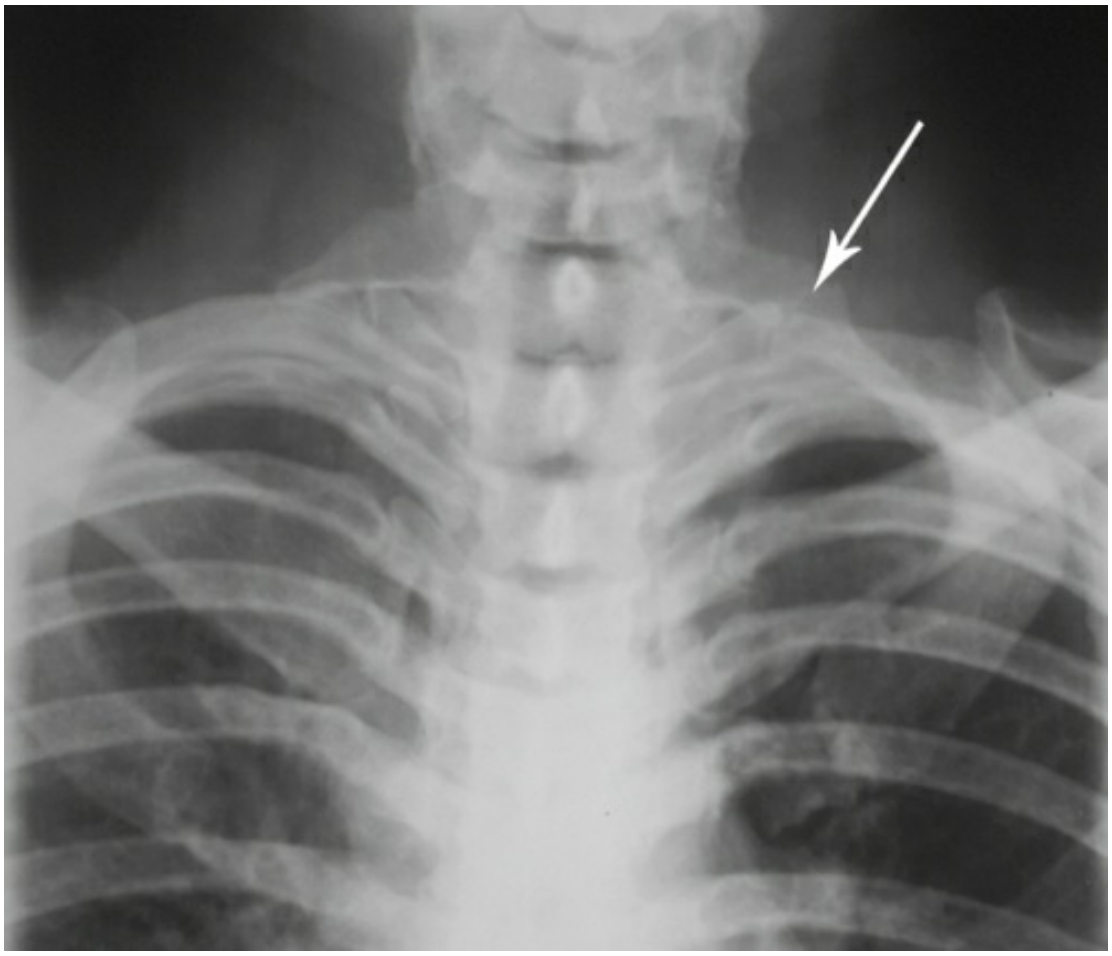

FIG. 30-15Cervical rib on the left side (arrow).

Treatment

Treatment depends upon the presenting symptoms. Anti-inflammatory drugs and analgesics with appropriate therapeutic measures are prescribed as per the symptoms. However, strengthening of the shoulder girdle muscles, especially elevators and retractors, is important. Self-resistive, progressive resistive exercises or scapular PNF patterns are effective.

Excision of the cervical rib is undertaken in cases with

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vascular and/or neurological pressure symptoms.

Physiotherapy is directed mainly towards strengthening of the muscles of the shoulder girdle and neck extensions.

Note: Spina bifida and scoliosis are discussed in Chapter 32 on 'Spine'.

Developmental dysplasia of the hip (fig. 30-16)

The term developmental dysplasia of the hip (DDH) is being used nowadays in place of the conventionally used term congenital dislocation of the hip (CDH).

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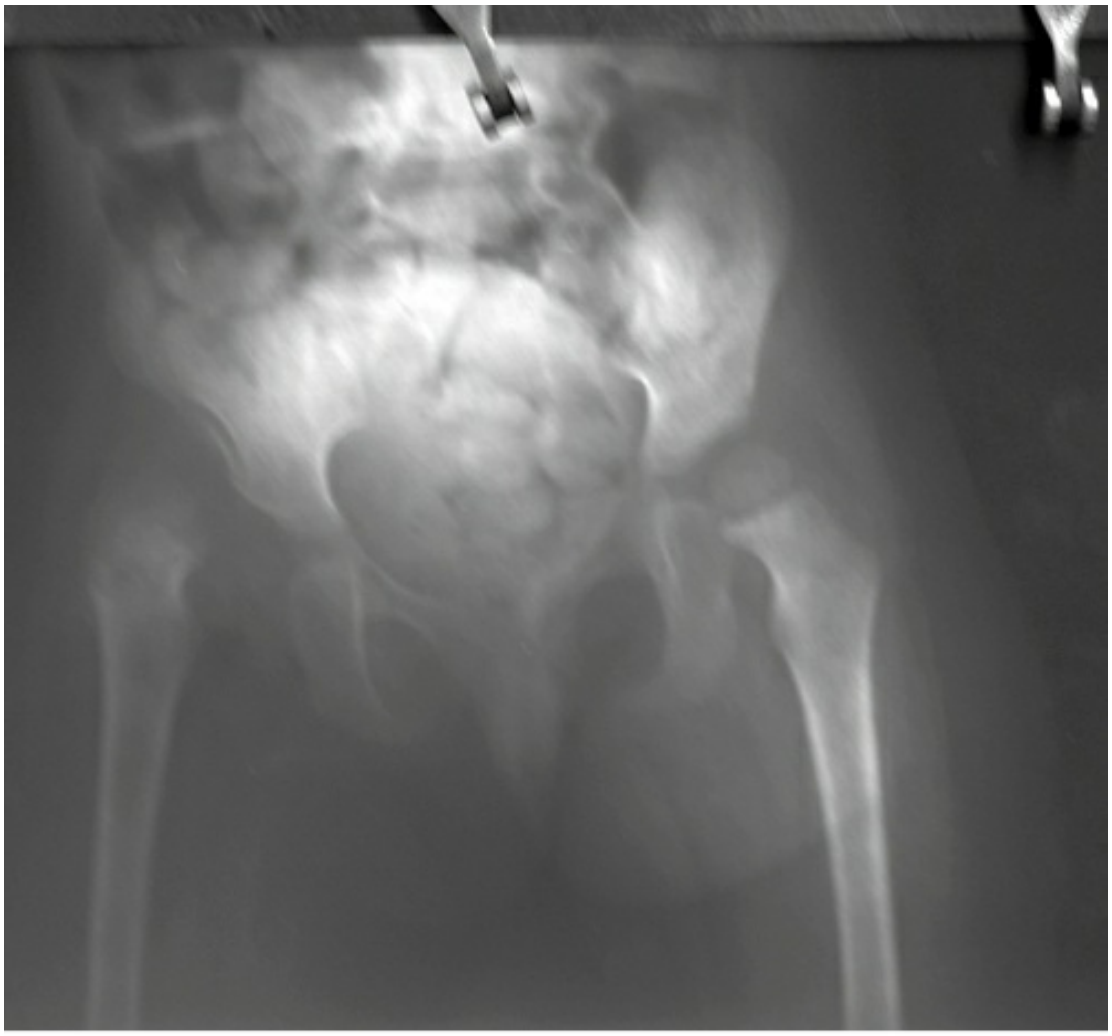

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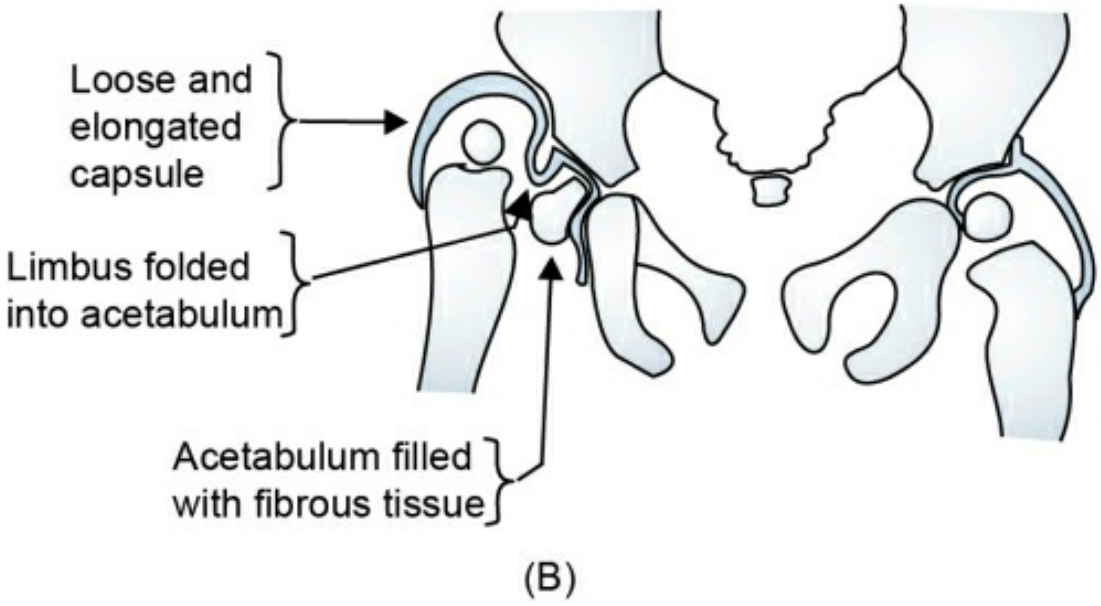

FIG. 30-16**(A)** Congenital dislocation of the right hip. Note that the acetabulum is shallow and the femoral head is out of the acetabulum. **(B)** Congenital dislocation of the right hip: pathological changes (diagrammatic representation).

CDH or DDH includes subluxation, dislocation or dysplasia of the hip. In subluxation of the hip, there is only partial contact between the femoral head and the acetabulum. In dislocation of the hip, there is no contact between the acetabulum and the femoral head. Dysplasia of the hip refers to inadequate development of the acetabulum, femoral head or both.

CDH can be because of abnormalities in the bones as well as in the soft tissues. The skeletal anomalies include shallow acetabulum, posterior displacement of the head of the femur with tendency for flattening, change in the neck shaft angle of the femur or excessive anteversion of the neck.

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Clinical features

In early childhood, observant parents may notice asymmetry in the buttock folds (Fig. 30-17) and limitation of movements of the hip joint. In the older child, walking may be delayed or the child may walk with a limp (in unilateral dislocation) or with a waddling gait in bilateral dislocation.

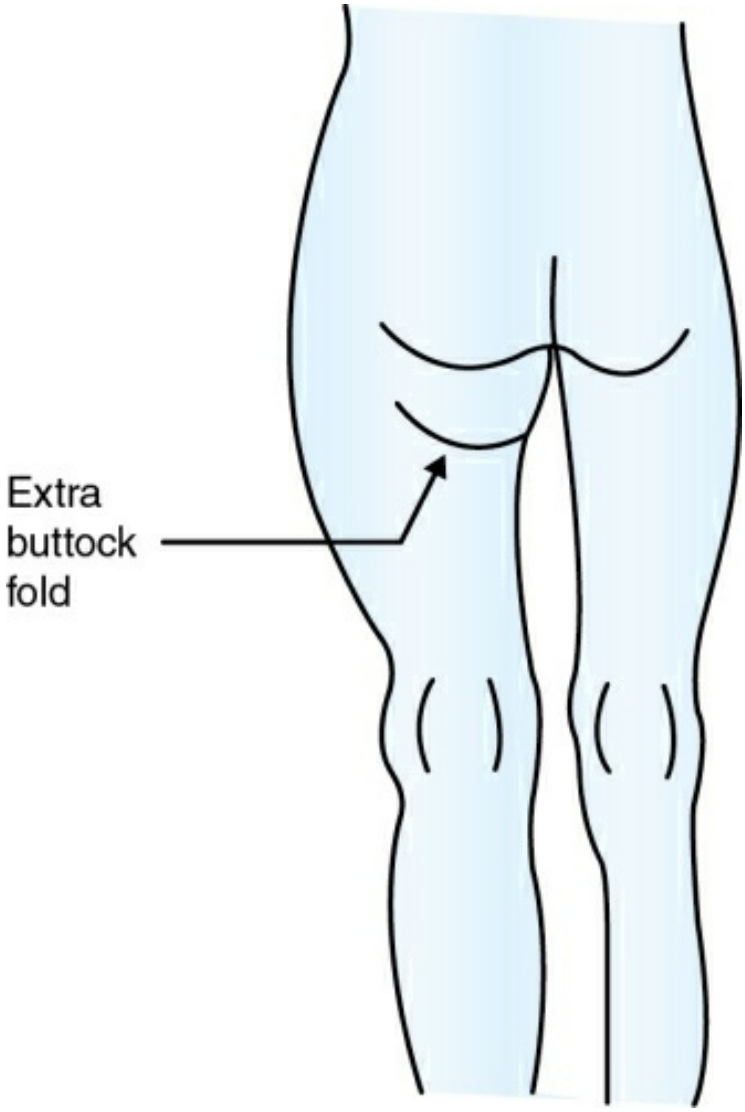

FIG. 30-17Asymmetry to the buttock folds, as seen from behind.

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On examination, there may be asymmetry of the buttock folds when the child is standing upright and limitation of abduction of the hip, particularly in flexion (Fig. 30-18). There is shortcoming of the affected lower extremity.

Galeazzi test: In supine position, when both the hip and knee joints are held in flexion with feet resting on the bed, there is lowering of the knee on the affected side (Fig. 30-18C).

In the newborn, the following two clinical tests are performed to detect instability of the hip:

Barlow test: This will test the subluxation of the hip which is the most common abnormality encountered. The examiner grasps the upper part of both thighs, with his thumb in front of and fingers on the back of the hip joint. The hip and knee are flexed and the hip is gently adducted. During adduction, a gentle posterior force is applied which will dislocate the femoral head posteriorly with an audible or palpable 'click' (considered as a 'posture test'). The hip is then pushed back into the acetabulum with gradual abduction (Fig. 30.19).

Ortolani test: This is a test of reduction in the hip. The thighs are held as described in the previous test. The hip is gradually abducted and with gentle traction, the femoral head reduces into the acetabulum, from the position of dislocation, with a click (Fig. 30-20).

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(A)

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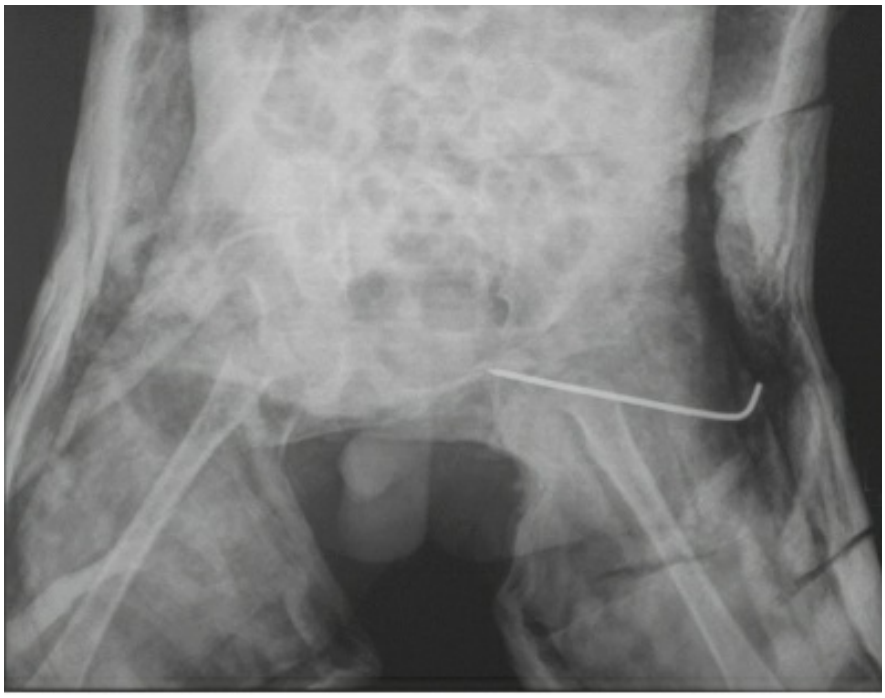

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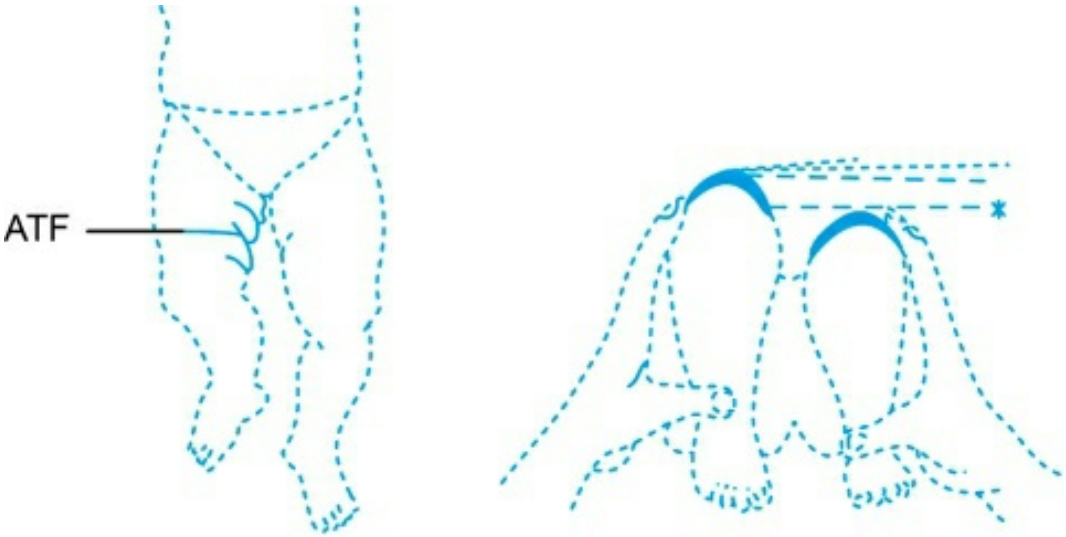

ATF = Asymmetrical thigh folds on the right thigh indicating CDH of the right hip

Galeazzi sign
Lower level of the left knee indicates dislocation at the left hip joint

(C)

FIG. 30-18**(A)** Radiograph of both hips showing

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dislocation of the left hip joint. **(B)** Closed reduction in the dislocated hip has been done under general anaesthesia. The head of the femur (on the left side) is inside the acetabulum, and has been fixed with a Kirschner wire. **(C)** Congenital dislocation hip (early detecting clinical tests and signs): congenital signs.

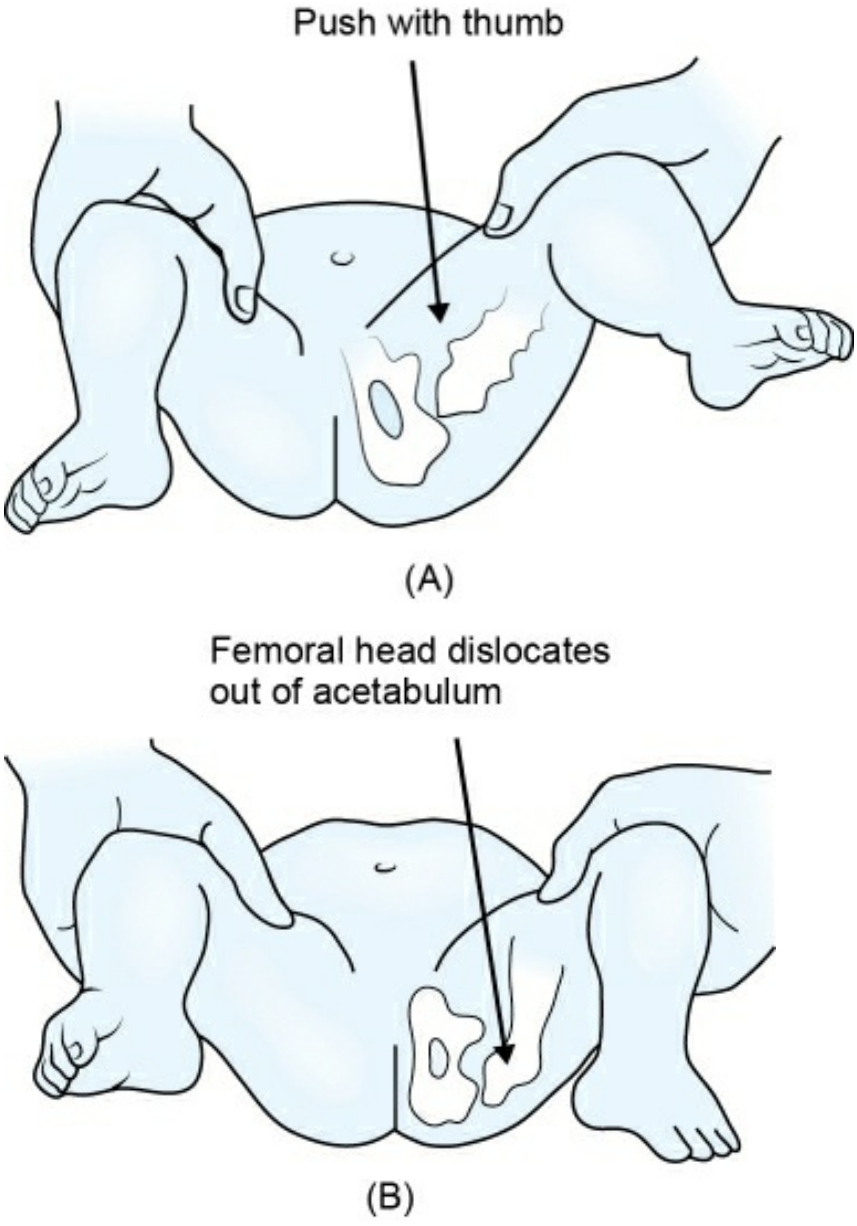

FIG. 30-19Barlow's test: **(A)** femoral head is pushed

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with thumb, and **(B)** femoral head dislocates.

FIG. 30-20Ortolani's test: **(A)** from the position of dislocation, the femoral head is pushed into, and **(B)** acetabulum by gradual abduction.

Summary

Barlow test: Test of subluxation of the hip

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Ortolani test: Test of reduction of the hip

Soft tissue anomalies

Ligaments

1. Ligamentum teres is either rudimentary or absent.

2. Joint capsule is overstretched, hypertrophied or adherent anteroinferiorly.

3. The joint cartilage may be defective and the glenoid labium may be absent.

Muscles

All the long muscles crossing the hip joint, e.g., sartorius, rectus femoris, hamstrings, tensor fascia lata, quadriceps femoris and adductor group get shortened.

Short muscles passing over the hip joint like glutei, obturators, psoas, quadratus femoris are altered in their action. They cannot act effectively as their direction and line of action are altered. They are at a mechanical disadvantage and thus fail to act normally. The weak action of the abductors results in marked pelvic instability, during weight transfers. Similarly, weakness of the gluteus maximus predisposes posterior instability of the pelvis. Excessive tension on the psoas compresses the joint capsule and the lumbar spine is pulled forward producing exaggeration of the lumbar lordosis with hip flexion deformity. Thus,

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complications like instability, Trendelenburg and marked limp are noticed.

Unilateral scoliosis may result with convexity towards the sound side.

Radiography

Plain X-ray of the pelvis with both hips shows the following features (Fig. 30-20):

1. The epiphysis of the head of the femur appears small.

2. The epiphysis of the head of the femur is displaced upwards and laterally away from the acetabulum.

3. The acetabulum is shallow; its roof has an upward slope.

Ultrasonography

Ultrasonography may help in detecting the position of the head of the femur in the newborn, when diagnosis on an X-ray may be difficult.

Treatment

The aim of the treatment is to reduce the hip and maintain it till the hip becomes stable.

The treatment of CDH is age-related and can be divided into the following groups:

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1. Up to 6 months of age: Application of a splint, like von Rosen splint or Pavlik harness (Fig. 30-21A and B), in the position of hip flexion and abduction facilitates spontaneous reduction.

2. Six months to 2 years of age: The dislocation is reduced by manipulation under general anaesthesia and maintained in a POP hip spica. The spica is removed after 3 months to check the stability of the joint. In some cases, after 6 months of age, soft tissue contractures, particularly the hip adductors, develop. This adduction contracture prevents reduction in the hip joint by closed manipulative methods. Therefore, adductor tenotomy is done followed by reduction in the hip by skin traction. Alternatively, the reduction, after adductor tenotomy, can also be maintained in a POP hip spica for 3–6 months.

Open reduction is indicated when the conservative methods fail.

3. Two years to 8 years of age: A dislocated hip in this age group cannot be reduced by conservative methods. It always requires open reduction with or without pelvic osteotomy (Salter, 1961). This osteotomy tilts the acetabulum downwards, forwards and laterally, providing better containment of the femoral head inside the acetabulum (Fig. 30-22). In children above 4 years of age, some sort of shelf operation is generally required as there are no further potentials for remodelling of the joint (Fig. 30-23). In older age group, Chiari pelvic osteotomy is more suitable. The ilium is divided immediately above the level of the head and displaces the lower fragment with the femoral head medially

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under cover of the upper fragment. A bony shelf could be constructed over the femoral head (Wainwright, 1976) (see Fig. 12.24).

The femoral anteversion is corrected by derotation osteotomy of the proximal femur.

Plaster immobilization is continued till the osteotomy is united, following which mobilization is started by physiotherapy.

4. Above 8 years of age: The results of any form of treatment are poor in this age group. The patient is, therefore, left alone at this stage and is considered for total joint replacement at a later age when secondary osteoarthritis develops.

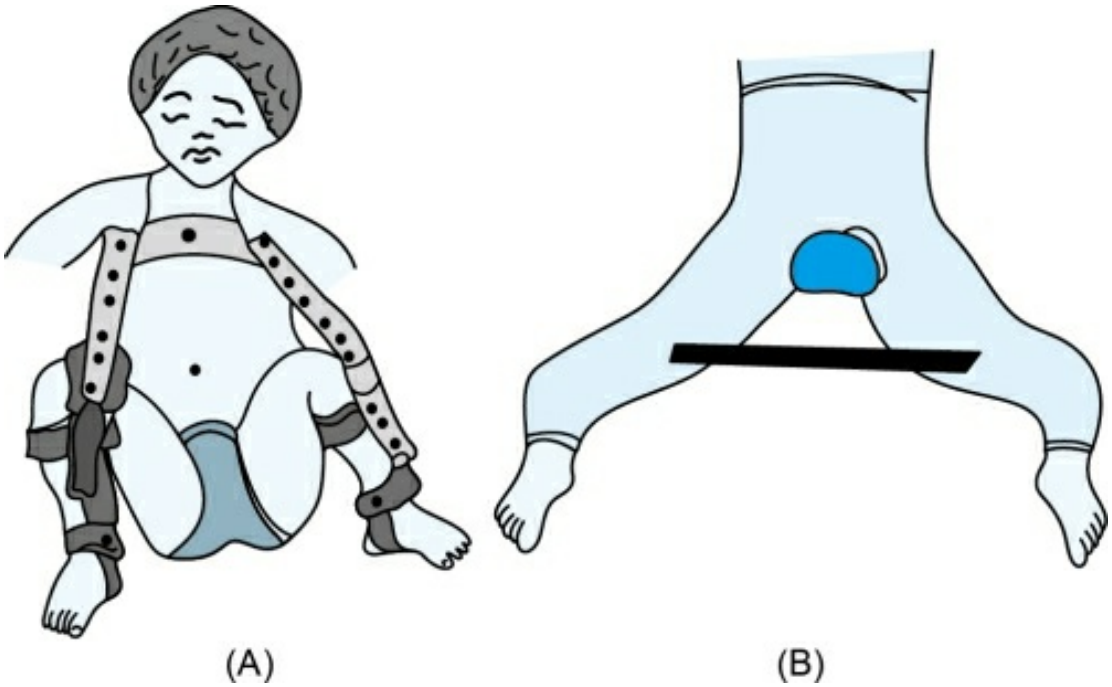

FIG. 30-21**(A)** Pavlik harness. Maintaining the hip in flexion and abduction. **(B)** Plaster of Paris (POP) hip spica. Maintaining the hip in abduction and internal

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rotation.

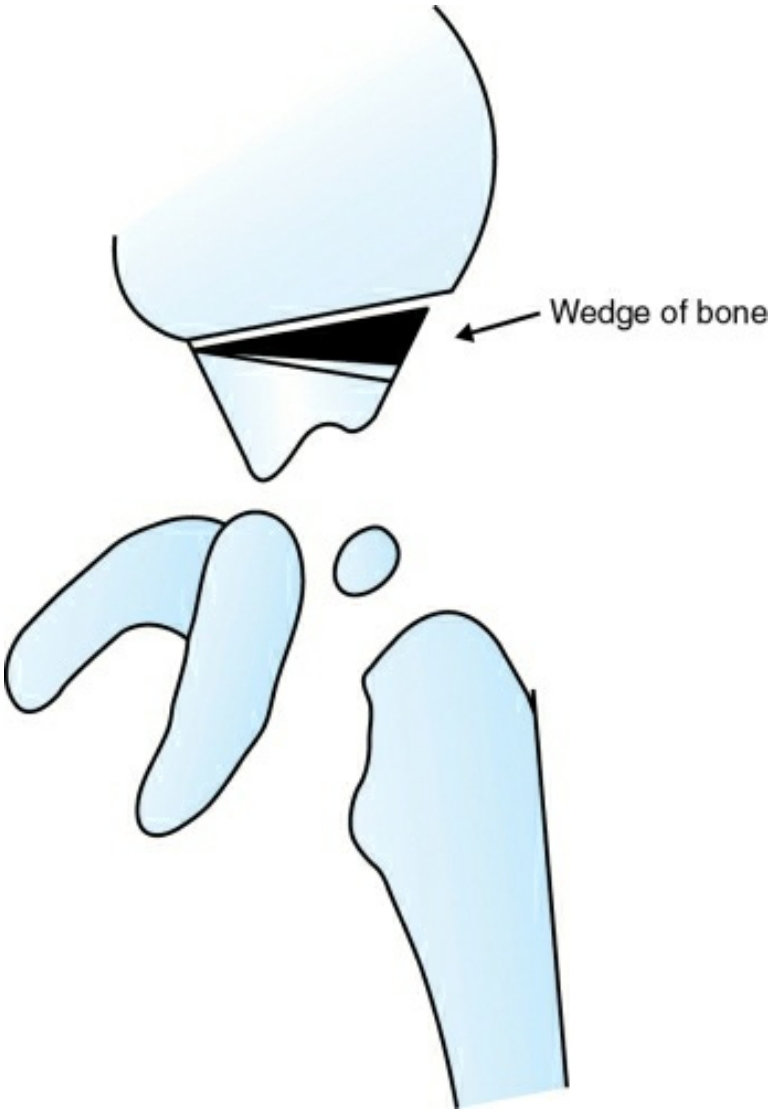

FIG. 30-22Salter's osteotomy. Wedge of bone put after osteotomy.

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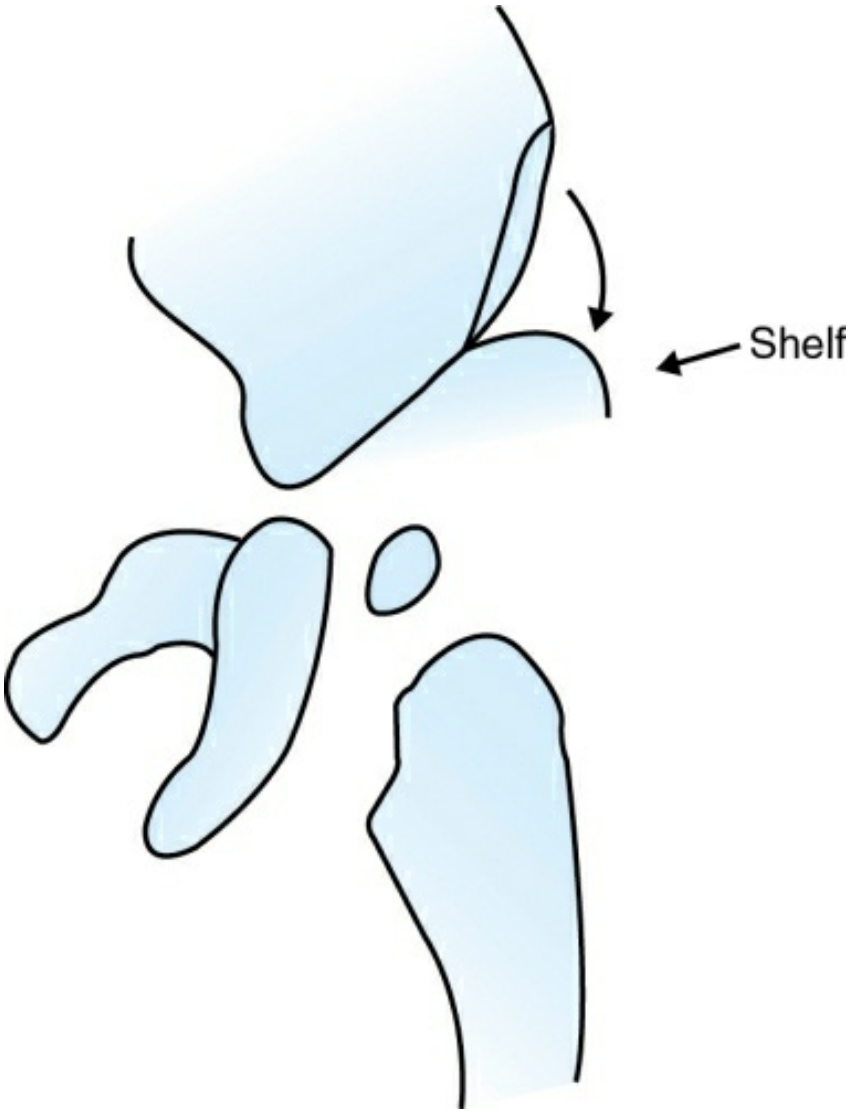

FIG. 30-23Shelf operation. A shelf is created by reflecting a chunk of bone from the ilium.

Physiotherapy management

During immobilization: Active movements to be encouraged whenever possible, e.g., when immobilization is done with pelvic harness, even hip movements within the available range should be encouraged. If possible, isometrics to gluteal muscles and quadriceps should be taught.

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Mobilization: As the limbs are immobilized in abduction for a prolonged period, the maximum limitation is present in the movement of adduction.

Mechanically malaligned gluteal muscles are weak. Therefore, all the measures for gradual mobilization of the hip, especially adduction, are taken. Relaxed passive adduction in a very small range should be initiated and progressed. Care is to be taken to stabilize the pelvis to avoid tilting during adduction.

Other movements of the hip should also be given to improve ROM. Hip rolling can be started with stabilization of the pelvis. Strengthening exercises should be well planned and progressed to the glutei. Ideally, it should be started as a quadruped knee standing and progress to knee standing (kneeling).

Walking should be initiated with enough support so that proper weight bearing and weight transfers without dropping of the pelvis are achieved. It may be necessary to initiate ambulation with a wide base.

Assisted ambulation should be made independent as the muscle power, stability and ROM improve.

Caution

The movements of hip adduction and internal rotation should be performed gradually to avoid recurrence of dislocation.

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Congenital coxa vara

This condition is also called *infantile coxa vara*. Coxa vara means reduction in the neck-shaft angle of the femur, from the normal of about 125 degrees to 90 degrees or less. There is a developmental defect at the inferior part of the neck of the femur (Fig. 30-24).

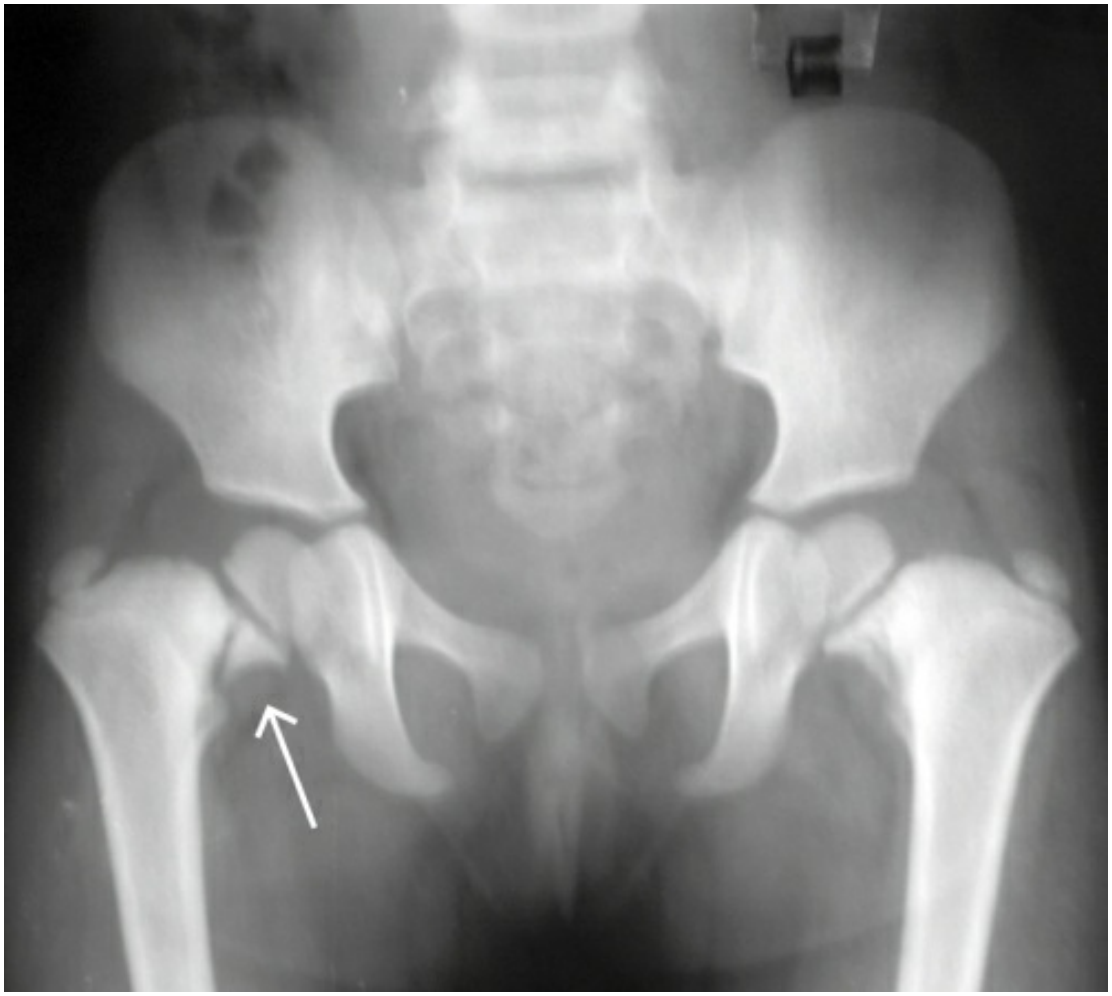

FIG. 30-24Congenital coxa vara. Note the reduction in the neck of the shaft angle with a separate triangular piece of bone.

It is often bilateral and is noticed by a painless limp when the

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child begins to walk. On examination, the greater trochanter is raised and there is limitation of abduction and internal rotation at the hip. There is often shortening. Laxity and great mechanical disadvantage occurs to the weak abductor muscle groups. They become weak and ineffective, especially when the weight is borne on the single limb. Adductor muscle group tends to become short and contracted. There is also marked limitation of the passive range of abduction and flexion, with excessive extension. There is limitation of external rotation but internal rotation is in excess.

Standing posture: The patient stands with the hips in adduction and external rotation and the foot in eversion.

Gait: In bilateral coxa vara, there is waddling gait with occasional scissoring. It is also associated with bilateral lateral swaying of the trunk.

In unilateral affections, there is marked limp. The patient drops the pelvis towards the sound side every time the weight is borne on the affected limb. To counteract this, the trunk is jerked to the opposite direction (i.e., towards the affected side). There may be associated compensatory lordosis and scoliosis with apparent limb shortening.

Treatment

In severe cases, the deformity is corrected by a subtrochanteric valgus osteotomy (Fig. 30-25).

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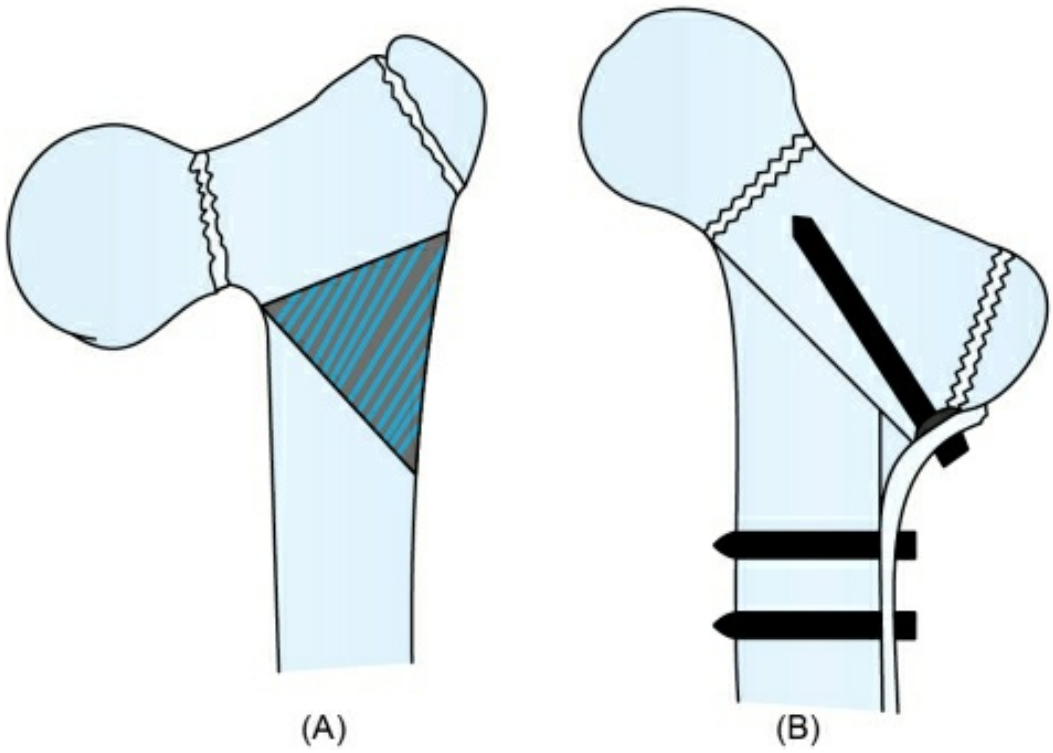

FIG. 30-25**(A)** Congenital coxa vara: Wedge of bone (shaded area) to be removed in valgus osteotomy. **(B)** Neck of theshaft angle restored after valgus osteotomy. The osteotomy has been fixed internally with a plate and screws.

Physiotherapy treatment: When treated by traction in abduction, frequent movements to the ankle and toes are advised.

Isometric exercises for the hip abductors are taught with the traction on.

Intermittent removal of traction and relaxed full range hip and knee movements are given once a day.

After removal of traction, the patient may or may not need

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weight relieving orthoses. Correct standing with equal weight on both the hip joints is taught. It is then progressed to assisted weight bearing on the affected leg with gait training.

Full range of abduction is initiated early as a relaxed passive movement, progressed to assisted and finally to resisted movements.

Congenital short femur

The proximal femur is usually short and rudimentary resulting in marked shortening of the leg (Fig. 30-26). The limb length disparity gives rise to difficulty in standing and walking, besides putting extra strain on the normal limb.

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(A)

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(B)

FIG. 30-26**(A and B)** Proximal focal femoral deficiency.

Treatment

It depends upon the degree of limb length disparity. Compensatory shoe raise can be given in mild cases.

Surgical treatment: Surgery can be performed either on the affected limb or on the normal limb.

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On the affected limb

Limb lengthening operation may be performed either on the femur or the tibia.

On the normal limb

Sometimes growth of the normal limb is checked or stopped by epiphysiodesis. In this procedure, the epiphyseal growth is checked by a bone block or by inserting staples (Fig. 30-27).

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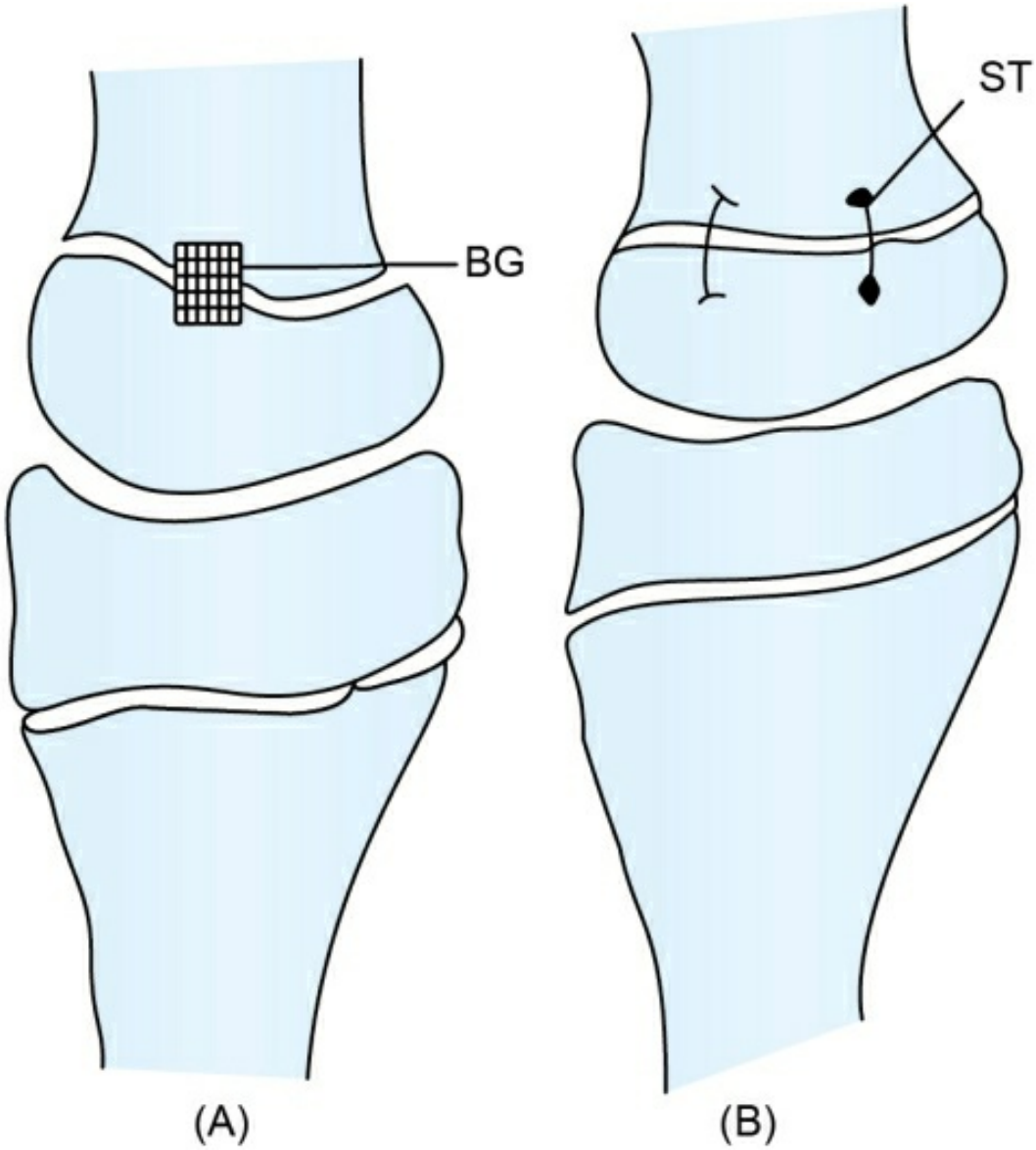

FIG. 30-27Methods of arrest of bone growth. **(A)** Epiphysiodesis, BG: bone graft. **(B)** Epiphyseal stapling, ST: Staples.

After surgery

Maximum caution is necessary while initiating weight bearing on the operated leg. It has to be gradual maintaining accurate alignment of the axis of the lower limb.

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Talipes

The word ‘talipes’ means foot.

The foot has four basic movements:

1. Dorsiflexion at the ankle joint

2. Plantar flexion at the ankle joint

3. Inversion and adduction at the subtalar

4. Eversion and abduction at midtarsal joints

The various deformities of the foot are described as follows:

1. Talipes equinus: ankle and foot in plantar flexion.

2. Talipes calcaneus: ankle in dorsiflexion.

3. Talipes varus: foot is adducted and inverted.

4. Talipes valgus: foot is everted and abducted.

Besides these major deformities, there can be:

5. Pes-planus or flat foot where the arches of the foot are depressed. Flat foot can be of three types:

(a) Pes planus: A foot where there is dropping of the foot arches without eversion.

(b) Pes valgus: There is no dropping of the arches but the

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foot is everted.

(c) Pes plano valgus: Here the combination of dropping of the arches is present along with eversion.

6. Pes cavus: Foot arches are exaggerated.

These deformities of the ankle and foot present in various degrees, from mild to severe. Mild deformities are easily stretchable needing rigid immobilization in a corrected position. Severe ones are rigid.

Many a times, these deformities are present in combination. In about 50% of the cases, they are bilateral; when unilateral, involvement of the right foot is more common. Four common deformities are as follows:

1. Congenital talipes equinovarus (clubfoot)

2. Calcaneo valgus

3. Flat foot (vertical talus)

4. Metatarsus adductus (metatarsus varus)

Congenital talipes equinovarus (ctev)-clubfoot

Congenital talipes equinovarus is one of the commonest congenital anomalies seen.

The word *talipes* is derived from ‘talus’ and ‘pes’ and was applied to those walking on their neglected deformities wherein the talus rested on the ground as the foot (pes).

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It is characterized by plantar flexion (equinus) at the ankle joint, inversion at the subtalar joint and adduction at the forefoot (Fig. 30-28).

FIG. 30-28Bilateral congenital talipes equinovarus (CTEV).

Clinical features

1. The inner border of the foot is raised and shortened with cavus.

2. The longitudinal arch is exaggerated.

3. The outer border of the foot is convex and bears weight. The skin in this region eventually gets thickened and

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callosities and false bursae develop.

4. The heel remains inverted and small with thin skin.

5. The foot may be small with shortening of the leg.

6. In bilateral cases the gait is awkward and waddling.

7. There is marked limitation of eversion and dorsiflexion.

This deformity is difficult to treat. The treatment continues for a long time and there is a high incidence of recurrence if the child is not followed up properly.

The correction of this deformity has to be done in a definite order. In the conventional Kite method, forefoot adduction deformity is corrected first, followed by correction of heel inversion, then cavus and equinus in the end.

The correction is said to be complete when the child can voluntarily perform foot dorsiflexion with eversion.

Treatment

The method of treatment depends upon the age at which the child is brought for treatment (Cranna, 1967). Following are the corrective methods:

Manipulation: Passive manipulation should be taught to the mother for children below 2 months of age. The heel is stabilized by one hand and by the other hand the forefoot adduction is corrected first. This is followed by correction of

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inversion by exerting pressure over the undersurface of the 4th and 5th metatarsal heads. Dorsiflexion of the foot combined with pressure on the inner border of heel corrects the cavus, equinus and inversion of the heel.

In children above 2 months of age, manipulation is carried out by the same technique and maintained by strapping, (Fig. 30-29), splintage or serial POP cast. The POP should extend from toes to thigh with the knee bent at right angles. The plaster is changed every 2 weeks. Mild-to-moderate deformities may be corrected by serial plaster casts. Following this, Dennis Brown splint (Fig. 30-30) is applied and retained till full correction is achieved. However, these days a new brace called Wheaton brace (Fig. 30-31) is used which can go inside a normal shoe.

Tenotomy of the tight tendoachilles may sometimes be necessary if full correction is not achieved and the heel remains tightly drawn up.

Ponseti method: In this method, the foot is manipulated in a particular sequence and immobilized in an above-knee POP cast. The plantar flexion of the first ray is corrected first, maintaining the foot supinated inside the cast. In the next sequence, the calcaneum is abducted, extended and everted under the talus in a supinated foot by pressing against the head of the talus. The fully abducted foot is then dorsiflexed for the correction of the equinus. Percutaneous tenotomy of the tendoachilles may be necessary in some cases. The number of serial casts required is much less, usually 2–4. The reduction is subsequently maintained in a Dennis Browne splint.

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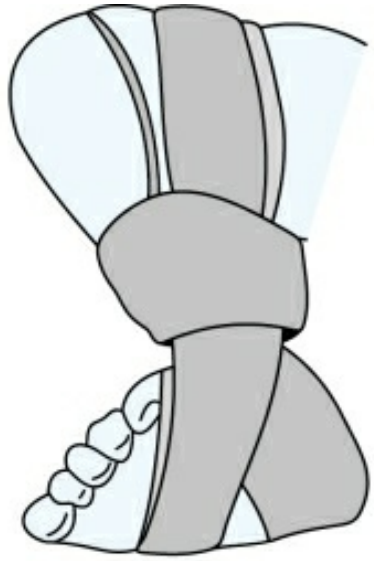
Wrenching: More resistant feet, chronic deformed feet or feet with relapse need wrenching and tenotomies.

Surgical release: Surgical release of soft tissues is indicated in rigid and neglected feet after the age of about 6–9 months.



Strapping in the overcorrected position using adhesive tape and felt. An ideal corrective technique at the early stage of the CTEV

FIG. 30-29Strapping to correct congenital talipes equinovarus (CTEV).

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FIG. 30-30Dennis Brown splint.

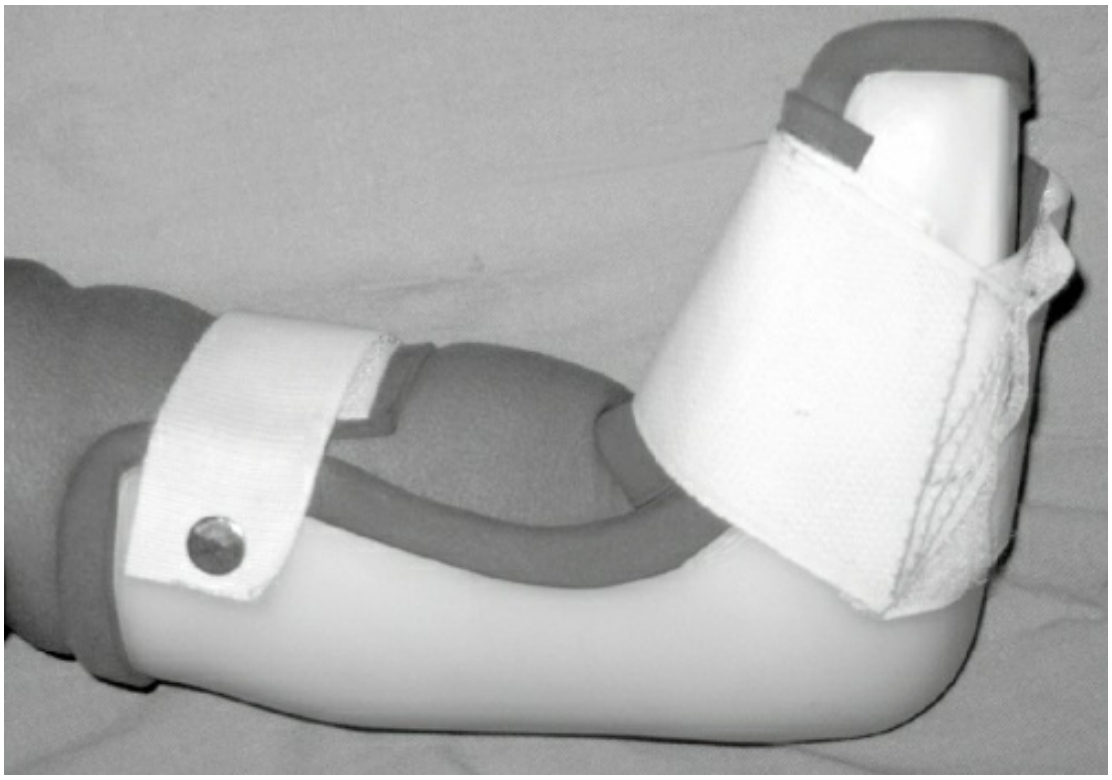

FIG. 30-31Wheaton brace.

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Surgical procedures

1. A long incision is made from behind the medial malleolus to the base of the first metatarsal. Tight structures on the inner side of the foot are divided under vision. This included (i) tibialis posterior tendon; (ii) the capsule of the talonavicular joint; (iii) the tendon sheaths along the long flexors; (iv) the plantar calcaneonavicular ligament with the capsule of the subtaloid joint; and (v) the origin of the plantar muscles and fascia. The tendoachilles is lengthened by Z-plasty (Fig. 30-32). This procedure will give adequate overcorrection of the deformity. Following this, the foot is immobilized in a POP cast for 4–6 weeks.

2. Bony correction: Triple arthrodesis or subtaloid-midtarsal-arthrodesis.

Bony deformities get organized in still older and neglected cases. This operation is performed only after the age of 12 years and in cases where there is relapse even after soft tissue correction (Fig. 30-33).

3. Wedge tarsectomy: A wedge of bone is removed from the tarsal bones – calcaneum, cuboid and talus of the foot (Fig. 30-34). The talonavicular joint and the deltoid ligaments are divided. POP cast is applied after manipulating the foot in the corrected position. Plaster is maintained for 6 weeks.

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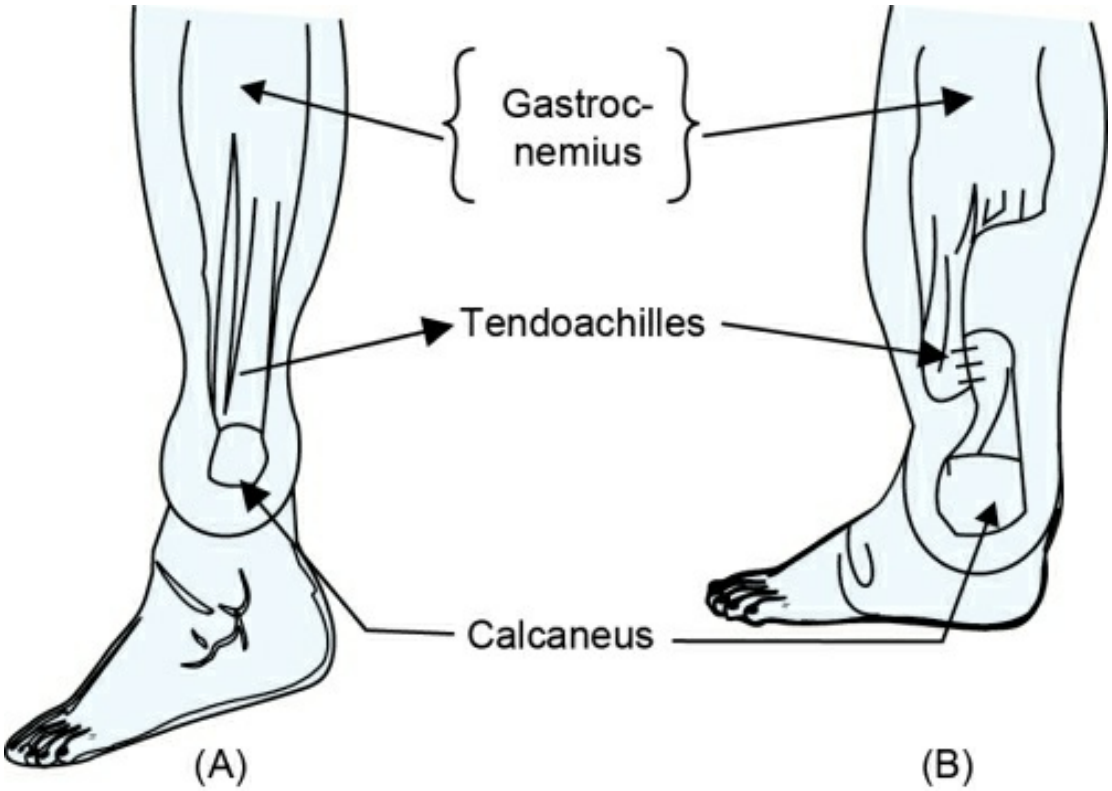

FIG. 30-32Tendo-achilles lengthening: **(A)** foot in equinus and **(B)** equinus deformity of the foot corrected by Z-plasty of tendoachilles.

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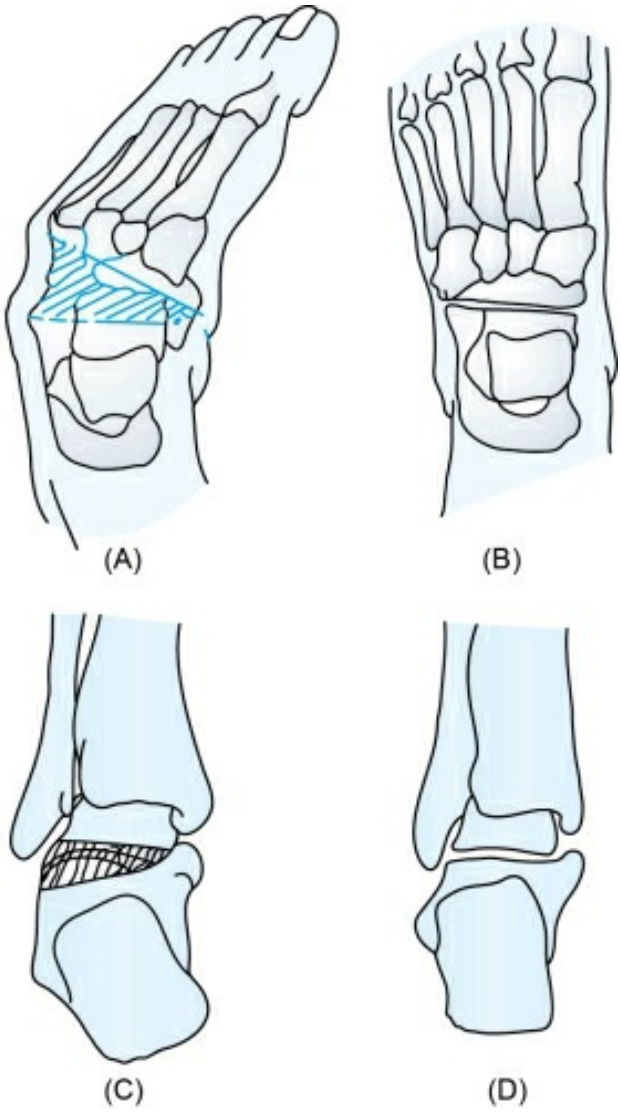

FIG. 30-33Subtaloid midtarsal arthrodesis to correct inversion of forefoot and heel. **(A)** Triple arthrodesis: resection site of the calcaneocuboid and talonavicular joints. **(B)** Correction of adduction and inversion of forefoot. **(C)** Resection site of talocalcaneal joint. **(D)** Correction of inversion of heel.

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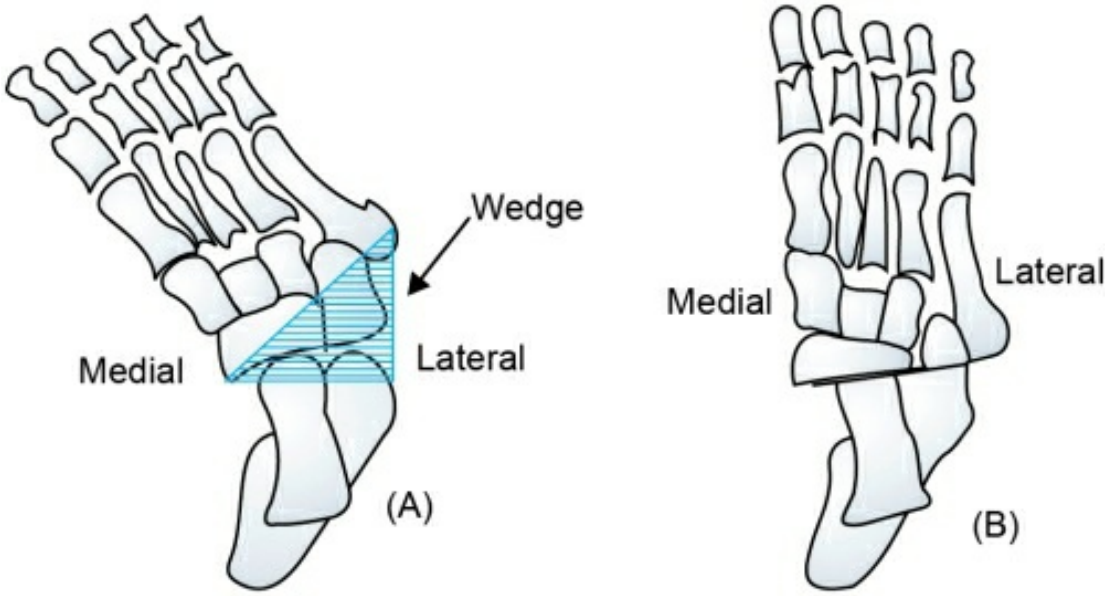

FIG. 30-34Wedge tarsectomy. **(A)** wedge of bone to be removed and **(B)** correction of deformity.

Physiotherapeutic management

Congenital talipes equinovarus: When reported early, most the children can be managed by passive manipulation. It should be followed by immobilization either by strapping, if the deformity is minimal, or by POP cast.

Manipulation

There are three components of the deformity:

1. Pes cavus or the exaggerated arch

2. Adduction and inversion of the forefoot and heel

3. Plantar flexion of the ankle

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Graded manipulation by passive movement is done in the direction opposite to the deformity. The pes cavus deformity is corrected first. The contracted soft tissues at the sole of the foot are stretched gradually till total correction is achieved.

Secondly, the adduction deformity is corrected by keeping the thumbs of both the hands over the talus; the talus thus becomes the fulcrum of the movement. The fingers of the distal hand hold the foot and those of the proximal grasp the lower portion of the leg and medial aspect of the heel. The distal hand will abduct and evert the foot, turning the sole downwards and outwards (eversion and dorsiflexion).

Thirdly, by shifting the distal hand along the length of the sole, the foot is raised to dorsiflexion, thus correcting the component of plantar flexion.

By using the same order of manipulation, all the three movements can be combined in one operation.

The most important factor is the optimal maintenance of correction. The mother should be educated to identify any distortion if it occurs. Regular follow-up is required to avoid any lapse on the mother's part, which may hamper the improvement.

In mild cases, immobilization can be done by a strip of adhesive plaster. A strip of plaster is taken from the medial condyle of the knee passed under the heel to pull it to the valgus and taken right up to the outside of the knee. Another strip is taken from below the lateral malleolus, across the dorsum of the foot, under the great toe to pull the foot into

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valgus position terminating on the outer side of the knee. This can be continued for 2 months. If there is no correction, then

1. Serial POP casts may be applied.

2. Dennis Browne splint could be given (Fig. 30-30).

3. Padded simple aluminium splint – applied over the lateral border of the leg and foot – may be necessary. This aluminium splint is light and can be gradually bent till overcorrection is achieved. Care should be taken regarding the following:

(a) Correct method of applying.

(b) Repeated checks on the maintenance of alignment.

(c) To check for the areas of pressure of the splint or POP.

(d) To check that the circulation of the limb is not interfered with, at the same time, ensure that gradual correction of the deformity is being attained.

With plaster casts, only toe movements and the movements to hip and knee can be encouraged by tickling or just holding the child high in suspension with hands supporting the lateral part of the chest under the axilla.

In surgically treated cases, if these children are of walking age, gradual walking with underarm supports or walkers can be given.

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Maintenance of correction of the deformity after removal of the cast is very important. It also helps in preventing recurrence.

Night splints or resting posterior corrective splints are ideal in the prevention of recurrence as the foot is maintained in an overcorrected position.

Active movements stimulated through tickling or objectively by placing some toy should be encouraged in proper and correct groove of the movement.

Ambulatory training with maintenance of the foot in the corrected position is to be taught in the department with the physiotherapist supporting the foot in a corrected position. For free walking, correct BK orthosis should be given so that the foot is maintained in the correct position. Orthosis should be reviewed at regular intervals and the mother should be educated on the correct method of applying it.

The child should be seen at least once a week, then every month and also at later stages.

The physiotherapist must remember that the ultimate success of the treatment depends upon how effectively the mother is taught the home care programme.

Calcaneovalgus deformity

Here the foot is excessively dorsiflexed at the ankle with eversion of the sole; strong calf muscles are instrumental in recovery. Passive overcorrection is also unnecessary.

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Spontaneous recovery occurs as the child starts walking. Light aluminium splint may be necessary in some children.

Physiotherapeutic management

Mild cases: As there is excessive dorsiflexion, there occurs limitation of plantar flexion. Gradual sustained passive stretching in the direction of plantar flexion and its maintenance forms an important part of exercise.

Splint: An aluminium splint may be given holding the foot in the corrected and stretched position. It, however, needs to be checked regularly and the technique of application taught to the parents.

Active exercises: Active or even resisted movement of plantar flexion is valuable. Sometimes sessions of passive stretching followed by active resisted exercises are sufficient to correct this deformity.

Surgical cases: Treatment approach is the same as described for talipes equinus. The only difference is that the treatment is concentrated to re-educate and regain the range and power of plantar flexion.

Passive correction of the position of foot during the phase of toe off needs special attention.

Congenital flat foot (vertical talus)

The foot has an appearance of a ‘rocker bottom’ deformity. The longitudinal arch is completely obliterated. The sole of

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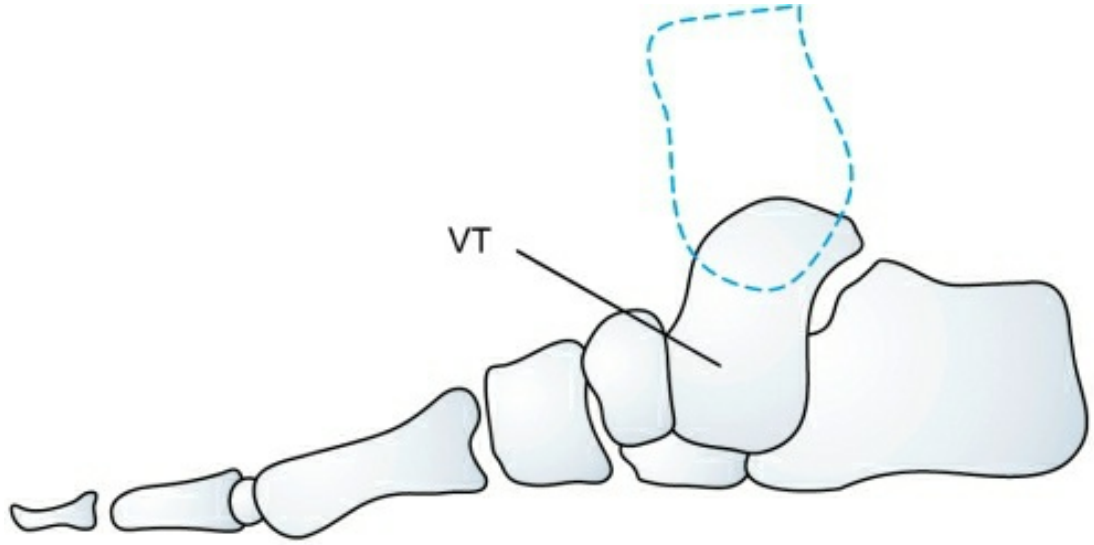
the foot is convex downwards with apex at the midtarsal joint (Fig. 30-35).



(A)

(B)

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(C)

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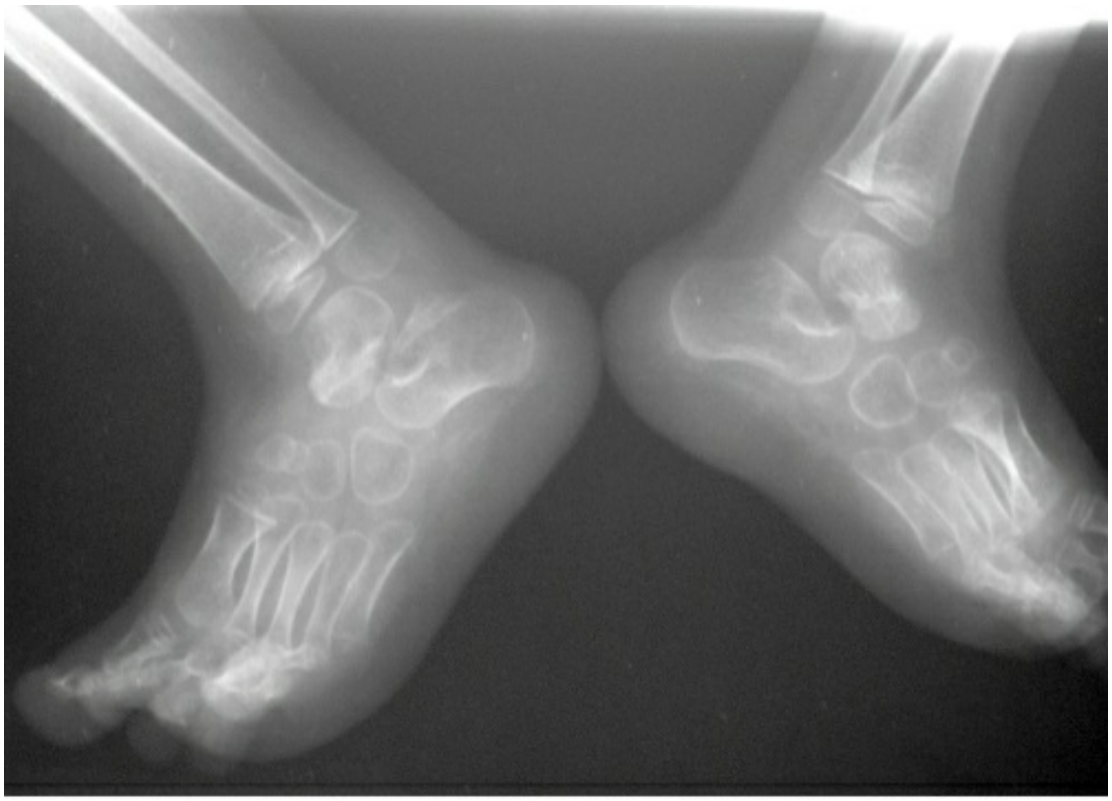

(D)

FIG. 30-35**(A)** Diagrammatic representation of a congenital flat foot with vertical talus (VT). **(B)** Congenital VT – note the vertical position of the talus on both sides. **(C)** Clinical photograph of congenital VT. **(D)** Result - after surgical correction. Note the corrected position of the talus.

Radiologically the lateral view shows that the head of the talus points almost vertically downwards with upward displacement of the navicular. In the anteroposterior view, it points medially towards the other foot at an angle of 65–70 degrees instead of straight forward towards the great toe. There may be associated tightness of the tendoachilles.

Treatment – orthopaedic management

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1. Manipulation: By manipulation the forefoot is adducted, inverted and plantar hexed. Later the tight tendoachilles is stretched taking care not to allow recurrence of 'rocker bottom' at the midtarsal joint. Mid-thigh cast is applied with the foot in corrected position.

2. Surgery: The surgical treatment consists of open reduction in the talus.

Physiotherapeutic management

During the period of immobilization in a POP cast, strong toe flexion movements and movements to the other free joints are encouraged.

Following surgery and removal of POP: Gradual mobilization of the foot is started with emphasis on the intrinsic muscles. Frequent cupping of the foot, toe curling or holding a piece of foam rubber or cloth inside warm water helps in strengthening small muscles of the foot.

Standing, mainly on the outer border of the foot, with curling of the toes and cupping of the foot is made interesting with timing. The child is encouraged to walk in this position for a small distance at a slow speed, bearing weight mainly on the outer border of the foot. Proper gait training with surgical boots is necessary. Walking on sand (barefoot) helps in developing these small muscles of the foot.

Metatarsus adductus (metatarsus varus)

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Here the forefoot is adducted at the tarsometatarsal joints but the foot is plantigrade. Even an easily corrective deformity has a tendency of recurrence in spite of prolonged immobilization. Considering this and the negligible disability, no specific treatment is given.

Surgical

In selected cases, osteotomy of the metatarsal neck may be performed. Postoperatively the foot is immobilized in a plaster cast for 2–3 weeks. In cases where there is neuroma of the digital nerve, the neuroma is excised. This causes spontaneous relief of pain.

Foot exercises and re-education in walking are gradually included with proper thesis.

Exercise programmes to strengthen the lumbricals and interossei are intensified.

Acquired deformities

The following acquired deformities are commonly encountered:

1. Acquired torticollis (see page 486)

2. Dupuytren's contracture

3. Coxa vara (see page 533)

4. Genu valgum (see page 564)

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5. Genu varum (see page 565)

6. Talipes equinus (see page 577)

7. Pes cavus (see page 578)

8. Hallux valgus (see page 580)

9. Hallux rigidus (see page 581)

10. Hammer toe (see page 581)

11. Metatarsalgia (see page 574)

Developmental disorders of the bone

Deformities may be formed as a result of disturbances of growth and the development of the bone. They are known as developmental disorders of the bone.

The disturbance in the maintenance of perfect homeostasis of haematopoiesis, reticuloendothelial system and calcium metabolism results in the disturbance of growth and development of bones and cartilages – a root cause of developmental bone disease.

Classification of developmental disorders:

1. Bony dysplasias – may be due to one of the following three factors:

(a). Decreased osteoid formation (e.g., osteogenesis imperfecta)

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(b). Increased osteoid formation (e.g., osteopetrosis)

(c). Abnormal osteoid formation (e.g., fibrous dysplasia)

2. Cartilaginous dysplasias

(a). Mucopolysaccharidosis (MPSI) (e.g., chondro-osteodystrophy)

(b). Idiopathic (e.g., achondroplasia)

(c). Heterotrophic proliferation of epiphysis (e.g., enchondromatosis)

Osteogenesis imperfecta (syn: Fragile ossium)

Decreased osteoid formation and defective type I-collagen formation render bone soft and brittle.

The bones are short and have bubous epiphyseal expansion.

A familial inherited autosomal dominant disease in which a child may be born with multiple fractures, or remain highly susceptible to fractures with a trivial trauma, which decreases if the child survives. The child may develop blue sclera, deafness, joint laxity and cardiac anomalies too (Fig. 30-36A–C).

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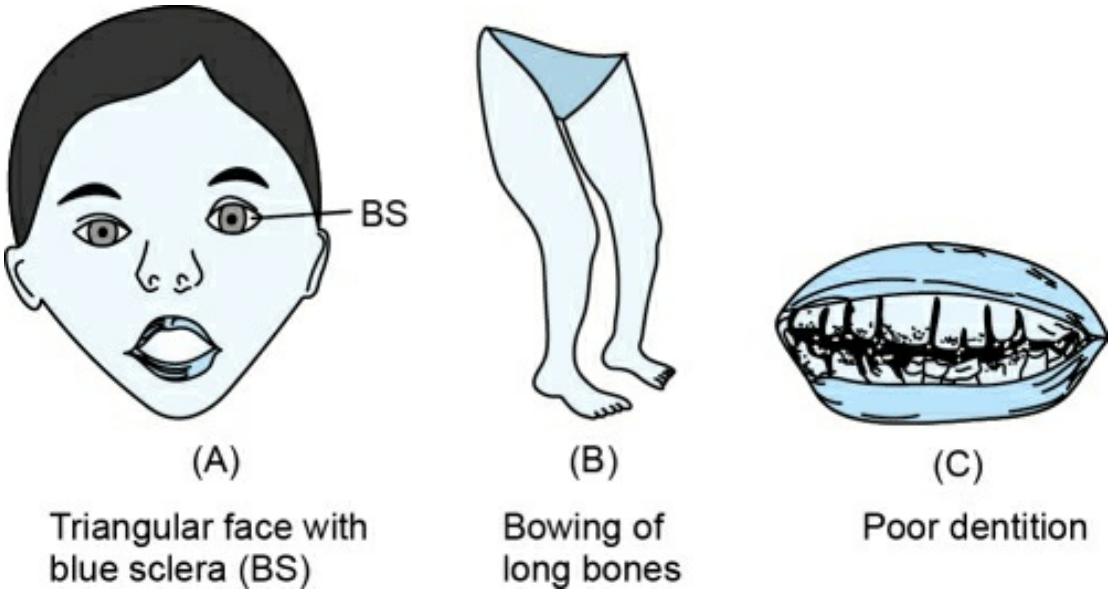

FIG. 30-36**(A, B and C)** Osteogenesis imperfecta.

Treatment

Protection from fractures by the use of supportive orthoses supplemented by mother's education and guidance is the best treatment.

As the fractures are prone to develop malunion (Fig. 30-37), the bones should ideally be treated by internal fixation, followed by graduated physiotherapy measures to provide maximum self-sufficiency.

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FIG. 30-37Osteogenesis imperfecta: gross deformity of the right femur due to malunion of a fracture. Note the deformity of the left femur also.

Osteopetrosis

It is known as marble bone disease (Albers-Schonberg

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disease) due to imbalanced reaction between the osteoblasts and the osteoclasts. The skeletal system becomes dense and brittle with susceptibility for fractures. Decrease in the marrow cavity results in anaemia and immunocompromised status.

When the base of the skull is involved, it may cause blindness and sensory neural deafness or multiple cranial nerve palsies. However, it is a self-limiting disease with a better prognosis when the child survives beyond childhood.

Fibrous dysplasia

A bone is replaced by fibrous tissue, eroding it and resulting in irregular bent long bones with possible shortening and recurrent pathological fractures. Fibrous dysplasia is commonly seen in children or adolescents involving single bone (monostotic–femur, tibia, or mandible) or multiple bones (polyostotic).

Radiograph shows typical expansible lytic lesion with ground glass appearance (Fig. 30-38).

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FIG. 30-38Fibrous dysplasia.

Symptomatic cases are treated with curettage and bone grafting; open reduction and internal fixation (ORIF) may be required for pathological fractures.

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Chondro-osteodystrophy (morquio-brailsford disease)

It is an autosomal recessive disease due to abnormal metabolism of mucopolysaccharides resulting in defective ossification in the spine and hip. Normal child up to the age of 3 years starts developing kyphosis at the dorsolumbar junction. The neck is shortened and displaced forward. The sternum becomes prominent with pectus carinatum. A child with genu valgum stands with hips and knees in flexion.

Radiologically, there is flattened and elongated with tongue like projections. All the epiphyses are bulbous and enlarged with delayed ossification.

The prognosis is poor and fatal in early childhood.

Achondroplasia

It is an autosomal dominant disease with defects in the endochondral ossification, mainly in the long bones, causing dwarfism (Fig. 30-39). The dwarfism is disproportionate as the size of the trunk remains normal. The limb shortening is more marked in the proximal segment; the central three digits are equal in length; the head is abnormally large and the life expectancy is normal. Due to abnormal body structure and normal average intelligence, patient remains gainfully employed as clowns and comedians.

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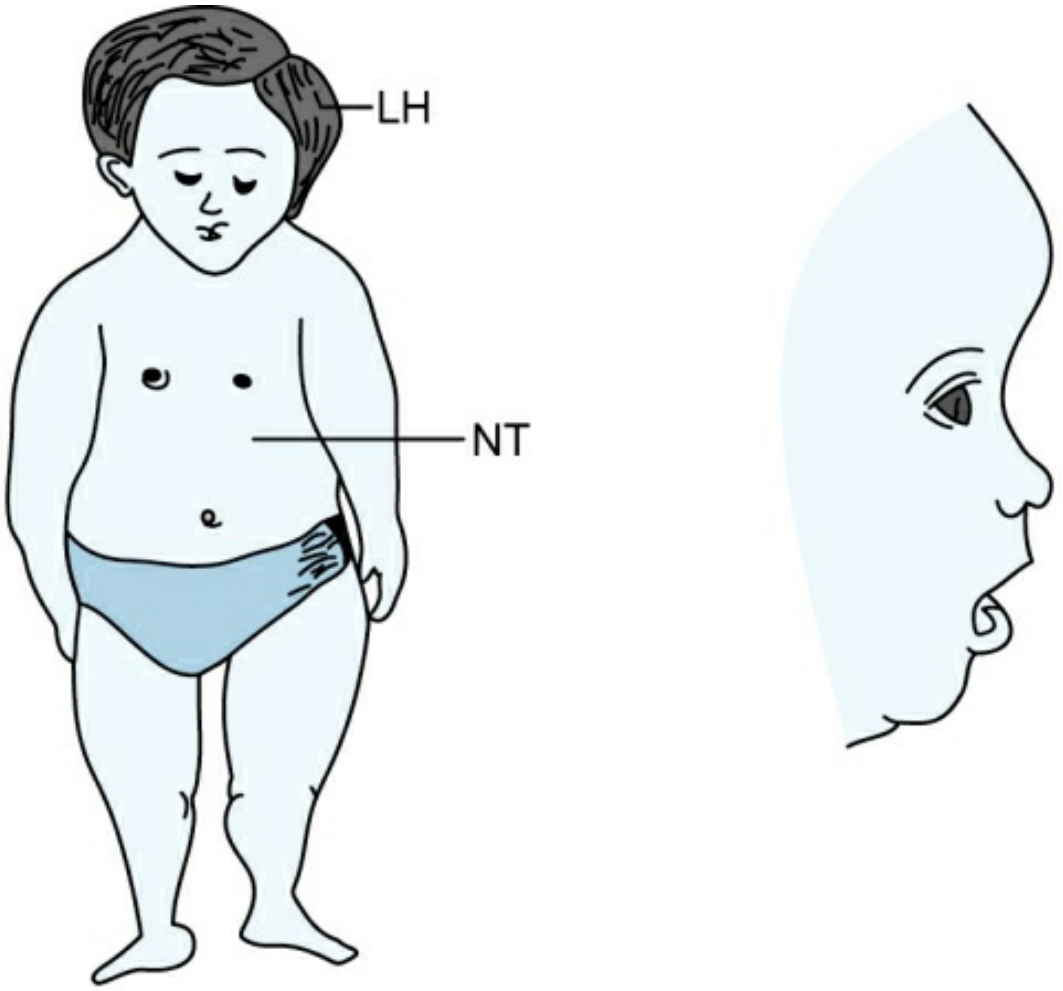

LH – Large head; normal size trunk; frontal bossing
short arms and legs; depressed nasal bridge (dwarfism)

FIG. 30-39Achondroplasia.

Multiple enchondromatosis (ollier disease and dychondroplasia)

The cartilage cells fail to ossify and remain in the metaphyseal region of the long and short bones. Hands are commonly involved with enchondromatosis (Fig. 30-40) with multiple cavernous haemangiomatas.

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FIG. 30-40Multiple enchondromatosis.

Painful lesions are treated with curettage and bone grafting. Lesions are likely to develop malignancy.

Paget disease (osteitis deformans)

It is a suspected viral pathology of increased bone resorption and disorganized bone formation. Bone pain, bowing and thickening radiograph shows honeycomb-like spongy and widespread appearance.

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Pathological fractures usually occur.

Paget disease is treated by calcitonin and bisphosphonates.

Congenital multiple exostosis (diaphyseal aclasis)

This is a congenital autosomal dominant disease characterized by multiple cartilage capped bony exostosis at the metaphysis of the long bones because of failure of remodelling forming exostosis from the epiphyseal cartilage plate.

Usually the patients are short statured with prominences over the ends of long bones and deformities.

Radiographically, multiple pedunculated exostosis are seen pointing away from the joint. Metaphyseal ends are broad with a trumpetting appearance (Fig. 30-41).

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FIG. 30-41Diaphyseal aclasis.

This disease is treated by excision of the symptomatic exostosis

Due to the multiplicity of the basic pathology and varied deformities, each condition needs an independent suitable approach of physiotherapy with the ultimate objective of achieving maximum self-sufficiency in performing activities of daily routine (ADRs).

Besides, congenital, acquired and developmental disorders, a variety of deformities are seen in the disorders of the neurological and muscular origin. For example:

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- Anterior poliomyelitis (discussed in Chapter 28)
- Neuropathies (discussed in Chapters 26 and 27)
- Cerebral palsy
- Muscular dystrophy

Cerebral palsy

It is nonprogressive as a result of neuronal under development in the brain. The clinical picture depends upon the area of lesion and its varied forms, e.g., spasticity, ataxia and athetosis. It may develop during intrauterine (prenatal), perinatal or postnatal periods. Occasionally, it is associated with mental retardation (MR).

Multiplicity of a clinical disposition needs a team approach by various specialists. Physiotherapy plays a dominant role in the management to provide maximum self-sufficiency.

The child always remains prone to develop a variety of deformities of neuromusculoskeletal origin and requires watchful efforts to prevent these deformities. Common amongst them are mainly due to the muscular imbalances.

Physiotherapy besides preventing the development of deformities plays a most important role in guiding a child to improve lost or insufficient motor control by using various modalities and specialized exercise techniques like Bobath facilitation technique.

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The prognosis is poor when it is associated with MR.

Muscular dystrophy

It is a group of muscular disorders (inherited myopathy) with progressive weakness of muscles and named after the more commonly involved muscle groups (Table 30-1).

Table 30-1

Characteristics of the Types of Muscular Dystrophy

Pseudohypertrophic Muscular Dystrophy (PMD)	Facioscapulohumeral Muscular Dystrophy	Limb-Girdle Type of Muscular Dystrophy
Inherited an x-linked recessive gene transmitted only to boys through a female carrier	An autosomal dominant disease	The disease is both autosomal dominant as well as recessive dominant
Onset around 3 years age	Commonly seen in adolescents of both the sex	May occur at any age in both the sexes
Mainly involves lower limbs with a complaint of frequent falls		
Progressive weakness develops;	It mainly affects the muscles of face, thus	Pelvic girdle muscles are

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however, a typical feature is the false hypertrophy of the calf muscles and deltoid	affecting speech. Gradually the speech becomes indistinct	involved first. Later on, shoulder girdle muscles too are involved
Diagnosis: Raised levels of serum creatinine–phosphokinase	Shoulder girdle muscles involving the limb get atrophied and weak progressively	Winging of the scapula becomes evident
Muscle biopsy, no specific treatment as the disease gradually progresses	The deltoid and the wrist flexors are spared	The progress of the diseases is slow
Physiotherapy, to prevent contractures, keep child as mobile as possible with appropriate orthoses and guidance to the parents	The treatment heavily depends on physiotherapy in a form of prevention of the deformities and all the efforts are functionally self-sufficient with fabrication of orthoses as per the individual requirementsProgressive in nature	Treatment is mainly by physiotherapy to prevent deformities and to keep the patient mobile. Maximum efforts are essential as the instability is more marked due to involvement

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		of muscles of both the girdles
Prognosis is poor and death occurs by early adult life when the paralysis involves respiratory muscles or by chest infection	The lifespan is normal	The lifespan is normal

Some common examples:

1. Pseudohypertrophic muscular dystrophy (PMD) or Duchenne muscular dystrophy

2. Facioscapulohumeral muscular dystrophy

3. Limb-girdle type muscular dystrophy

4. Arthrogryposis multiplex congenital

Other rare conditions

■ Arthrogryposis multiplex congenita: Striated muscles are replaced by fibrous tissues giving rise to muscular weakness and soft tissue contractures. Rigid CTEV and hip dislocation are the most common deformities. Soft tissue release and open reduction in dislocated hip joints may require physiotherapy to prevent deformities, and postsurgical functional maintenance is usually needed (Fig. 30-42).

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■ Myositis ossificance progressive: Characterized by the ectopic ossification in the muscles of neck, trunk and the limbs. As and when the disease progresses, it may result in further limitation of ROM of the involved joint. Most common site is elbow joint.

FIG. 30-42Arthrogryposis multiplex congenita.

Physiotherapy is concentrated to keep maximum possible mobility of the joints where the ectopic ossification begins to appear.

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CHAPTER

31

Locomotion and gait

OUTLINE

- Locomotion
- Methods of gait evaluation
- Gait abnormalities
- Gait training

Locomotion

What is gait?

Gait is the process of purposefully losing or disturbing the body's balance and then regaining it at each step by counterbalancing the various external and internal forces which try to disturb the balance.

It is a highly complex mechanism, requiring the precisely coordinated controlled and synchronized action of various muscle groups and related joints to re-establish the disturbed balance of the body.

A forward pedal locomotion of the body is composed of a series of forward steps. A step of each individual leg is in itself one gait cycle.

To understand the complicated mechanism of a gait cycle and and perform a gait analysis, it is important to know the following three aspects of a gait:

I. Gait cycle

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II. Kinetics and kinematics of gait

Gait cycle

Each gait cycle has two phases:

1. Stance phase

2. Swing phase

Sequential events of a gait cycle (Fig. 31-1):

1. Stance phase: It has five phases and occupies 60% of the gait cycle.

(a) Heel strike (HS): The heel strikes the ground making initial contact (or early stance) with the ground.

(b) Foot flat (FF): The whole foot rests on the ground and the body weight begins to transfer to the foot.

(c) Midstance (MS): The loading of the body weight reaches its maximum.

(d) Heel off (terminal stance): Heel begins to rise from the ground.

(e) Toes off or push off (PO): When the toes begin to prepare for early swing when the toes are raised off the ground.

2. Swing phase: It has three phases, and it occupies 40% of the gait cycle.

(a) Acceleration: Initial stage of swing begins with acceleration of the leg.

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(b) Midswing: The swing reaches its maximum (decelerate).

(c) Deceleration: The swing begins to slow down (decelerate), and the heel gets ready for the heel strike with the ground. Thus, completing a gait cycle.

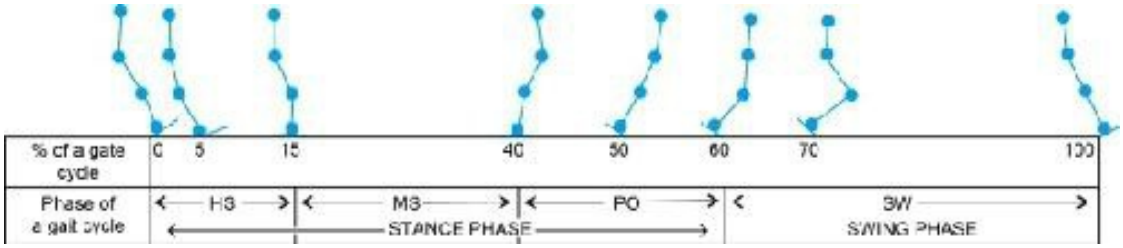

FIG. 31-1 Sequential events of a complete gait cycle and their duration in forward progression. HS, heel strike; MS, midstance; PO, push off; SW, swing.

In a normal gait, each leg alternately moves through a stance and a swing phase, with an intermittent brief phase of double limb support, lasting for about 10–11% of the gait cycle.

Human body participates in a gait cycle with two distinct units.

1. **Passenger unit:** The involved body segments do not actively participate in locomotion but are just the passengers.

2. **Locomotor unit:** Where the involved body parts actively participate in the locomotion as follows:

1. **Passenger unit components**	2. **Locomotor unit components**
• Head, neck, arms and the upper trunk • Shoulder joints – respond by coordinated rhythmic relaxed, free, alternate arm swings	• Lumbosacral spine, pelvis • Both the hip joints • Both the knees • Both the ankle joints

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	• Both the subtalar joints • Both the metatarsophalangeal joints

Importance of centre of gravity (CoG) and the gravitational force in a gait cycle:

- The body uses the gravitational force as a major propulsive force in moving the body forwards.
- But, technically, the body at this stage is falling from the stance limb to the contralateral limb.
- At this moment, CoG comes into action in maintaining the body's balance – by its appropriate displacement.
- Type of the displacement of CoG is important to maintain body's balance during a gait cycle.

Kinetics and kinematics of gait cycle

Kinetics of gait

It is the study of the forces that produce or change motion. It is concerned with the internal forces developed within the body by muscular action as well as external mechanical stresses acting on the body. The external forces acting on the body are as follows:

1. Gravitational force

2. Ground reaction forces

These two external and internal forces acting on the body are important in the analysis of locomotion.

Centre of gravity

CoG plays an important role in the balance of a body. It is an imaginary point at which all the body weight is assumed to be

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concentrated. In a normal erect posture, it lies just anterior to the second sacral vertebra. Its position is rhythmically displaced and replaced during each gait cycle as follows:

1. Vertical displacement of CoG: The highest point of displacement occurs when the supporting limb is in midstance and the lowest at the time of double limb support. The range of vertical displacement is about 5 cm in normal walking (Fig. 31-2A).

2. Lateral displacement of CoG: The shift of pelvis and trunk to the side of the weight-bearing leg displaces the CoG laterally to that side. This excursion of CoG is also normally around 5 cm and remains over the supporting leg (Fig. 31-2B). Therefore, the displacement is proportional to the width of the walking base.

3. Horizontal dip of the pelvis and CoG: In normal walking, there is continuous horizontal dipping of the pelvis on the side of the weight-bearing limb. The extent of this horizontal dipping on the side of the weight-bearing limb does not exceed 5 degrees in normal walking (Fig. 31-2C).

4. Transverse rotation of the pelvis and CoG: Transverse rotation of the pelvis around its vertical axis takes place to facilitate the advancing leg. If the width of the walking base is maintained within the normal limits, the lateral displacement of CoG will be minimal (Fig. 31-2D).

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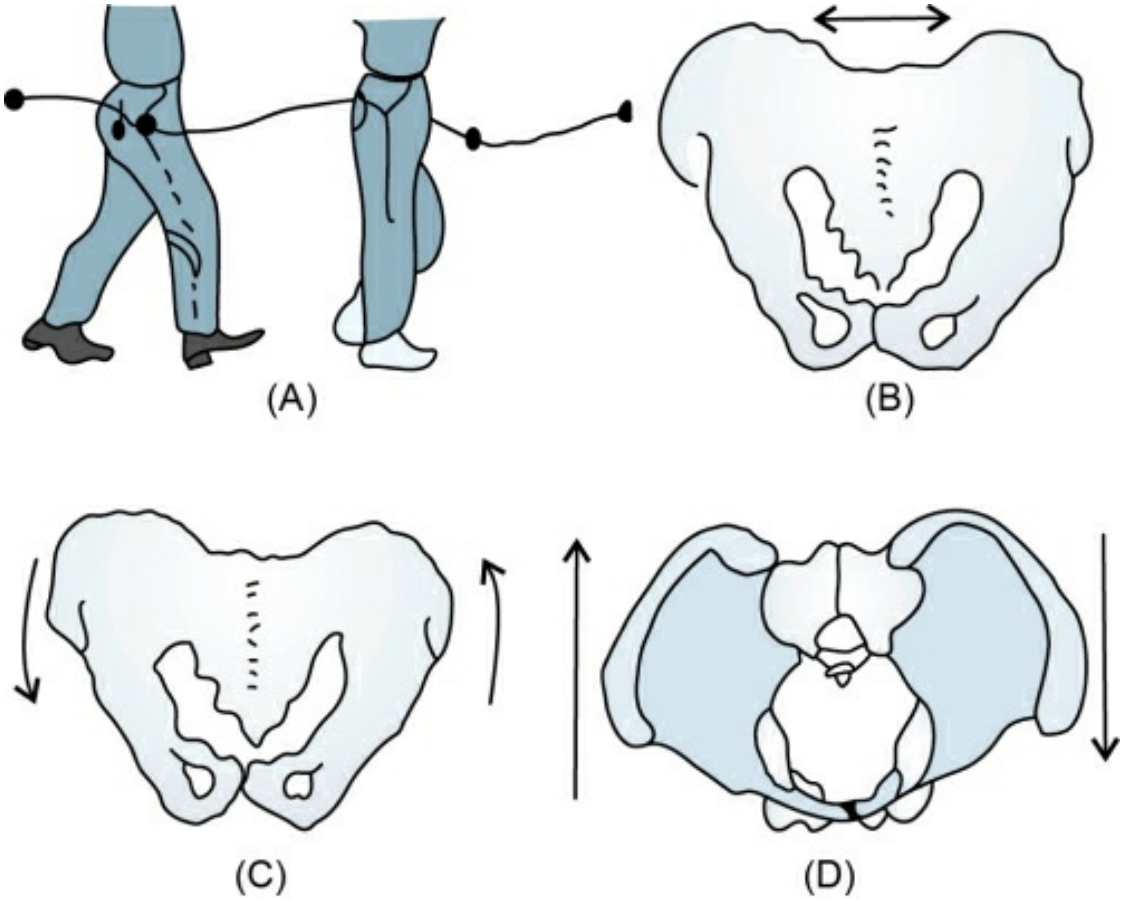

FIG. 31-2 Displacement of the centre of gravity (CoG) of the body and pelvis while walking. **(A)** Vertical displacement: CoG assumes highest point when the supporting limb is in midstance and lowest at double limb support. **(B)** Lateral displacement: during the transference of weight to the forward leg, the CoG as well as the pelvis oscillates laterally from side to side. **(C)** Horizontal dip (tilt) of the pelvis occurs in the frontal plane at midstance. **(D)** Transverse rotation of pelvis: the transverse rotation of pelvis around the vertical axis occurs to assist forward movement of one leg while the other leg is firm on the ground.

The various displacements of CoG aided by selective muscular contractions help in energy conservation during continued ambulation.

Velocity of the CoG of a body: At normal optimal velocity of 2.5–3 miles/h, the energy consumption is minimal. If abnormality in gait function occurs, a change and restriction in the velocity of CoG will be necessary to retain balance.

What is the centre of pressure (COP)?

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It is a point around which all the forces act during ambulation (e.g., walking aids, or plantar surfaces of the feet).

Ground reaction force (fig. 31-3)

This is expressed as a vector. It is a line that represents the direction and magnitude of the force encountered by the body at heel strike. Its relationship to all the joints of the body determines the mechanical interaction of gravitational and muscle forces about each joint.

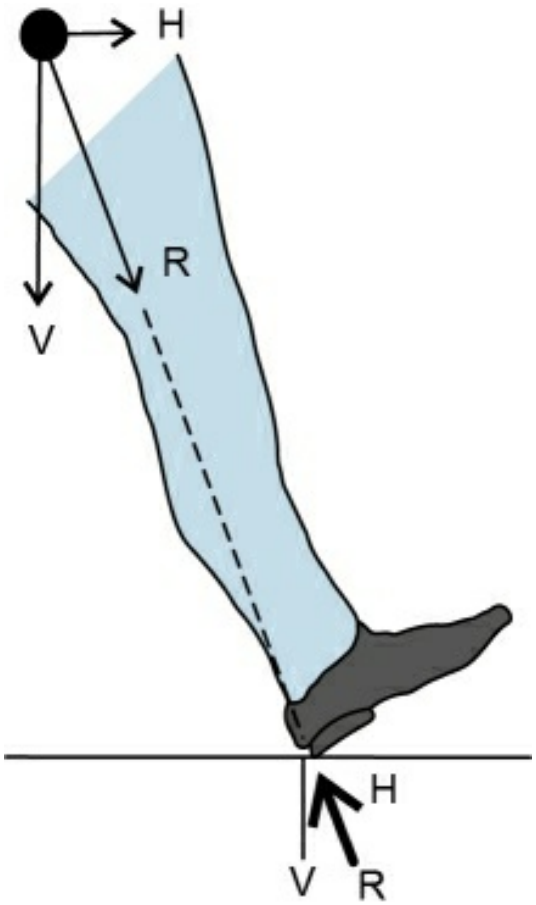

FIG. 31-3 Ground reaction force and its components at heel strike. V, vertical force; H, horizontal force; R, resultant force.

It is the single force which produces the same effect as two or more forces. The length of the vector is proportional to the magnitude of the force. The ground reaction force, horizontal as well as vertical, can be

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measured by force platforms (force plates). As the patient walks over a force platform, the components of force which are equal and opposite to that exerted by the patient are registered.

Vector and the phases of gait cycle: At heel strike, the vector acts anterior to the hip causing hip flexion, anterior to the knee causing knee extension and posterior to the ankle causing plantar flexion movements.

At foot flat, the vector is still anterior to the hip maintaining flexion, but it is posterior to the knee and ankle causing knee flexion and ankle plantar flexion. At midstance, it passes through the hip joint stabilizing the hip in neutral, passes posterior to the knee causing knee flexion and anterior to the ankle causing dorsiflexion. At heel off, it passes posterior to the hip causing hip extension, passes anterior to the knee and ankle causing knee extension and ankle dorsiflexion.

At toe off and during swing, the ground reaction loses its significance as a majority of the body weight is transferred to the contralateral supporting limb. At heel strike and single leg stance, the vertical ground reaction force is 1.2 times the body weight. It is around 0.8 times the body weight at midstance and nearly 3 times the body weight in running.

Kinematics of gait (table 31-1)

Kinematics of the gait, also called *kinesiology*, is the study of the pattern of angular movements and their excursion by smooth coordinated muscular control. It analyses the gait in terms of time, space, velocity and acceleration.

Table 31-1

Kinetics and Kinematics of a Gait Cycle

At Stance Phase					
Joint	*Heel Strike*	*Foot Flat*	*Midstance*	*Heel Off*	*Toes Off*
Hip Motion GRF Movement Muscles acting	Flexion (25–30 degrees) Anterior Flexion Gluteus maximus Hamstrings	Flexion 25–30 degrees Anterior Flexion Gluteus maximus	Extension Anterior → posterior Flexion (0 degree) No muscular action	Extension Posterior Extension Adductors	Flexion Posterior (0 degree) Extension Flexors

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	Adductor magnus				
Knee Motion GRFV Movement Muscles acting	Flexion (5 degrees) Anterior Extension Quadriceps Hamstrings Popliteus	Flexion Posterior Flexion Quadriceps	Extension Posterior → anterior Flexion/extension Quadriceps	Extension/flexion Anterior → posterior Extension/flexion Gastro-popliteus	Flexion Posterior (0 degree) Flexion → Gastro-popliteus
Ankle Motion GRF Movement Muscles acting	PF (0 degree) Posterior PF Dorsiflexors	PF Posterior PF Dorsiflexors	DF Anterior DF PF	DF → PF Anterior DF PF	PF Anterior DF → (0 degree) PF
At Swing Phase					
Joint	***Acceleration***		***Midswing***	***Deceleration***	
Hip Movement Muscle acting	Flexion Flexors		Flexion Adductor longus, gracilus	Flexion with extension at the end Extensors	
Knee Movement Muscles acting	Flexion Hamstrings, sartorius, gracilis		Extension Hamstrings	Extension → flexion Hamstrings, quadriceps, popliteus	
Ankle Movement Muscles acting	Dorsiflexion Dorsiflexors		Dorsiflexion Dorsiflexors	Dorsiflexion Dorsiflexors	

A: DF, dorsiflexion; GRF, ground reaction force; PF, plantar flexion.

Movement components at both the phases of a gait cycle

Stance phase

Spine and pelvis: The pelvis rotates towards the opposite side and prevents dropping of the pelvis on the unsupported side.

Hip: Reduction of flexion and external rotation followed by slight internal rotation. Prevention of abduction of thigh and dropping of pelvis to the opposite side.

Knee: Slight flexion at the moment of contact followed immediately by extension.

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Ankle and foot: Slight plantar flexion followed by slight dorsiflexion and prevention of further dorsiflexion caused by body weight, plantar flexion of ankle and hyperextension of metatarsophalangeal joints at the end of the propulsive phase.

Swing phase

Spine and pelvis: Rotation of the pelvis towards the opposite side; prevention of dropping of pelvis on the unsupported side.

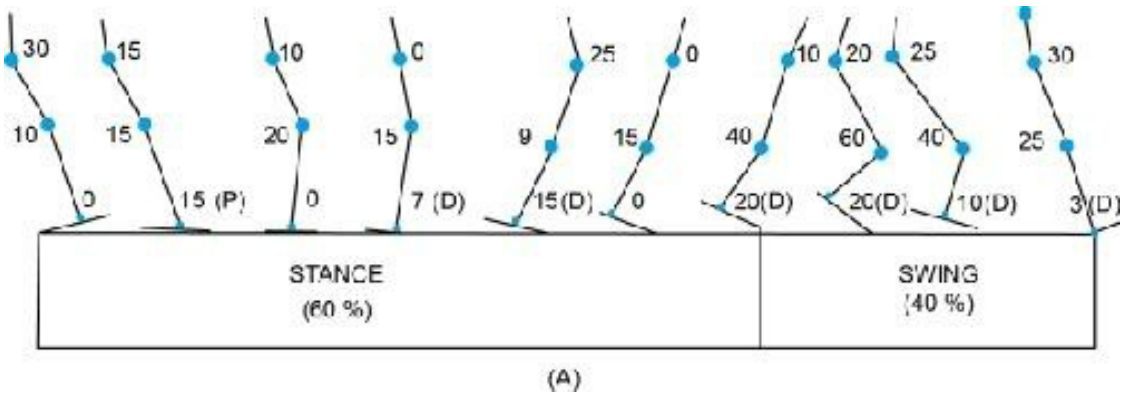
Hip: Flexion, external rotation because of pelvis rotation, adduction at the beginning and abduction at the end phase, especially if the stride is long.

Knee: Flexion during the first half; extension during the second half.

Ankle and foot: Dorsiflexion to prevent toe drag.

Various studies have established the arc of joint movements and the character and activity of various muscle groups during both the phases of the gait cycle.

The electrogoniometric data and electromyographic (EMG) findings of various studies are compiled at each phase of the gait cycle at the three basic segments of lower extremity: hip, knee and ankle (Fig. 31-4).



(A)

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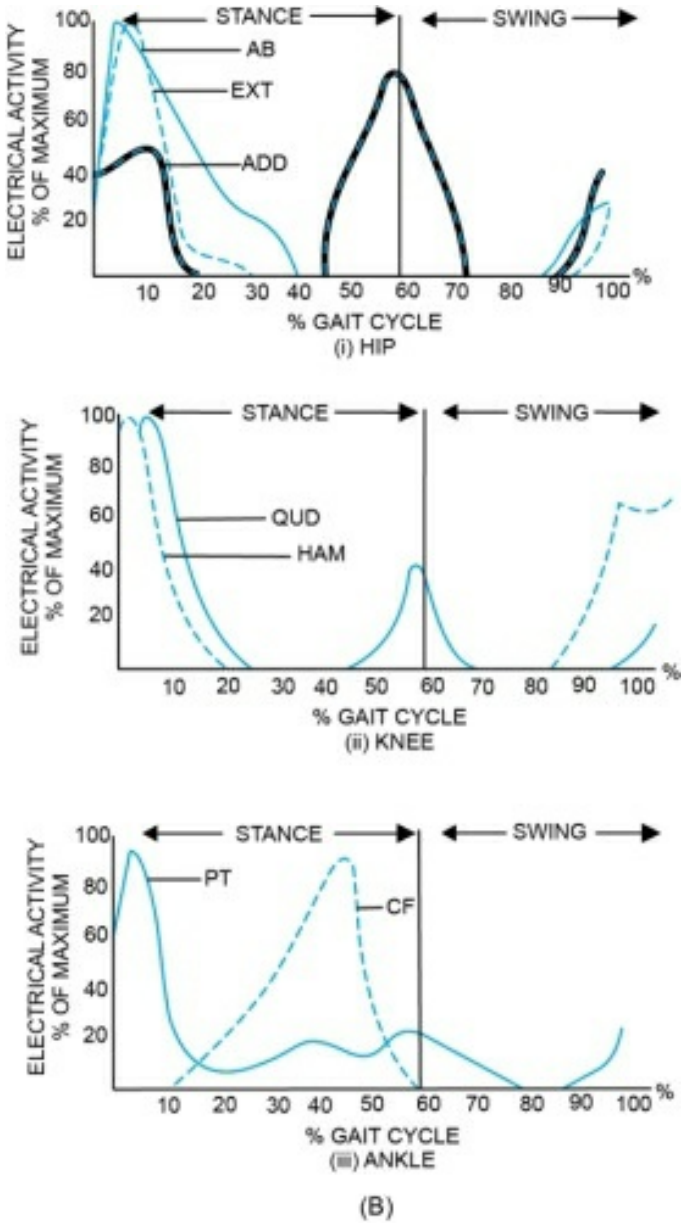

FIG. 31-4 **(A)** Electrogoniometric data of hip, knee and ankle during both the phases of the gait cycle. D, dorsiflexion; P, plantar flexion. **(B)** Electromyographic data on the activity of major muscle groups in walking (i) at hip, (ii) at knee and (iii) at ankle. (i) AB, Abductors. EXT, extensors; ADD, adductors. (ii) QUD, quadriceps; HAM, hamstrings. (iii) PT, pretibial; PF, plantar flexors.

Muscular activity at each phase of a gait cycle

Stance phase

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Early stance

Hip: When the heel comes in contact with the floor, the hip is flexed to 25–30 degrees for forward reaching of the step. Just after heel strike (at about 5% of gait cycle), the abductor muscle group shows peak activity (90% of its maximum), basically to provide lateral stability to the pelvis. This prevents the opposite side of the pelvis from sagging. This activity of abductors tapers but continues to 40% of the gait cycle. Hip extensor shows maximum activity (90% of its maximum) after heel strike at 10% of the gait cycle, to control further hip flexion and to ensure stability and erect posture over the base. Hip adductors also assist hip abductors during this phase. The maximum electrical activity is present in all the hip stabilizer muscle groups during 10–15% of gait cycle.

Pelvic rotation and relative pelvic drop also occur on the side of the advancing leg.

Knee: At heel contact, the knee is nearly extended, slight flexion (about 10 degrees) occurs immediately after heel contact under the impact of body weight.

Quadriceps show peak activity at this stage (about 90% of its maximum at about 7–8% of the gait cycle). Acting eccentrically, it controls the rate of knee flexion and is the main force preventing buckling of the knee. It also controls the path of the CoG from falling or rising abruptly.

Ankle: At heel strike, as the heel strikes the ground, the angle between the foot and the leg is about 90 degrees (neutral).

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As weight bearing is transferred to the foot by advancement of the body, the sole of the foot is lowered gradually to the ground.

The dorsiflexors (pretibial group) show peak activity (90% of its maximum) immediately after heel strike (from 5% to 15% of the gait cycle) to check sudden plantar flexion with controlled lengthening contractions (eccentric). Peroneus longus shows a small burst of activity during weight acceptance as a co-contraction to the tibialis anterior (Winter & Yack, 1987). Immediately after heel strike, hamstrings acting as hip extensors, along with soleus and posterior tibial muscles decelerate the forward movement of the tibia, preventing the trunk from flexing forward on the femur by inertia.

Midstance

Hip: The hip assumes neutral position as the trunk advances forward on the fixed leg.

Knee: As the leg reaches vertical position, the knee attains 10 degrees of flexion and continues to extend till it gets locked in neutral. The activity of the quadriceps drops sharply and stops completely by the time the gait cycle reaches 20%, which is well before midstance. This proves that the quadriceps activity is not needed at midstance.

Ankle: At midstance, the ball of the foot makes contact with the ground. The leg starts pivoting forward over the ankle. Thus, the ankle joint moves from 5 degrees of plantar flexion to 10 degrees of dorsiflexion.

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At this phase, the maximum lengthening activity of controlled elongation takes place at the plantar flexors. It starts at 10% of the gait cycle and reaches its maximum at about 45% of the gait cycle. Long toe flexors and intrinsic muscles are active during all the parts of the stance phase.

Late stance

Hip: At late stance, the hip is in an extended position of 10 degrees as the body has crossed forward. This hip extension lessens (10 to 0), and it starts flexing due to plantar flexion of the foot. Adductor longus and magnus activity give stability by restraining the lateral shift.

Knee: There is a rapid marked knee flexion (0–50%) without the activity of the hamstrings. This flexion occurs as a result of the small ground reaction force and plantar flexion of the foot. Second quadriceps activity is noticed at about 50% of the gait cycle during the transition from stance to swing phase. This is because the rectus femoris prepares to act as a hip flexor to initiate the swing.

Ankle: At the near culmination of the stance phase, as the limb prepares for forward swing, the heel raises from the ground with simultaneous flexion at the knee. The ankle reaches 20 degrees of plantar flexion. Gastrosoleus along with peroneus longus shows peak activity of shortening contraction. They actively plantar flex the foot and generate explosive force to push off to initiate the swing (estimated at 250% of body weight in tension). Minor degree co-contractions are noticed in the extensor digitorum longus (EDL) to stabilize the ankle joint at push

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off (Winter & Yack, 1987). At this stage of onset of heel raise, the intrinsic activity occurs (at 35% of gait cycle) as body weight concentrates on the forefoot (Basmajian & Stecko, 1963; Mann & Inman, 1964).

Swing phase

The swing phase begins with toe off and ends with heel strike.

The forward acceleration of the limb is brought about by gradual hip flexion to about 20–30 degrees and knee flexion of around 40–65 degrees. The ankle reaches neutral and gradually attains the position of 5 degrees of dorsiflexion.

The muscle activity is present in the hip flexors at the initial stage. The hip adductors control abrupt external rotation and abduction. Rapid knee extension from 50 to 60 degrees of flexion occurs due to the relaxation of hamstrings. The knee then begins to extend with pendular action and mild contractions of the quadriceps muscle. However, hamstrings show peak activity at the terminal stage of swing (from 85% to 100% of the gait cycle). They act as hip extensors mainly to decelerate and control the excessive forward flexion of the leg. The dorsiflexors (pretibial group) are active throughout the swing to prevent foot drop and show maximum shortening activity in the late swing phase (concentric) to prepare the ankle and foot for heel strike (at 90–100% of the gait cycle).

It must be remembered that the muscle activity in walking is mainly shock absorbing rather than propulsive.

The limb moves forward mainly by inertia with minimal muscular activity.

Role of reciprocal arm swinging: The reciprocal relaxed arm swinging provides opposite reaction forces. Arm movements in conjugation with trunk rotation offer necessary balance as well as symmetry to the gait. Thus, it forms one of the important components of gait assessment and gait training, an aspect which is not given its due importance.

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Methods of gait evaluation

1. Observational method: This method was first reported by Weber and Weber (1836). In this method, the skill and experience of the clinician is the basic factor which records deviations in the gait cycle by visual observation. Brunnstrom (1964) assigned numerical values to the quality of movement pattern at specific anatomical sites (hip, knee and ankle) in the adult hemiplegics.

2. Photographic method: It includes video, cine and TV film analysis. Marey (1855), Fisher (1898) and Murray et al. (1964) used photography to measure various kinematic components like velocities, acceleration, linear and angular displacements during gait cycle.

3. EMG methods: This method involves the study of muscular forces on the muscles participating in the gait cycle of various joints (Johnston & Smidt, 1969). Scherb (1938) also reported on the myokinetics of gait which is useful in neurological or myopathic disorders.

4. Force studies method: This method is the analysis of a gait cycle by the data of reaction of forces. Morrison (1969) presented data on floor reaction forces. They have reported forces to the tune of four and three times the body weight to the concerned joint at the hip and knee, respectively.

5. Electrogoniometric method: Johnston and Smidt (1969) and Smidt (1971) reported objective studies on the range of motion of joints participating in the gait cycle by strapping on a electrogoniometer.

6. Energy cost and energy requirement method: This method analyses the energy requirements and energy expenditure during each gait cycle. It has been proved that the energy cost of gait in pathological conditions is much higher than the normal.

7. Spatial and temporal measurement method: Analyzes the basic

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temporal and spatial characteristics, speed and distance parameters of gait.

8. Combination of various methods: Simultaneous record accelerograms, EMG and high-speed motion pictures are used to correlate normal and pathological gaits (Liberson et al., 1962).

9. Multichannel functional stimulation method: Use of multichannel functional electrical stimulation (FES) to six main anatagonistic groups, i.e., ankle dorsiflexors, plantar flexors, knee extensors and flexors, hip extensors and triceps surae, has been reported as a successful method of gait analysis and training (Bogataj et al., 1989; Malezi et al., 1984), but it involves the factors of time and cost.

At present, a number of gait laboratories with sophisticated methodology have come up at various centres. These will be able to detect and record the minute details regarding deficiencies in gait. It is not feasible to have such extensive and expensive laboratories for routine clinical practice. Therefore, some simple, cheap, less time consuming but reasonably objective methodology has to be evolved as a practical alternative.

Suggested method of gait analysis. To evolve such a methodology, we suggest a technique which is based on a combination of (a) observational data on the major segmental deviations at the hip, knee and ankle–foot joints and (b) qualitative analysis of the temporal and distance parameters. This method should be able to provide adequate data to detect major deficiencies of the gait so as to plan the gait training programme. Basic, well-established data are available on the following parameters:

1. The range of movement at the joints participating in normal gait.

2. The degree of electrical activity of the various muscle groups during normal gait.

3. Common deviation in pathological gaits as a result of expected

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deficiencies.

We suggest that the observational gait analysis should be adopted as a basic procedure to evaluate the major deviations from the normal. The data thus recorded can be correlated by clinical examination of the patient.

Secondly, a simple but objective method of quantitative analysis of the temporal and distance parameters of gait is carried out critically. The combination of both these methods can provide adequate information on the patient's gait deviations. This will help not only in planning the gait training programme but also in assessing the efficiency of the technique.

Methods of observational analysis

As a routine, every physiotherapist has to develop an art of observation or eye ball analysis to critically record gait deviations during both the phases of the gait cycle. Although these visual impressions cannot be quantified, they can provide useful information to assess the major deviations from the normal. This has been adequately demonstrated by Brunnstrom in 1964. In this method, the physiotherapist systematically and critically observes and records the minute deviations at the three main weight-bearing joints: the hip, knee and ankle. Total attention needs to be concentrated on a single joint at a time. The joint needs to be carefully observed from the anterior, lateral as well as posterior aspects during both the phases of the gait cycle. The observations are to be recorded at both the phases and subphases of the gait cycle by several repetitions. The patient is asked to walk at his normal walking speed. This analysis as a rule should be preferably done without any assistance. Along with hip, knee and ankle, the observations for trunk and pelvis should also be recorded separately. The interpretation of the data thus recorded can provide an overall picture of the patient's gait.

The major deviations or deficiencies thus identified should be correlated with the clinical examination of the patient in various basic body postures, especially in standing, to formulate the gait training

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programme.

Evaluation of the temporal and spatial characteristics of gait

To assess the overall performance of a patient, quantification of the ambulation profile is very essential. Normal values for this have been established. A clinical method of quantitative gait evaluation is reasonably adequate, simple and inexpensive. It also does not require large space or time-consuming methodology (Cerny, 1983). The parameters of temporal and distance data include stride length, step length, step width, velocity and cadence.

1. *Stride length:* Distance between two consecutive ipsilateral heel contact marks.

2. *Step length:* Distance between two consecutive contralateral heel contact marks.

3. *Step width:* Distance perpendicular to the line of progression from left contact mark to right contact mark and from right to left.

4. *Velocity:* Distance between the first and last heel contact mark divided by the time required to cover that distance.

5. *Cadence:* Steps per minute calculated by dividing the product of number of marks and 60 by the number of seconds it took to traverse the total distance.

This method needs a 16-m (50-feet) walkway, which is divided into three segments: two 5-m segments on either side of the 6-m segment which is the main area of evaluating the gait. Two felt-tip-marking pens are taped to the back of the patient's shoes so that the tip just reaches the floor and puts a mark on the floor at every step. We suggest modification to Cerny's method by adding one more marking pen to be secured anteriorly at the centre of the toe line of the shoe, which will put a mark at toe offstage (Fig. 31-5). Joining the line of the

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heel and toe markers will provide information about the angle of the foot in relation to the midline.

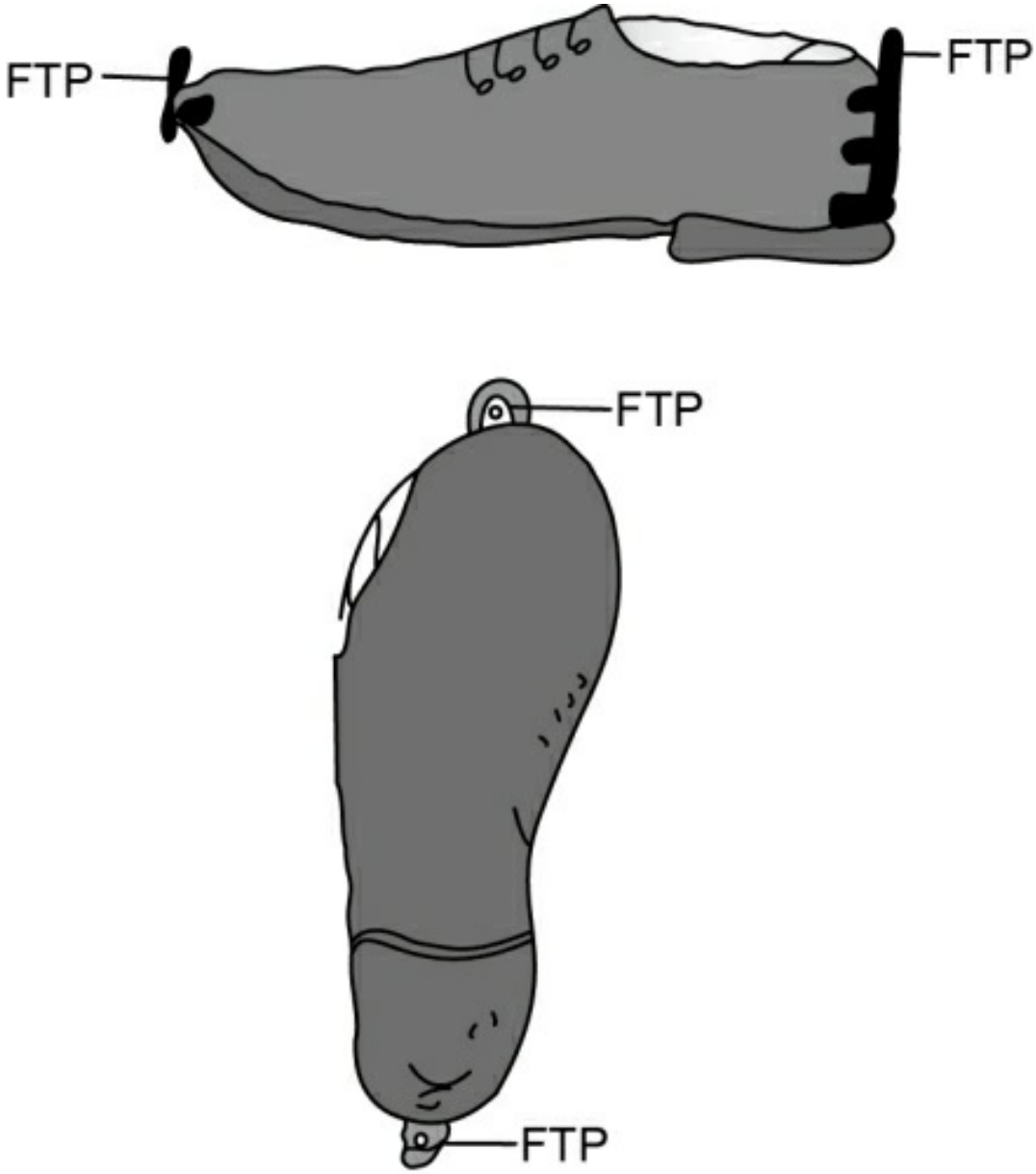

FIG. 31-5 Felt tip pens (FTP) taped to the front (centre) and the back (centre) of the shoe.

The patient is asked to walk at his usual speed. The physiotherapist, using a stopwatch, records the total time taken to cover the centre 6-m area to calculate the velocity and the cadence. Measurements of the

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stride length, step length, step width and foot angle (as suggested by us) can be done by joining and measuring the contact pen marks to the midline within the central 6-m walkway (Fig. 31-6).

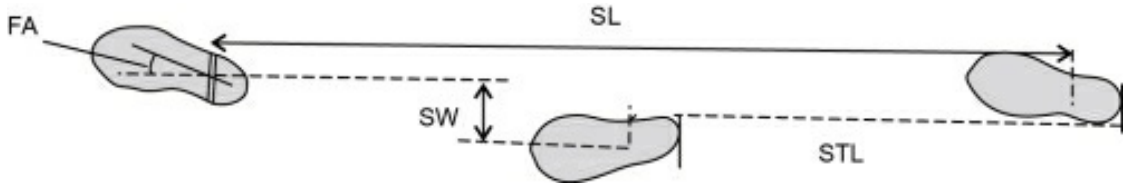

FIG. 31-6 A simple method of quantifying various parameters of gait. SL, stride length; SW, stride width; STL, step length; FA, foot angle.

By this method, a variety of temporal and spatial variables can be quantified and used to describe an individual's gait.

This method of evaluation can also be used effectively to assess the efficiency of the treatment programme.

To understand the deviations from the normal, it is essential to know the standard values of various important parameters of gait. The standard values are shown in Table 31-2 (Murray et al., 1964).

Table 31-2

Parameters of Normal Gait

Parameter	Measure
Duration of stance	0.59–0.65
Duration of swing	0.38–0.42
Duration of double limb support	0.10–0.12
Complete cycle	0.98–1.08
Steps per minute	111–122
Mean step length	Left to right: 75.9–81.1 cm
Mean stride length	Right to left: 74.9–81.4 cm
Mean stride width	150.8–162.5 cm
Foot angle, degrees of out toeing	7.1–9.6 cm
Average speed weight; acceptance and push off	Mean right, 6.7° Left, 6.8° 3 mph of (130 cm) The vertical floor reaction force is 115% of the body weight during the midstance

At the comfortable walking speed of 3 miles per hour, the energy cost and the muscle force are minimal. The work of moving the body forward is done mainly by gravity and inertia, the ground reaction

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forces being mainly absorbed by the weight-bearing joints.

Gait abnormalities

Relationship of physical deficiencies and gait abnormality: Pathological gaits due to various deficiencies vary markedly due to the different compensatory methods adopted by the body.

Pathological gait abnormalities and the probable causative factors (table 31-3)

Weakness of biceps femoris, fixed inversion of the heel results in hip internal rotation gait.

Table 31-3

Common Pathological Gaits

Patological Gait, with Probable Causes	
Hip • Hip pain • Abductor weakness • Hip extensor weakness • Loss of movement control of hip flexors and hamstrings, e.g., stroke • Hip hiking – spasticity in the hip extensors, foot drop or weak hip or weakness of hip flexors • Internal rotation of hip • Hip external rotation	• On bearing body weight, patient leans on the affected side • Pelvis drops on the normal side on bearing body weight (Trendelenburg gluteus medius dip) • Backward thrust of the trunk on bearing body weight • Hip circumduction to clear the ground • Combined action of quadratus lumborum, lateral abdominals to elevate pelvis to clear the ground and then leg is propelled forward with a pendular swinging action • Biceps femoris weakness, fixed inversion of the heel • Fixed eversion of the weak tibialis anterior, posterior and plantar flexors
Knee • Paralysis or paresis of quadriceps or unstable knee joint on bearing body weight • Arthritic knee	• Knee stabilization by jerky hyperextension with both hand supports above the knee, with trunk bent forward • Knee is stabilized in slight flexion, or else stiff knee gait, short step forward with longer step by the less painful leg
Ankle–Foot • High step • Foot drop • Pescalcaneous • Varus with inversion • Valgus foot with eversion	• Excess hip flexion to clear the ground • There is no phase of toes off in a gait cycle. Entire sole is used for push off, e.g., hammer toes, metatarsalgia or fixed position of foot in neutral or slight plantar flexion like ankle arthrodesis • Peroneal paralysis • Anterior tibial group paralysis
CNS affections • Speedy shuffling gait with small steps; trunk bent forward with rigidity of the whole body	• Parkinson disease, ataxia to secure balance • Hip circumduction due to the loss of hamstrings control, inability to flex knee and hip on the affected side • Scissors gait (spastic gait) • Does not lift legs which otherwise can do so against resistance,

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• Cardiovascular accident (CVA) or hemiplegic gait • Spastic paraplegia or CP • Hysterical gait	mostly walks with shuffling gait but in between with near normal gait

Weakness of hamstring, tibialis anterior, posterior or plantar flexors results in hip external rotation gait.

Some of the basic deviations in gait are as follows:

1. Weakness of hip flexors: The patient is unable to flex the hip and shortens the step length during the swing.

The compensatory mechanism adopted by the patient will be a backward thrust of the trunk with circumduction, lateral trunk movement towards the side with elevation of the hip on the affected side or hip hiking.

2. Weakness of hip abductors: Dropping of the pelvis on the opposite side with lateral flexion of the trunk and head on the affected side. This is known as *Trendelenburg* or *gluteus medius dip gait*.

Compensated gluteus medius gait: Here the gluteus medius weakness is compensated by the medial deviation of the hip on the affected side. The trunk bends sideways on the affected hip on weight-bearing, and the opposite hip is lifted up for the clearance of the ground. In the presence of limb length disparity, the patient has similar tendency which needs to be rectified by limb length measurement and manual muscle test.

3. Weakness of hip extensors: In gluteus maximus gait, following heel strike of the affected leg, jerky backward thrust of the trunk occurs with simultaneous protrusion of the affected hip. Backward thrust of the trunk keeps the CoG behind the hip joint to counteract the inertia produced by the forward movement of the trunk. At midstance, the knee is held in extension.

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Exaggeration of lumbar lordosis: During the stance phase, the gait may suggest hip flexion contracture on the side of the stance leg.

Persistent inclination of the pelvis, to one side during all the phases of gait cycle, combined with lack of heel strike suggests an adduction contracture on the side of the inclination.

4. Weakness of quadriceps: There is forcible extension on the knee at heel strike. This is done by using 'hand support on thigh' position at midstance, knee can be drawn backward by hip extensor as well as by gastro-soleus on weight bearing by producing equinus foot. Unprotected repeated extension may result in genu recurvatum.

5. Weakness of hamstrings, especially along with gastrocnemius: It may give rise to genu recurvatum due to repeated posterior thrust of weight bearing.

6. Weakness of dorsiflexors: This produces foot slapping at early stance and foot drop at the swing phase. It is compensated by excessive flexion at the hip and knee (high stepping gait). When the hip flexors are too weak to perform hip flexion, the foot may be dragged forward with external rotation of the whole limb.

Moderate weakness of dorsiflexors may not produce foot drop during the swing phase but may result in foot slap at heel strike.

Mild weakness of the dorsiflexors will give rise to foot slap only during speedy walk or after the subject is tired.

7. Weakness of plantar flexors: It results in dropping of the pelvis on the affected side with slowing of the forward movement at the

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terminal phase of stance phase. Speedy walking increases calf limp whereas it decreases during a gluteus medius limp. It must also be remembered that in gluteus medius limp, the pelvis on the side opposite to the affected limb is dropped as against the calf limp.

8. Antalgic gait: In antalgic gait, due to the pain arising from ankle, foot, knee or hip, the stance period is reduced on the side of the painful leg. At the onset of the stance, the patient jerks his head, arms and trunk downwards; then with a jump and a long forward step leans towards the affected side and quickly shuffles the normal limb with a jump and a long forward step. This manoeuvre decreases downward force of gravity. This type of gait is commonly seen in patients following fracture or injury to one lower limb.

In degenerative disease of the hip, the patient walks with extended stance. There occurs excessive hip abduction, rotation of the trunk laterally over the affected extremity and maximum external rotation just after heel strike. These modifications are the purposeful compensations to minimize the resultant force transmitted through the hip joint and to increase lateral stability (Wardsworth et al., 1972). Common gait deviations in certain diseases like Parkinson disease, stroke hemiplegic and Duchenne muscular dystrophy are easily identified because of their well-established peculiar gait patterns.

Gait training

It is important to note that gait training should be started after the first evaluation of a patient and not only when the patient is allowed to stand and walk. It consists of five phases:

1. Pregait training evaluation

2. Detection of the restricting factors

3. Therapeutic measures

4. Commencement of gait training

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5. Independence in other activities of ambulation

1. Pregait training evaluation

It is done on the basis of the biomechanical, kinetic as well as kinematic requirements of the normal gait. It involves careful examination of the following:

1. Range of motion of the joints principally involved in ambulation with measurement of limb length.

2. Muscle strength and endurance of the muscle groups participating in ambulation.

3. Status of coordination of the joints of ambulation having fixed deformity.

4. Overall sensory status of the limb, particularly of the distal segment.

5. Status of static and dynamic balance.

6. Age, body built, cooperation and attitude of a patient towards walking.

7. Type of physical activities involved at work and at home.

8. Degree and guidance of the possible assistance at home.

9. Diagnosis and general cardiorespiratory status and exercise tolerance of a patient.

2. Detection of the restricting factors

Proper interpretation of this data will help in detecting the possible restricting factors in gait and will also help in predicting the ultimate outcome.

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3. Therapeutic measures

Appropriate therapeutic measures to correct or reduce the influence of restricting factors can be taken, e.g., correction of the soft-tissue contracture or deformity. It may be necessary to enhance strength, endurance and coordination to prepare the upper extremities to facilitate the use of a walking aid which may be required in future.

4. Commencement of gait training

The commencement of gait training will depend upon any of the following conditions of the patient:

(a) Nonambulatory phase

(b) Ambulatory phase

(c) Special training sessions to teach other advanced activities in ambulation

Nonambulatory phase

The mode of gait training will depend on whether the patient needs non–weight-bearing or partial weight-bearing ambulation. The patient may need total or partial support of the assistive device.

During non–weight-bearing ambulation, the gait is nowhere near normal and the patient manages only by hopping on two crutches. But, at times the programme of conditioning the non–weight-bearing leg for future gait training needs more emphasis than crutch walking.

As soon as the patient is allowed, partial weight-bearing becomes important to educate and guide him on the requirements of normal gait cycle. No matter even if one has to continue with adequate assistance of walking aids. Efficacy of gait at this early stage of ambulation should never be sacrificed. Therefore, the assisted walking should be critically observed for all the characteristics of the normal gait. Shadow walking should be initiated as early as possible.

Ambulatory phase

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At the baseline, the gait should be thoroughly evaluated and recorded for future review. A careful correlation of the deviations in gait in relation to actual deficiencies as noted earlier should be established. The end result of optimal expected correction in the gait training should be planned and begun. Important factor to gait training is the education of the patient to normalize the abnormal attitudes by self-correction and encouragement. The ultimate goal is the normal to near normal pattern of gait which is safe and effortless.

If any compensation in length or orthotic device or walking aid is necessary, it should be given before starting gait training.

On the spot correction with the patient made to practise in front of a postural mirror over the footmarks marked on the floor provides an excellent mean of gait training.

It is generally observed that overemphasis on ambulation at an early stage sometimes gives rise to a limp. If imposed on patients, it gets habitual and organized and is very difficult to rectify at a later stage.

The usual physiotherapy techniques are practised to provide sound static and dynamic balance and stability to the gait; improving efficiency of gait along with training sessions for adopting the functional positions.

Reciprocal arm swinging provides opposite reaction forces. Arm movements in conjugation with pelvis and trunk rotation offer the necessary balance as well as symmetry to the gait. This forms a very important component of gait training. Unfortunately, this aspect is not given enough attention in our clinical programmes of gait training. This arm swing is basically a reflex action and if prevented, the upper trunk tends to rotate in the same direction as the pelvis, causing tense and awkward gait.

Judicious application of various physiotherapy gait training techniques supported by appropriate assistive devices and orthotic and prosthetic appliances can contribute potentially towards the improvement of the stability and gait pattern.

PNF techniques of resistive gait (pelvic resistance) with approximation at heel strike and rhythmic stabilization are very

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effective for any gait training programme (Voss & Knott, 1968).

Long sessions of standing balance on the affected leg alone are very effective to give confidence in improving the stability and the pattern of gait.

It may be ideal, to provide normal pattern of gait to a patient. However, one must never forget that in pathological situations, the limp is a compensatory mechanism at the lowest energy cost of ambulation.

Undue long sessions with emphasis on normal gait may lead to more complex gait problems rather than ease of ambulation. Therefore, the physiotherapist must be skilled enough to judge the extent of gait training programme as per the limits of the patient's condition and give the patient a gait with three 'S'-its stability, security and safety.

5. independence in other activities of ambulation

Gait training cannot be considered complete unless the patient learns other ambulatory activities. Guidance and graded techniques of controlled resistance are very useful in providing independence in the following ambulatory activities:

1. Back walks

2. Turning

3. Side walks

4. Managing steps

5. Negotiating rough, uneven surfaces and slopes

6. Falling on the floor and raising

Several sessions of practice and efforts are needed to achieve proficiency in these tasks.

The metabolic cost of walking increases significantly in patients with lower extremity deficiencies resulting in early fatigue.

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Caution

Any breathlessness, early fatigue, chest pain and allied symptoms of cardiovascular origin need to be monitored carefully.

Whenever possible, analysis of the parameters of oxygen consumption, endurance, cadence, step length and pulse rate may be done. This will provide objective assessment of the ability to walk (Stoodley & Sikorski, 1987) along with the patient's tolerance to walking.

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CHAPTER 32

Spine

OUTLINE

- Congenital spinal anomaly
- Developmental disorders of the spine
- Low back pain
- Degenerative disc diseases

Congenital spinal anomaly

Spina bifida

Spina bifida, a neural tube defect, is the result of the defective fusion of one or more posterior vertebral arches with resultant protrusion of the contents of the spinal canal.

Classification

1. Spina bifida occulta (Fig. 32-1B)

2. Spina bifida cystica (manifesta)

   (a) Meningocoele (Fig. 32-1C)

   (b) Myelomeningocoele (Fig. 32-1D)

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1. In *spina bifida occulta,* there is merely a radiographic defect between the laminae. The presence of an overlying midline skin defect, such as haemangioma, lipoma or a tuft of hair, points to an underlying spina bifida occulta (Fig. 32-2). It is rarely associated with neurological deficit. These children, therefore, do not require any specific treatment. Simple physiotherapeutic procedures can be effective to make them functionally independent.

2. In *spina bifida cystica*, there is a developmental deficiency of laminae, spinous processes and the overlying muscles and skin.

(a) *Meningocoele*: In this variety, usually the spinal cord and its nerve roots are intact, only the covering membrane (meninges) projects as a dural sac (Fig. 32-1C). If this defect is closed by early surgery, paralysis in the lower limbs is avoidable and the rehabilitation is easy.

(b) *Myelomeningocoele*: Here, the spinal cord is exposed to the surface as a plaque or nervous tissue. It is invariably associated with muscle paralysis, sensory loss and paralytic deformities of the lower limbs, and involvement of the urinary bladder and bowel. It may present anywhere from the fourth thoracic to the first sacral vertebra. However, it is more common in the lumbosacral region (Fig. 32-1D).

This type is associated with the usual complications of paraplegia, bladder and kidney infections, skin ulceration, etc. It may also be associated with deformities, and is prone to develop pathological fractures, meningitis and hydrocephalus.

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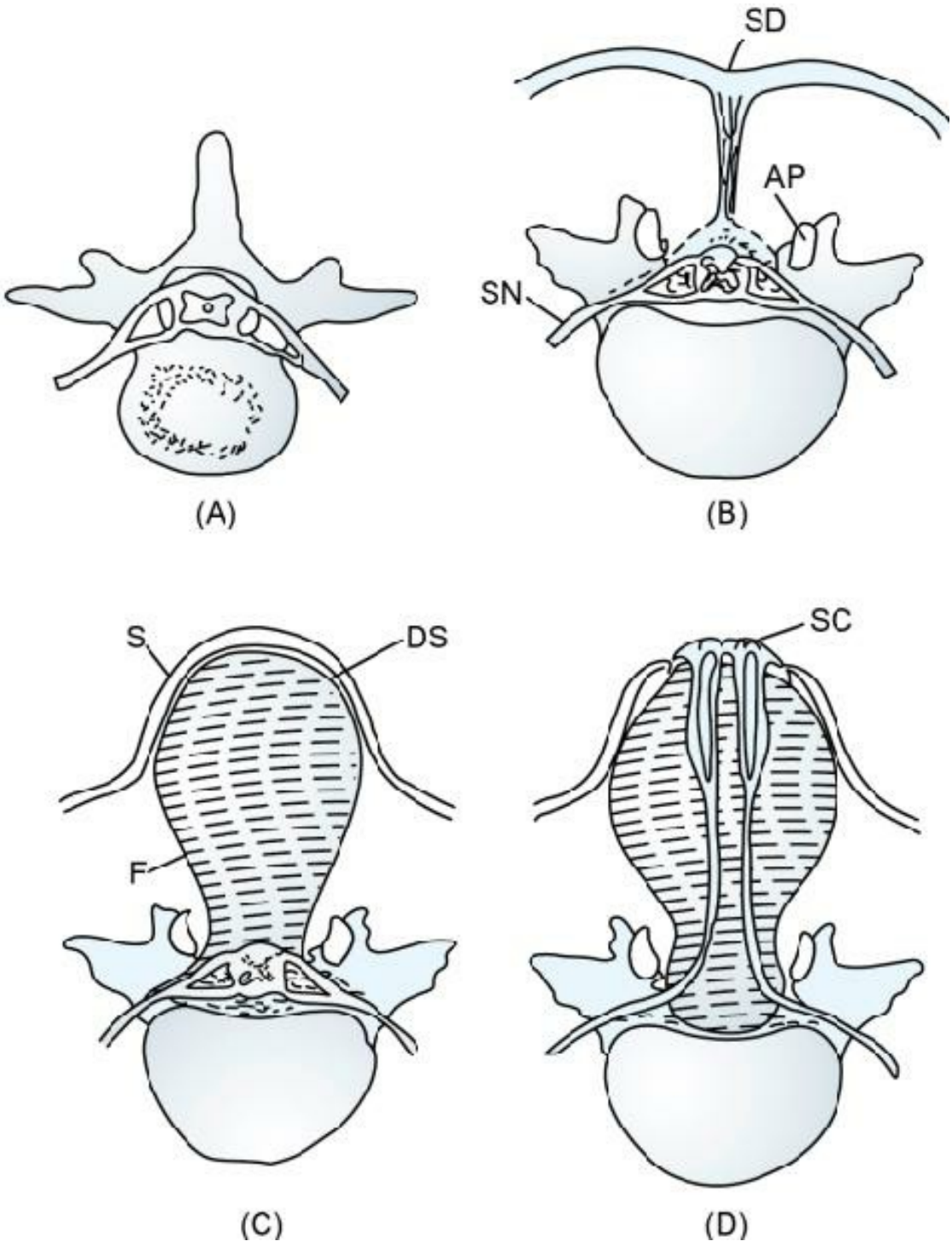

FIG. 32-1 Spina bifida, meningocoele and myelomeningocoele. **(A)** Normal with well-formed and posteriorly closed neural arch. **(B)** Spina bifida occulta. SD, depression in the skin; AP, articular process; SN, spinal nerve. **(C)** Meningocoele, S, skin and subcutaneous covering; DS, dural sac, F, fluid collection. **(D)** Myelomeningocoele. SC, spinal cord.

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FIG. 32-2 Spina bifida. Note the tuft of hair.

Treatment

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Physiotherapeutic approach

Considering all these complicated factors, a generalized prescription of physiotherapeutic management is impossible. Each problem has to be managed on its own merit.

The extent of deformities, paralysis as well as sensory impairment needs to be evaluated thoroughly. Muscular paralysis is the main disabling factor. The paralytic involvement depends upon the level of the lesion.

Although difficult, careful and thorough assessment of the neuro-musculosketetal system is the first priority of any therapeutic procedure.

The basic objective of physiotherapeutic management is to reduce the deformities, improve the muscle power to the maximum and make the child functionally independent, especially in ambulation.

1. *Paralysis at the thoracic level*: Because of the higher level of the lesion, there are multiple problems such as loss of trunk control and paralysis of both the lower extremities; bladder and bowel incontinence are the major areas of management. The goal to offer maximum physical independence can be achieved by imparting proper education to the child's mother to take proper measures to avoid complications, and offer assistance. A fair amount of physical independence is possible as children have tremendous potential towards self-adaptations and adjustments.

2. *Paralysis below the first and second lumbar nerve roots*: There is complete paralysis of hip abductors and extensors. Due to the unopposed action of hip flexors and adductors, the child is prone to develop hip dislocation or flexion contracture. Regular monitoring and avoiding improper weight bearing are the most important aspects of the management.

3. *Paralysis below the third or fourth lumbar roots*: Hip flexors and adductors and extensors of the knee are normal and the tibialis anterior may be active with the paralysis of the glutei, hamstrings gastrosoleus and toe flexors.

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This imbalanced action at the hip, knee and ankle may give rise to hip dislocation, rigid genu recurvatum and calcaneovarus deformity, respectively. Measures to avoid deformity due to muscular imbalance need special attention and care.

4. *Paralysis below the level of the fifth lumbar nerve root*: As the hip abductors are active, the chances of hip dislocation are rare. Similarly, activity of the medial hamstrings reduces the incidence of rigid genu recurvatum. The degree of deformity at the ankle and foot is reduced due to the activity of long toe extensors.

However, the possibility of hip flexion contracture and limitation of plantar flexion may exist. Measures to avoid them by repeated check are important.

5. *Paralysis below the first sacral nerve root*: Weakness exists in the gluteus maximus, biceps femoris, triceps surae and intrinsic muscles of the foot. Hence, there is a possibility of developing hip flexion contracture, calcaneus deformity with limitation of plantar flexion.

Physiotherapeutic management

Physiotherapeutic management includes the following:

1. Prevention and management of deformities

2. Management of muscle paralysis

3. Care of skin and joints

4. Management of bladder and bowel incontinence

5. Education in ambulation, and self-care

1. **Prevention and management of deformities**: All measures should

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be taken to prevent deformities, as far as possible. The mother should be taught simple procedures such as passive stretching and the use of night splints.

Mild to moderate deformities may be treated conservatively by passive stretching and adequate splinting. Rigid deformities may need manipulation under general anaesthesia, followed by plasters and splints.

Several deformities need surgical correction. Deformities such as congenital or acquired dislocation of the hip may need early surgery. The tendon of iliopsoas is detached from its insertion and transplanted posteriorly through a hole in the ilium to augment the action of the abductors and extensors.

After surgery: Re-education of the transplanted iliopsoas to function as an effective hip abductor and extensor is of primary importance. This maintains reduction of the hip joint and provides stability to the hip on bearing weight. When surgical elongation of the quadriceps is done to release the rigid genu recurvatum, it needs concentrated efforts to improve the muscle strength and range of movement (ROM) at the knee so as to stabilize the knee in standing and walking. Tendon transfer surgery may also be necessary to correct inversion or calcaneus deformity. Proper measures are necessary to re-educate the transferred muscles and to maintain an adequate range of motion at the ankle and foot. Efforts to achieve plantigrade position of the foot needs to be emphasized as this position of the foot is important for proper foot contact and weight transfer during ambulation.

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2. **Management of muscle paralysis**: Depending upon the level of the lesion, priority should be given to:

(a) Arm and shoulder girdle muscles. These should be developed for crutch walking and transfers.

(b) Functionally important weight-bearing muscles such as hip abductors and extensors, knee extensors, ankle dorsi and plantar flexors should be strengthened to the maximum.

(c) Establish the body equilibrium in various positions. This can be achieved by using arm muscles and visual and auditory feedback techniques. It can be initiated as rolling and progressed gradually to sitting.

Children with thoracic lesions need re-education of the trunk muscles.

(d) Proper re-education of the transferred muscles.

3. **Care of skin and joints**: Anaesthetic skin and insensitivity of the joint position need to be given due importance to avoid further damage and complications.

While using splints and braces and during passive stretching, protection of the skin from pressures and ulcerations is necessary. This is done by proper checking of the appliance and by frequent careful examination of the skin at pressure points. Parents should also be warned against exposing the insensitive parts of the limb to extreme hot and cold situations.

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Loss of joint position sense can be compensated by appliances and visual and auditory reflexes.

4. **Management of bladder and bowel incontinence**: Applying manual pressure above the symphysis pubis at regular intervals can be helpful in emptying bladder in boys. In girls, it is difficult to obtain such control.

Children who dribble constantly may develop ulcers at the napkin area, thus needing frequent examination of these areas and the necessary skin care.

Infection of the urinary tract and failure of the kidney function can be avoided by surgical diversion of the urine to a receptacle.

Bowel incontinence is manageable as most of the children develop an automatic bowel action. If necessary, suppositories or enema may be used.

5. **Education in ambulation and self-care**: Preparing a child for ambulation is the principal goal, and all the efforts to achieve this are initiated right from the beginning.

It has to be systematically progressed to:

(a) Strengthen the upper extremity, shoulder girdle and trunk muscles.

(b) Prevent adverse factors such as hip flexion, knee flexion and ankle dorsiflexion contractures by emphasizing hip extension, knee extension and ankle plantigrade programmes, respectively.

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(c) Develop equilibrium reactions.

(d) Develop static and dynamic weight-bearing programmes with properly fitting appliances.

(e) Re-education standing and gait training.

The goal of ambulation differs primarily with the neurological level of the lesion (Fiewell, 1980; Hoffer, Fiewell, Perry, Perry, & Bonned, 1973). Besides this, factors such as mental retardation, spasticity, hydrocephalus and spinal deformity can limit ambulation.

Patients are classified into four levels of functional groups (Fiewell, 1980):

1. Thoracic patients

2. High lumbar patients

3. Low lumbar patients

4. Sacral level patients

1. *Thoracic patients*: Children in the thoracic group rarely achieve independent ambulation due to total lack of muscle power and sensations in both lower limbs. They generally depend on wheelchair ambulation and, therefore, should be trained in transfer and self-care activities.

2. *Upper or high lumbar patients*: In this group, the muscle power is present in hip flexors and knee extensors. These patients can be made ambulatory by an AK orthosis with pelvic band.

3. *Lower lumbar patients*: Patients in this group can be made ambulatory with the help of a BK orthosis due to the presence of

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power in the following muscle groups: hip flexors and abductors; knee flexors and extensors and ankle dorsiflexors.

4. *Sacral level patients*: These patients have a high potential for ambulation due to the presence of power in the additional muscle groups such as hip extensors, plantar flexors and toe flexors.

Developmental disorders of the spine

Scoliosis

A lateral curvature of the spine is termed as scoliosis (Fig. 32-3). Basically, it is of the following two types:

1. Postural scoliosis (nonstructural)

2. Structural scoliosis

1. *Postural scoliosis*: This type of scoliosis has no structural (bony) changes in the vertebrae. The causes may be wrong postural habits, shortening of one leg, a disc lesion (sciatic scoliosis) or psychological factors.

2. *Structural scoliosis*. In this type of scoliosis, there is defect in the bone which results in contractures of the soft tissues on the concave side of the curve and reciprocal stretching on the convex side.

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FIG. 32-3 **(A)** Radiograph of the whole spine (AP and lateral views) showing dorsolumbar scoliosis. **(B)** AP view radiograph showing the normal spine for comparison.

Structural scoliosis can also be classified as follows:

1. Idiopathic scoliosis

2. Paralytic scoliosis

3. Congenital scoliosis

Idiopathic scoliosis

Infantile idiopathic scoliosis	Onset during the age of 3 years
Juvenile idiopathic scoliosis	The age of onset is between 3 and 10 years
Adolescent idiopathic scoliosis	The age of onset is between 10 and 20 years
Adult idiopathic scoliosis	The age of onset is over 20 years

Infantile idiopathic scoliosis: Usually there is spontaneous resolution of the curve. However, children for whom the curve progresses rapidly need early surgery.

Juvenile idiopathic scoliosis: Rapid progression of the curve occurs

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due to growing age. If bracing fails to control the deterioration, surgery may be indicated.

Adolescent idiopathic scoliosis: If detected earlier, acceptable correction is achieved by bracing.

Adult idiopathic scoliosis: In rare instances, scoliosis may develop as a result of disc degeneration. When the deterioration is rapidly progressive, surgery may be indicated.

Idiopathic scoliosis is more commonly seen in girls in the adolescent age group. Thoracic spine is involved often. Initially, there is slight curvature of the spine which may go unnoticed until asymmetry of the chest or shoulder develops. The evolution of the scoliosis is discussed in the following pages.

The curve may progress until skeletal maturity. If not treated, the curve may cause cosmetically unacceptable deformity, cardiorespiratory compromise and pain from degenerative changes in the spine later in life.

Paralytic scoliosis

Poliomyelitis, cerebral palsy or spina bifida may result in paralytic scoliosis. Greater degree of muscle imbalance and growing age complicate and rapidly deteriorate the scoliosis in these children. Surgery is indicated if there is rapid progression of the curve.

Congenital scoliosis

Congenital anomalies of the vertebra such as hemivertebra or block vertebrae (Fig. 32-4) cause congenital scoliosis.

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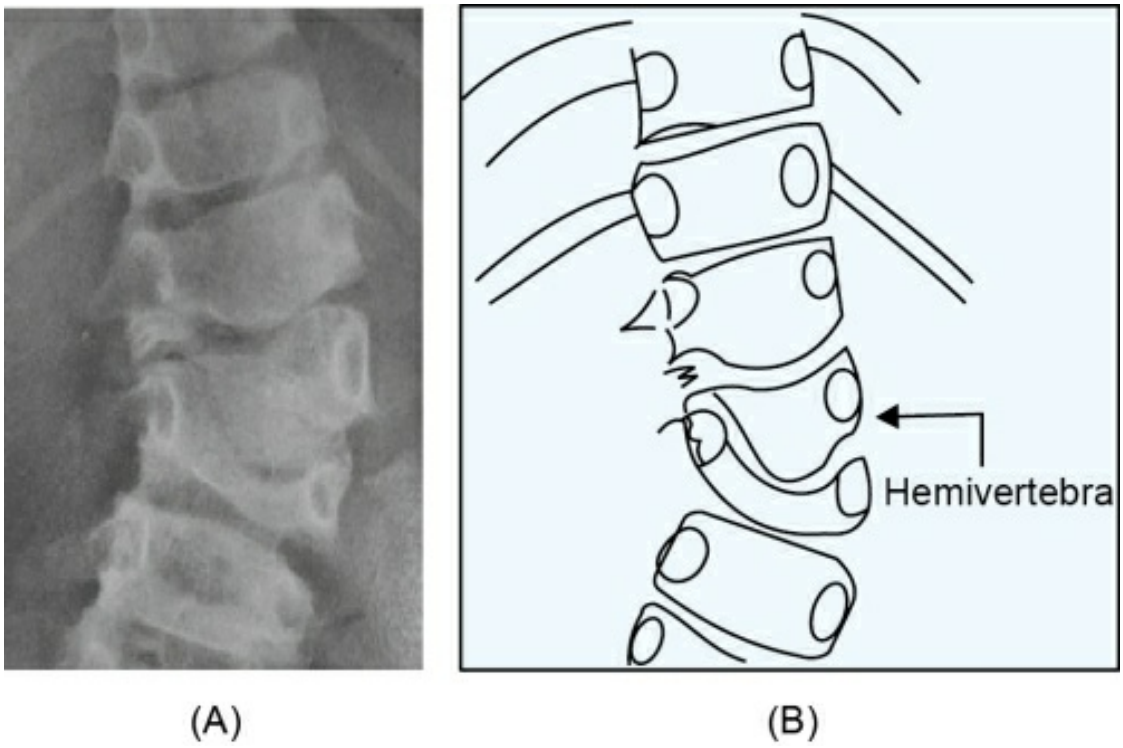

FIG. 32-4 **(A)** Radiograph of congenital scoliosis showing hemivertebra. **(B)** Congenital scoliosis. Note the hemivertebra (diagrammatic representation of the radiograph in Fig. 32-4A).

If severe, the curve may be detected at birth; in milder forms, it may appear at the time of the adolescent growth spurt. Its complications render the brace ineffective, and surgery may be required.

Scoliotic curves

1. *Compensatory curve due to primary curve*: In the presence of a primary curve, the erect body is put to tremendous gravitational forces on the convex side of the curve. To avoid this imbalanced strain and fatigue, compensatory secondary curve develops opposite to the primary curve (see Fig. 32-3).

2. *Compensatory curve due to deformities in other parts of the body*: Deformities of the neck, arm, trunk or leg may also give rise to compensatory curves. These may be due to postparalytic, congenital, rachitic or static causes. Unilateral organ diseases such as pleurisy,

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empyema or disc lesion may also give rise to scoliosis.

3. *Rotational element*: Structural scoliosis is accompanied by rotation of the vertebrae towards the convexity of the curve. However, the spinous processes are rotated away from the convexity (Fig. 32-5). The ribs are thrust backwards on the convex side. This element of rotation creates problems in the correction of the deformity.

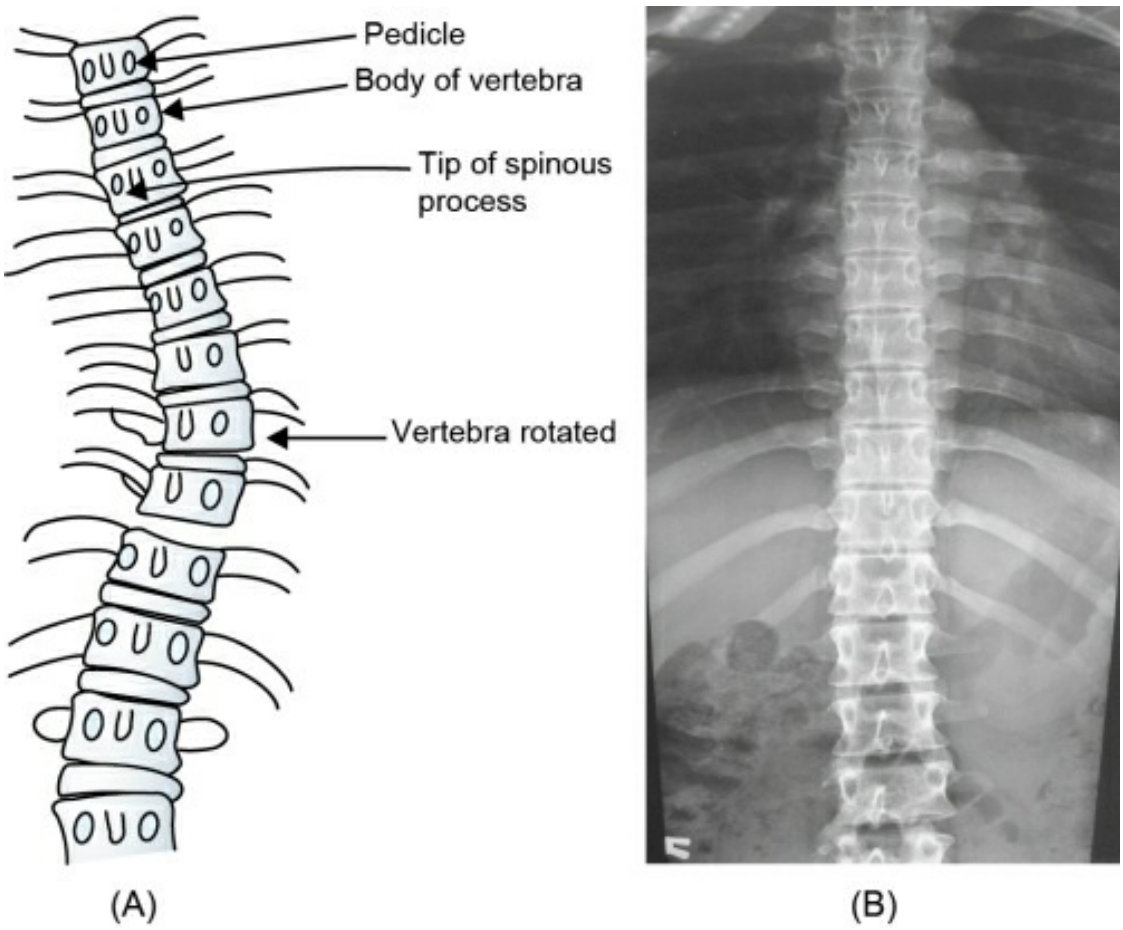

FIG. 32-5 **(A)** Thoracic scoliosis showing rotation of vertebrae. The vertebrae at the upper and lower ends of the curve have normal rotation – the tip of the spinous process is in the centre of the body of the vertebra and the pedicles are symmetrically placed. The vertebrae in the centre of the curve are rotated – the tip of the spinous process is eccentric and only one pedicle is seen. **(B)** Radiograph (AP view) showing the normal spine for comparison.

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Course and prognosis:

It depends upon the age of onset, time of detection, site of the primary curve and institution of treatment.

If the onset is at an early age, the curve tends to increase with age till the end of skeletal growth. The prognosis in such a case is poor, particularly in the thoracic curves. The thoracic curve also interferes with breathing efficiency. Thoracolumbar or lumbar curves compensate well, are far less noticeable and do not cause any functional deficiency.

In double curve, when the thoracic curve is primary, the situation is complicated further.

Treatment

Therapy plan

A complete evaluation is essential before planning the therapeutic programme.

Evaluation (fig. 32-6)

The evaluation is done by critical examination at various spinal levels. The patient stands with the bare back to the light. The examination is done by:

1. Inspection

2. Curve measurement

1. **Inspection**: The general outline of the spine is observed. The various anatomical levels are identified.

(a) *Level of the ears and contour of the neck*: Disparity in the level of ears or neck indicates the presence of a cervical curve.

(b) *Shoulder level*: Any disparity in the level indicates the

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presence of a cervico-dorsal or a high dorsal curve. The shoulder will be higher on the convex side of the curve.

(c) *Scapular level*: A shift in the level of the inferior angle and the vertebral border of the scapula away from the midline along with higher scapula and eversion of the inferior angle indicate a dorsal curve.

(d) *Position of the arms and the waist line*: The arm on the side of the high shoulder hangs close to the body and the waist line may be more on the opposite. The back appears wider on the convex side due to the bulging ribs.

(e) *Thorax*: The ribs appear to be crowded on the concave side, and further apart on the convex side. When the dorsal curve is more pronounced, there is rotation of the thorax (more apparent from the front). The ribs bulge backward on the convex side and appear flattened on the concave side.

(f) *Hips*: The hip and the posterior superior iliac spine are higher on the concave side.

(g) *Pelvis*: Forward rotation of the pelvis occurs on the concave side of the lumbar curve. Iliac crest will be prominent and higher on the concave side. Also, the gluteal fold on the side of the raised pelvis appears higher. The presence of coxa vara, fixed flexion and adduction deformities also need to be assessed.

(h) *Knees*: The alignment of the knee joints is checked. The shortening of leg should be measured. The levels of both

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patellae and their disposition are checked.

(i) *Feet*: Any deformity in the feet and toes is noted.

ROM assessment: All the spinal movements are evaluated.

Forward bending test: The patient in stride standing bends forward. In postural scoliosis, the curve is corrected with this test, but in structural scoliosis, the curve remains unaltered.

2. **Curve Measurement**: The scoliotic curves are termed by the apex of the curvature.

(i) *Cervical scoliosis*: The apex of the curve is between C1 and C6.

(ii) *Cervico-thoracic scoliosis*: The apex of the curve is at the cervico-thoracic junction.

(iii) *Thoracic scoliosis*: The apex of the curve is between thoracic 2 and thoracic 11 vertebrae.

(iv) *Thoracolumbar scoliosis*: The apex of the curve is at the thoracolumbar junction.

(v) *Lumbar scoliosis*: The apex of the curve is between lumbar 2 and lumbar 4 vertebrae.

(vi) *Lumbosacral scoliosis*: The apex of the curve is at the lumbosacral junction.

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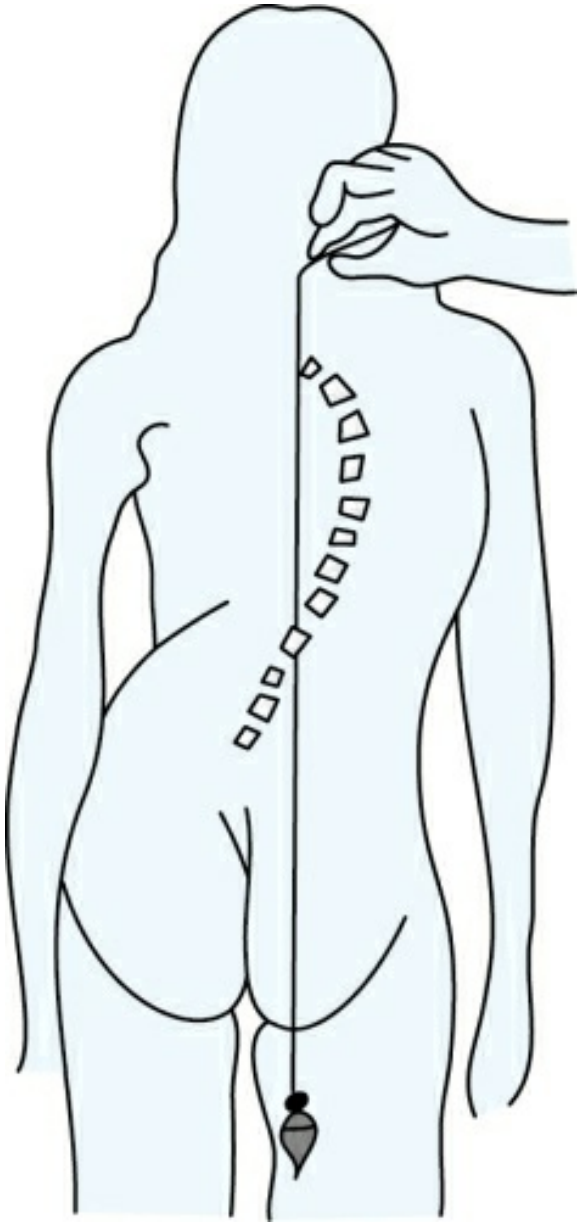

FIG. 32-6 Evaluation and inspection of various anatomic levels, plumb line to assess the trunk alignment.

The scoliotic curve is measured by Cobb's method.

Cobb's method: A posteroanterior radiograph of the spine is taken for measurements. The vertebra at either end of the curve which is tilting towards the concavity of the curve is taken as the end vertebra. A straight line is drawn which passes through the upper border of the upper end vertebra; and another that passes through the lower border of the lower end vertebra. The angle formed by the lines

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perpendicular to these lines represents the angle of scoliosis (Fig. 32-7). A curve measuring 60 degrees or more with respiratory insufficiency is an absolute indication for surgery.

Respiratory status: In scoliosis of the thoracic spine, the vital capacity and chest expansion are reduced. These should be measured and recorded. The exercise tolerance of the patient is also evaluated.

Rib hump: At the thoracic curve, the rib hump is measured with a gauge. The depth of the valley is measured in the low thoracic or lumbar curve either in forward flexion or in prone position by a scoliometer (Fig. 32-8A). The outline of the hump can be traced and transferred to a graph paper. Distortion also occurs in the ribs and vertebrae in the thoracic curve (Fig. 32-8B).

The physiotherapist marks the following bony points with a skin marker: The spinous processes, the inferior angles of scapulae, the posterior iliac spines and the anterior superior iliac spines. The spinous processes are marked again after achieving maximum correction of the curve with postural manoeuvres. Taking photographs in the corrected position as well as in the position of maximum curves is helpful in providing the exact therapeutic programme to a patient and also in assessing the results.

Test for function: Range of movement is tested and recorded for flexion, extension, lateral flexion as well as rotation (the method is the same as described under low back pain).

Test for pain: The whole spine is palpated with finger tips over the spinous processes from occiput to the sacrum.

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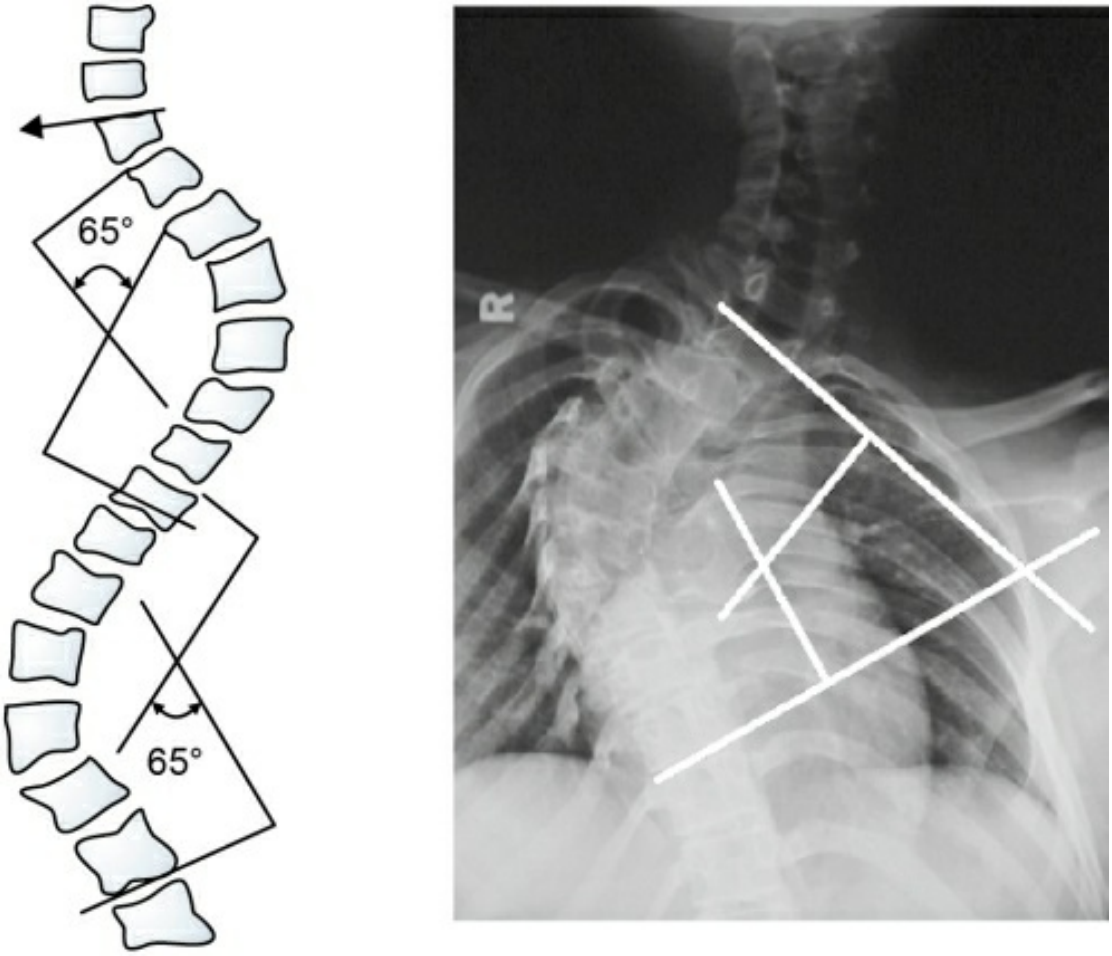
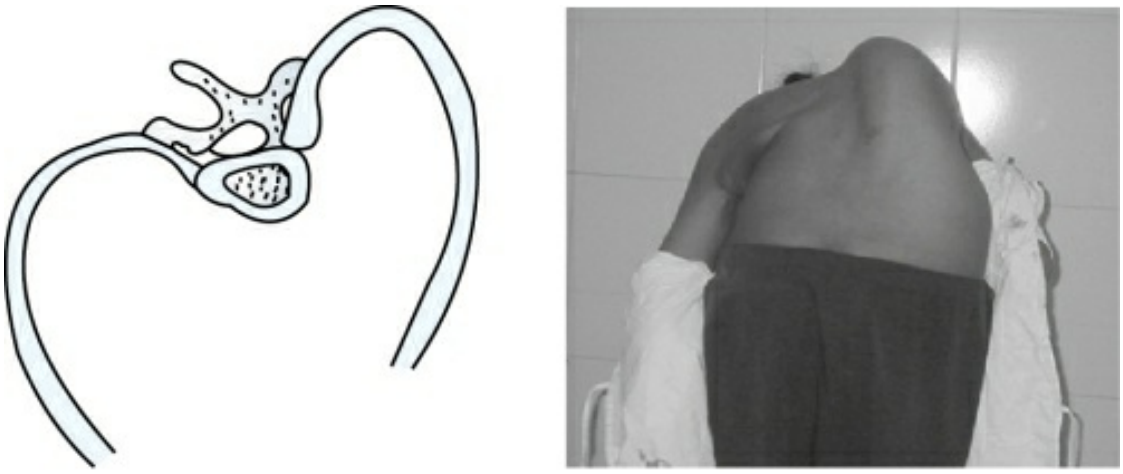


FIG. 32-7 Measurement of the scoliotic curves by Cobb's method.



(A) (B)

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FIG. 32-8 **(A)** Rib hump deformity in the patient, as seen from behind. **(B)** Rotation of the vertebra and distortion of the rib cage.

Tenderness or pain indicates the presence of some inflammatory lesion.

Patient in stable standing: If this test is positive, further investigations are conducted to ascertain the exact pathology.

In the presence of an inflammatory lesion, active physiotherapy would be strictly contraindicated.

Monitoring curve progression: Scoliosis in growing children or adolescents needs to be monitored till the cessation of spinal growth. This coincides with the cessation of growth in the iliac apophysis, known as Risser's sign. The apophysis appears at the anterior end of the iliac crest and gradually progresses posteriorly (Fig. 32-9). As seen in the radiographs, fusion of the iliac apophysis to the medial end denotes completion of the growth of the spine. All these measurements are repeated at regular intervals to assess the progress.

Treatment: The prevention or control of the curve in the early phase assumes priority.

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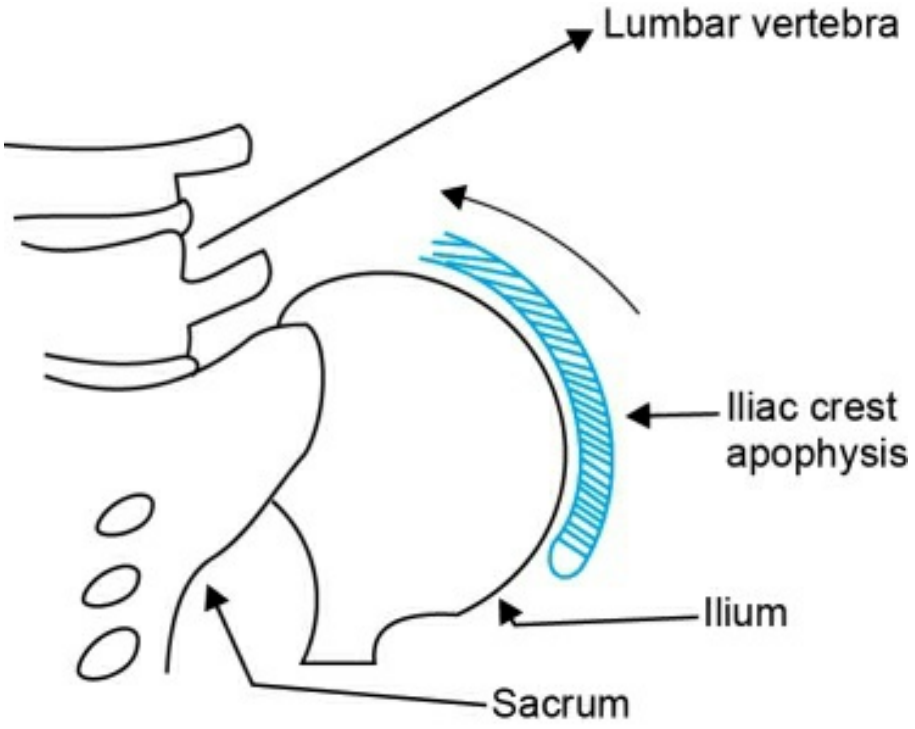

FIG. 32-9 Iliac crest apophysis starts ossifying anteriorly and progresses posteromedially (as shown by arrow).

Preventive role

1. Ideally, a screening programme of all children in the age group of 10–14 years is necessary. This age group has been proved to be the most vulnerable one.

2. Parents can also play an important role in the early detection of a scoliotic curve. Therefore, education of the parents on simple observational techniques may be helpful.

Conservative treatment is indicated in growing children with a curve of less than 40 degrees.

Mild postural curves

(Curve less than 40 degrees)

1. **Active correction**: As these curves are correctable, the physiotherapist identifies the postural adaptations by asking the

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patient to move and place the legs or trunk in such a position that optimal self-correction of the curve is attained. Once the correction is achieved, its maintenance becomes the basis of therapy.

2. **Passive correction**: Hanging provides the best method of passive correction; unequal hanging or hanging with one arm. Hanging in the head suspension apparatus always gives satisfactory results. If hanging is not feasible, sufficient amount of axial traction can be given by two therapists. One physiotherapist grasps the pelvis and gives traction towards the legs while the other grasps the chin and the occiput and stretches the spine in the opposite direction in the forward lying position.

3. **Maintenance of correction**: The most important aspect in postural curves is to educate the patient to maintain the correction by active efforts.

Management of postural scoliosis (grade I)

The correction of the deformity is obtained by progressive re-education of the bad posture.

The regimen includes the following:

1. General body relaxation by using the whole body relaxation technique.

2. The patient is trained to feel and hold the corrected posture. However, this may not be always possible.

3. The postures should be corrected passively by the physiotherapist.

4. Repeated sessions of maintenance of the corrected posture till correction becomes automatic.

5. General free mobility exercises to the whole spine and strengthening exercises to the spinal extensors and abdominals.

6. Deep breathing should be incorporated.

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7. Balance exercises, e.g., walking with a book on the head in a corrected posture is valuable.

8. Stretching of the tight soft tissues and their sustenance forms the most important aspect of therapy. Correction of the contractures and shortening of the soft tissues on the concave side of the curve can be achieved by guiding the correct posture in lying. This substantially helps the other methods of active postural correction.

9. After good correction, the patient should be advised to continue with exercises, avoiding especially the positions and the activities prone to produce the existing deformity.

10. The patient must report regularly for screening.

Management of structural scoliosis (grade II)

Structural curves of less than 40 degrees are treated conservatively. If it is almost impossible to achieve correction, active self-correction as well as maintenance of a brace (orthosis) is indicated to prevent deterioration of the curve. The brace also helps in gaining some correction while allowing the continued growth of the spine during adolescence. The braces for spine for use in scoliosis are named as follows:

(i) TLSO: Thoracolumbosacral orthosis

(ii) CTLSO: Cervico-thoraco-lumbosacral orthosis

(iii) CTO: Cervico-thoracic orthosis

The most commonly used orthosis is the Milwaukee brace (CTLSO) (Fig. 32-10). It has a contoured girdle which covers the pelvis firmly. It has an occipital pad and a chin pad. A lateral pad is placed over the rib hump. This orthosis immobilizes the spine and maintains a stretching effect. The Boston brace is another orthosis used for scoliosis below T8 level. Some other orthoses are the Wilmington TLSO and the Charleston bending brace.

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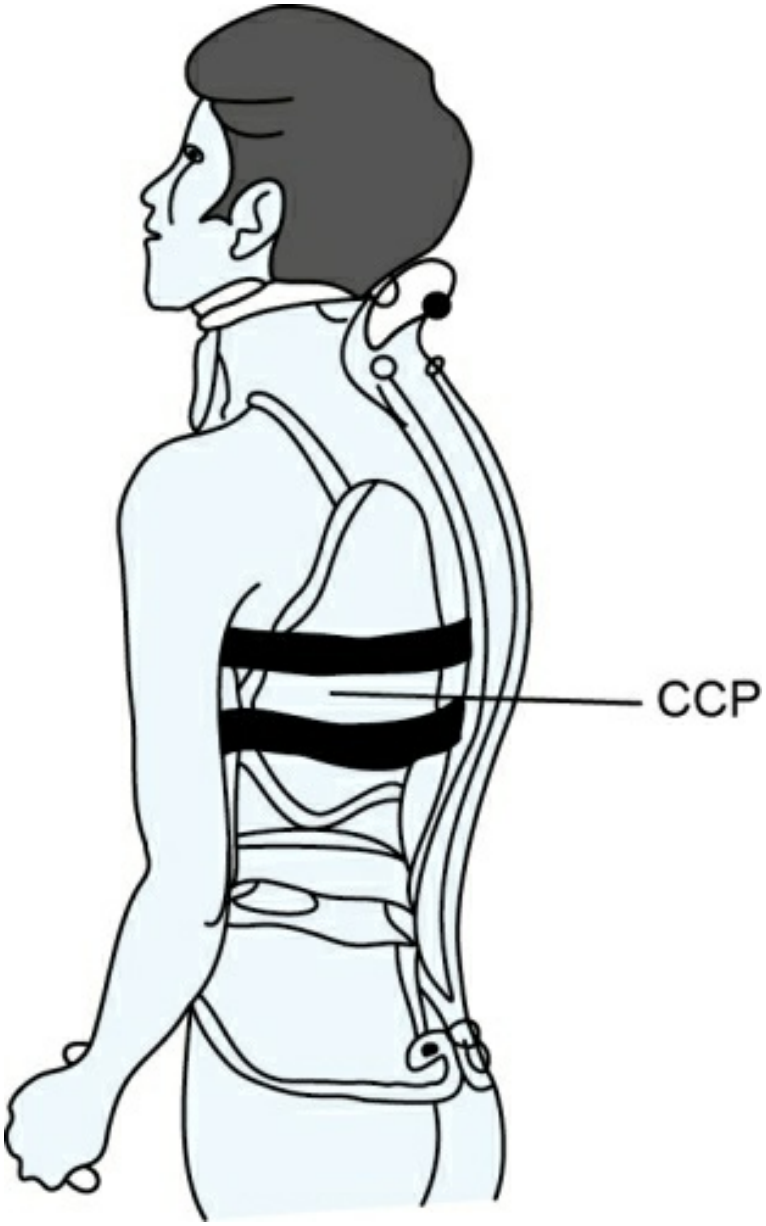

FIG. 32-10 Milwaukee brace. CCP, curve correcting pad.

The correction achieved in the orthosis is maintained by active exercises. The exercise programme is the same as for postural scoliosis.

1. Mobility exercises are more important as the spine remains immobilized in brace.

2. Deep breathing exercises are also important as the excursion of ribs

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is limited due to the brace.

3. Lumbar lordosis is usually associated with these curves; therefore, exercises to reduce and correct the anterior pelvic tilt are important.

4. Correction of a major curve is also achieved by putting a pad over the rib hump in the brace on the convex side of the curve (Fig. 32-10).

5. Repeated stretching sessions for hip flexors and hamstrings are important, as these have a tendency to shorten because of the pelvic tilt.

6. Hanging in head suspension apparatus or on stall bars can provide effective stretch to the whole spine.

The whole programme and the brace need to be continued uninterrupted during the day and night. The brace also needs repeated adjustments and is continued until the child attains skeletal maturity. It can be weaned off gradually thereafter. Miyasaki (1980) reported the efficacy of thoracic flexion exercises in the Milwaukee brace in reducing apical vertebral rotation and the thoracic curve. It is, therefore, necessary to teach this exercise with the brace on.

Severe structural curves (grade III)

Curves greater than 40 degrees need surgical intervention. In these patients, preoperative evaluation and training are essential.

Preoperative physiotherapeutic assessment and training

1. The parameters relevant in the immediate postoperative management should be repeated.

2. Measurement of the rib hump is done in prone.

3. Assessment of pulmonary function: It is necessary to check the overall efficiency of breathing. If necessary, it may be taught again along with the technique of intermittent positive pressure (IPP), which

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may be needed in some cases.

4. Muscle charting of the body and limbs should be done, especially below the level of fusion.

5. Detailed neurological examination is necessary to detect any compressive symptoms of the spinal cord. These may be present due to ischaemia following excessive stretching.

6. Vigorous and strong ankle and toe movements with isometrics should be taught to the gluteal and quadriceps muscles.

7. Gait analysis and functional status should be assessed, and requirements of normal gait explained.

8. Postural guidance: Guidance is given to learn the techniques of correction of the posture and its maintenance in front of a postural mirror. Correct technique of even weight bearing on the pelvis and lower limbs needs to be understood.

9. Spinal stretching and mobility: Stretching the whole spine to the maximum, maintenance of the stretch as well as techniques of improving the overall intervertebral mobility are important. This stretches the contracted soft tissues in preparation for the surgery of fixation of spine in corrected position.

Various forms of traction

1. Skeletal traction may be applied in the following forms:

(a) Halofemoral traction

(b) Halopelvic traction (see Fig. 4.9)

(c) Halo wheelchair traction

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2. Nonskeletal methods of traction can be:

(a) Intermittent traction followed by sustained traction

(b) Cotrel traction

(c) Gravitational traction

(a) Intermittent traction, followed by sustained static traction as applied commonly in LBP patients. It offers relaxation, which, in turn, promotes stretching of the spinal structures. The stretching is to be maintained by static traction.

(b) Cotrel traction (Fig. 32-11): This has double effect as it is a combination of sustained traction which is superimposed on intermittent traction and is operated by the patient himself. A constant traction of 2-kg weight is attached to the cervical halter at the head end of the bed. Intermittent traction is applied by the pulley system in such a manner that the extension of arms and legs provides extra force for spinal distraction.

(c) Gravitational traction: The patient lies supine on the tilted table with feet away from the foot plate. A corset is firmly secured in this position so that the body weight and the gravitational force provide graded traction to the spine as the angle of the tilt-table is altered from 30 degrees and 60 degrees to 90 degrees (Fig. 32-12). Initial traction time of 12 min may be increased to 1 h.

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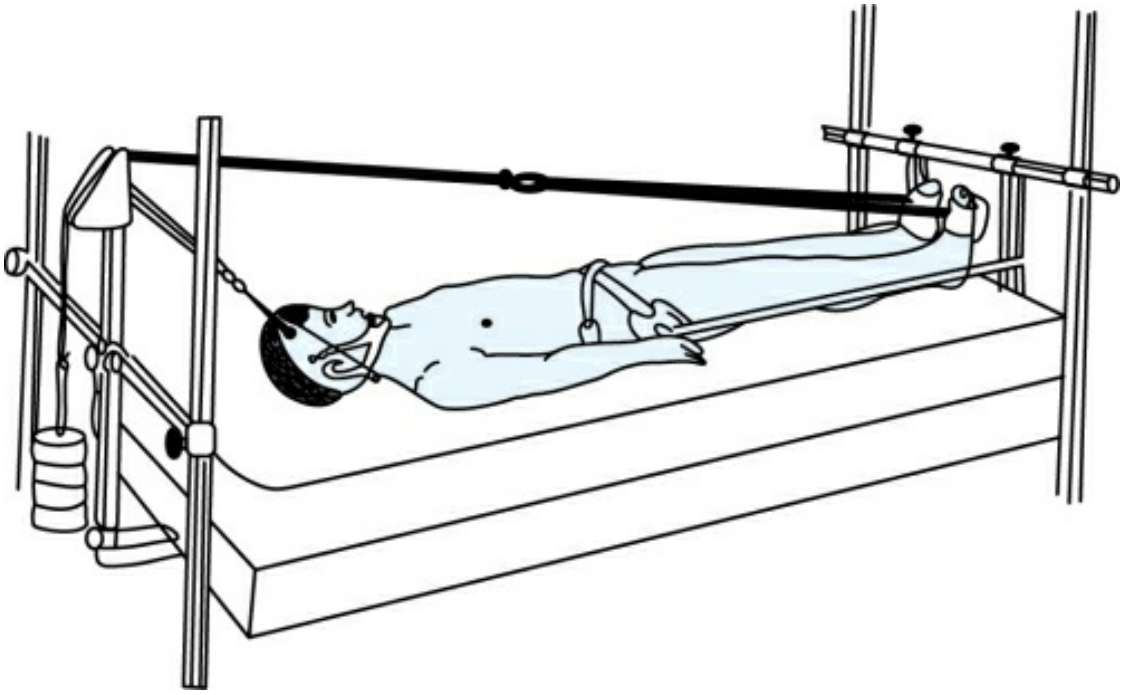

FIG. 32-11 Cotrel traction in extended position.

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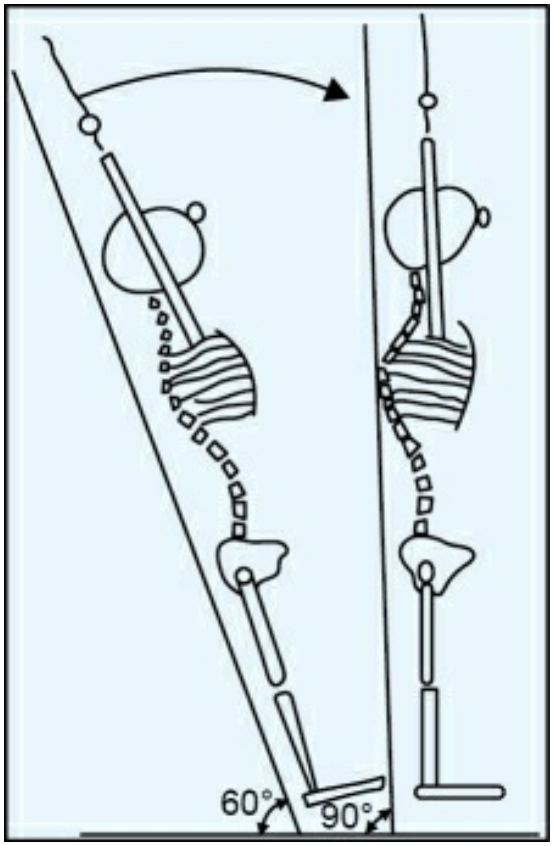

FIG. 32-12 Gravitational traction. As the angle is increased in graduated steps of 30 and 60 to 90 degrees, the traction force increases.

This method has been found to be twice as effective as the Cotrel traction.

Caution

This method is contraindicated in arterial hypertension, congenital spinal malformations, in the presence of any neurological disease and in the flaccidity of the ligaments of the cervical spine.

The patient should be warned about the temporary increase in pain following surgery.

Surgical treatment

Indications for surgery: Surgery is indicated in the following circumstances:

1. *Cord compression*: It is commonly seen in kyphotic deformities. Decompression of the cord is done and is usually followed by

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correction of the deformity with fusion of the spine.

2. *Rapid progression of the curve*: This is caused by the adolescent growth spurt or due to disc degeneration in older patients.

3. *Pain*: Correction of deformity only after thoroughly investigating the anatomical source of pain.

4. *Respiratory impairment*: Patients with severe paralytic deformities involving thoracic spine may develop respiratory insufficiency. Surgical correction and spinal fusion become necessary in these patients.

5. *Cosmetic*: Thoracic scoliosis with severe hump due to vertebral rotation is occasionally treated surgically for cosmetic reasons.

The basic principles of surgical treatment in scoliosis are as follows:

- Correction of the curve, if possible.
- Maintenance of the correction achieved by spinal instrumentation and/or spinal fusion.

The aims of treatment in scoliosis are as follows:

- To restore the symmetry of the trunk as much as possible by correction of the curve.
- To straighten the thoracic curves to stop the deterioration in the pulmonary functions.

Correction of the curve: The scoliotic curve is corrected as much as possible before surgery. In congenital scoliosis and in rigid scoliosis of neurofibromatosis, no attempt is made to correct the curve, lest the patient may develop neurological symptoms. Early fusion of the spine checks the progression of the deformity. Any of the following methods are employed to achieve maximal correction of the curve.

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1. *Corrective cast*: The patient is made to sit on a stool and an attempt is made to correct the scoliotic curve using a head halter. A plaster of Paris (POP) cast is then applied over the trunk with the scoliotic curve in the corrected position. A few days later, a window is made in the cast over the spine, through which the surgery of spinal fusion is performed. Since the cast maintains the correction of the curve, there is no need for any spinal instrumentation. The cast is maintained postoperatively for about 6 months till the fusion consolidates. This technique is generally employed in children.

2. *Distraction techniques*: Certain distraction techniques, such as halofemoral distraction and halopelvic distraction, are employed to correct the deformity of the spine. The spinal deformity is corrected by gradual distraction, and subsequently surgery is performed with the distraction apparatus in situ.

3. *Loosening of the curve*: In rigid scoliotic curves, the operation of loosening of the curve is performed as a first stage procedure. In this operation the intervertebral discs of the affected vertebrae are removed so that the spine gets loosened. Now a distraction technique (such as halopelvic traction) is used to achieve straightening of the spine (as much as possible). Spinal fusion with instrumentation is subsequently performed after about 4–6 weeks as a second stage procedure. These days, alternatively, two procedures of loosening of the curve and spinal fusion with instrumentation are performed in one single operation. This, of course, is a major surgical undertaking and requires the use of spinal monitoring during surgery to avoid traction injury to the spinal cord.

Maintenance of the correction achieved: This is achieved by fusion of the spine along with some sort of internal fixation of the spine (spinal instrumentation). The only exception to instrumentation being the cases where a POP cast has been applied preoperatively, as described earlier.

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1. *Spinal fusion*: Fusion of the spine is performed through a posterior approach. The area of deformity in the spine is fused along with at least two vertebrae proximally and two distally. After spinal fusion, a plaster jacket is applied, which is maintained for about 6 months till the fusion consolidates.

2. *Spinal instrumentation*: As described earlier, the scoliotic curve is corrected first, then the spine is fused and stabilized with any of the following instrumentations:

(a) *Harrington instrumentation*: It consists of a Harrington rod and two hooks. After fusion, each hook is fixed into the posterior elements of the vertebra at either end of the curve; the rod is then threaded through these hooks. Moderate distraction is applied to achieve maximum possible correction of the curve. The Harrington instrumentation now maintains the correction achieved (Fig. 32-13). Postoperatively, a plaster jacket or a brace is given for about 4–6 months. However, Harrington instrumentation is now being replaced by newer methods of segmental instrumentation, which also obtain better correction in terms of rotation of the vertebrae.

(b) *Segmental spinal (Luque) instrumentation*: In this operation, multiple wires are passed beneath the laminae of the vertebrae in the curve on either side of each spinous process. The wires are then twisted around two rods placed on the other side of the spinous processes and tied (Fig. 32-14). This instrumentation not only corrects the curve but also enhances the arthrodesis. The fixation is usually rigid and does not require external

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immobilization.

However, the passing of wires beneath the laminae makes it a technically difficult operation and more prone to neurological complications postoperatively.

The use of Harrington and segmental spinal (Luque) instrumentation has almost become obsolete and are replaced by newer instrumentations as discussed in the following pages.

(c) *Spinal instrumentation*: Many internal fixation devices are available to choose from which involve the use of pedicular screws and rigid rods (Fig. 32-15). This type of instrumentation obtains better correction of lateral angulation as well as the rotation of the vertebrae. It is a major surgical undertaking and is not without serious complications, including paraplegia.

Video-assisted thoracoscopic surgery (VATS): Endoscopic thoracic surgery is also employed in the spinal deformity correction and anterior instrumentation. With this technique, the postoperative morbidity is much less but there is certainly a steep learning curve.

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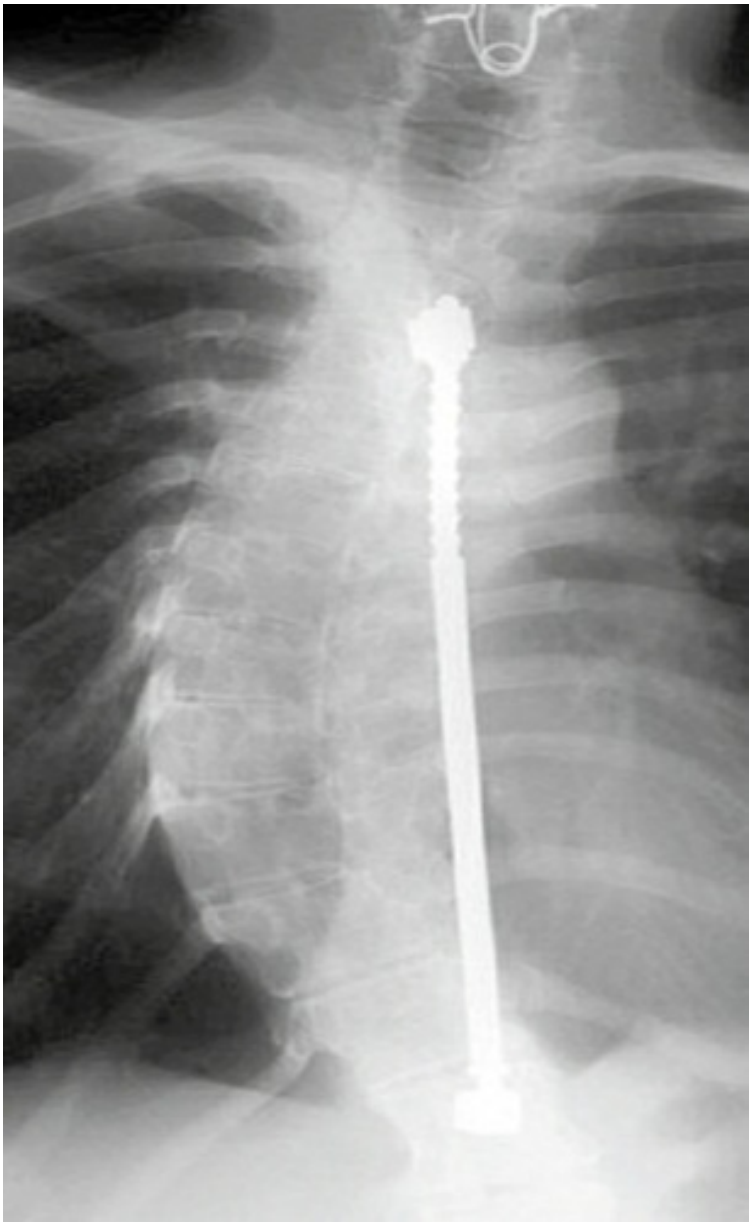

FIG. 32-13 Harrington rod instrumentation to maintain correction of scoliosis.

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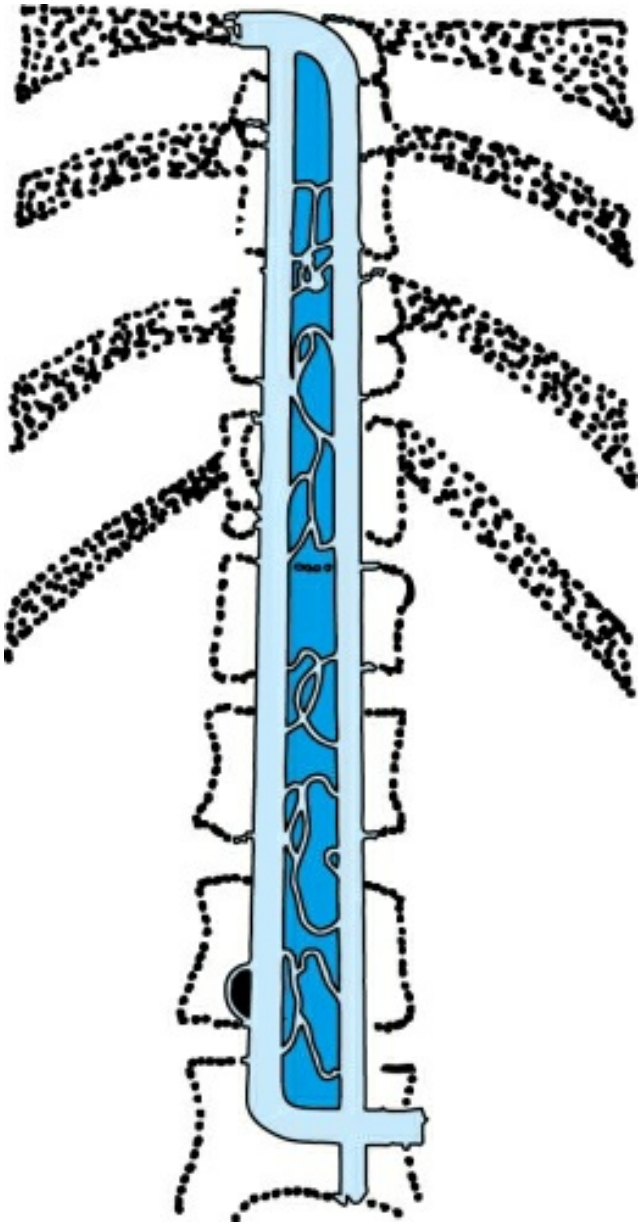

FIG. 32-14 Luque's segmental instrumentation.

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(A)

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(B)

FIG. 32-15 **(A and B)** Surgical treatment of the case shown in Figure 32-3A. Correction of the curve and spinal instrumentation are seen.

Postoperative physiotherapeutic management

The regimen of physiotherapy remains unaltered. Minor alterations may be necessary in relation to the surgical procedure performed.

The basic approach during the postoperative phase is as follows:

First two days

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1. Respiratory status: In patients with the anterior approach of surgery, this assumes primary importance. Besides, deep breathing and vibrations with assisted coughing need emphasis.

2. Strong sustained as well as speedy ankle and toe movements and active upper extremity movements are initiated to the maximum painless range.

3. Slow relaxed passive movements to the lower limbs assist in relieving pain and stiffness and improve circulation.

4. Neurological symptoms need careful assessment and treatment, if necessary.

5. Patients are turned to the sides alternating with prone lying every 2 h.

Third and fourth day: Increased full range passive and active movements to the hip and knee joints alternated with relaxed passive movement may provide pain relief.

The rib hump should be measured at this stage to ascertain the change.

After 5 days

1. *Assisted guidance*: Guidance in rolling, sitting and standing can be initiated with assistance, e.g., sitting up, getting down the bed by standing up and going to the bed from the reverse position, e.g., in prone position but sitting up, getting down. Reverse climb down technique without putting extra strain on the spine is initiated.

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Getting out of bed is taught by rolling to prone position, coming to kneeling position in prone and getting down by slowly sliding down from the foot end of the bed. The same technique is applied for getting into bed, climbing up is done by a forward approach.

2. *Sitting*: The standing is initiated from supine position, hanging legs and raising torso with arms support.

3. *Chair sitting*: Initially, lumbar roll may be provided in sitting. Progress to chair sitting without back rest with correct guidance. This will help the patient to learn to support the spine actively (McKenzie, 1981).

4. *Standing and walking*: Functional (assisted) standing to be initiated in supine position, hanging the legs at the side end of the bed and lifting the trunk (torso) with hand support. To begin with, assistance is needed in standing balance as the balance may be impaired because of fixation or impairment of proprioception. This leads to imbalance and postural deficiency, as the postural balance is regulated by the receptor system in the connective tissues and the muscles around the upper vertebral synovial joints. Gradual sitting should be started with a back rest. It should be progressed to unsupported sitting and standing as the proprioception returns.

5. *Walking*: As soon as balance in standing is acceptable, walking is initiated with correct gait pattern and progressed to achieve physical independence.

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The patient should be made to walk in parallel bars with the height of the hand rail raised and adjusted to avoid forward flexion of the spine as forward stooping puts maximum stress on the lumbar spine.

The patient should be made ambulatory at the earliest, and initially may need axillary crutches.

Caution

In the presence of unsteadiness, a spinal jacket may be necessary in thoracolumbar fusion. Exercise may occasionally cause excessive strain and pain. Therefore, the exercise programme should have periods of enough rest in-between.

Physiotherapeutic management for other surgical procedures of the spine remains the same as described earlier. However, the specific points to be remembered under each heading can be summarized as follows:

1. *In one Level one anterior fusion*: By 2 weeks, after suture removal, if the spine is stable with good muscle control, a corset is given, or else a POP jacket is applied for 3 months and then changed to a corset.

Exercises for the back are not advised, except the isometrics. Exercises are to begin only 3 months after surgery as simple movements to the spine. Swimming is an ideal mode of exercise to achieve mobility of the spine.

2. *Level two anterior spinal fusion*: The period of POP jacket is 3–6 months. Hip spica is necessary for patients with L5–S1 fusion. This needs suitable modifications in the programme of ambulation. Otherwise the management proceeds on the lines of general regimen.

3. *Posterior fusion with the Harrington instrumentation*: Rolling is taught as a one-piece rolling (log rolling) to avoid trunk rotation. POP jacket is to be worn for 6 months. Activities of daily living (ADLs) and work training are to be taught with the jacket on.

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4. *In combined anterior and posterior fusion with Harrington rod*: Turning in bed is used to facilitate safe rolling. This is progressed to tilt-table activity. The patient is given a single above-knee hip spica, POP jacket or a corset. By 4 weeks, specific aids may be given for dressing and other ADLs, including correct walking aid and ambulatory techniques.

5. *In anterior and posterior fusion 2 weeks apart*: There is excessive muscular weakness because of repeated surgery. Hydrotherapy is ideal. The combined procedure gives better and quicker results as regards pain and mobility.

6. *In laminectomy/discectomy*: If laminectomy is done for spinal stenosis, only isometrics are taught to the patient. A corset may be applied at the time of discharge.

If nerve root decompression with partial laminectomy is performed, 2 weeks bed rest is followed by corset.

Caution

Following any surgical procedure to the spine, excessive strain of lifting and bending is to be avoided. This should be taught on ergonomic principles, as detailed for LBP patients.

Postsurgical complications: The common complications are as follows:

1. Deep vein thrombosis

2. Pulmonary embolism

3. Paralytic ileus

4. Associated stiffness of spine, neck or shoulder

5. Wound infection

6. Neuralgia

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7. Graft site pain

8. Plaster sores

Physiotherapy plays an important role in the prevention as well as management of all these complications.

Kyphosis

Kyphosis or round back is the exaggeration of the posterior spinal curve and is generally localized to the dorsal spine (Fig. 32-16). The back is rounded, the head is carried forward and the chest is flattened. This results in typical round shoulders with excessive protrusion of the scapulae.

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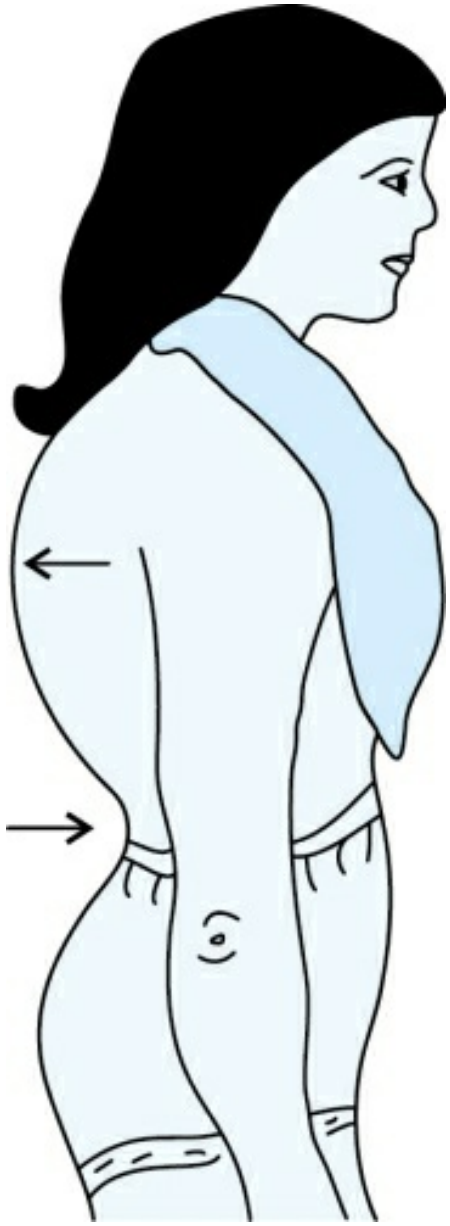

FIG. 32-16 Adolescent exaggerated thoracic kyphosis with compensatory lumbar lordosis.

Habitual bad posture at school is the common cause. It could develop as a result of undetected defects of vision or hearing. Mental or physical fatigue could also precipitate such habitual postural tendencies.

In the adolescent age, this deformity may occur as a result of arthritis, rheumatism, lung affections (e.g., emphysema) and vertebral diseases besides habitual bad sitting postures.

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In old age, it may be the result of previous bad posture, muscular weakness, osteoporosis and degenerative diseases of the spine.

The deformity may be divided into three degrees according to its severity:

1. First degree

2. Second degree

3. Third degree

Progress of the deformity from first to third degree: A bad habitual posture is the precipitating factor. Initially (first degree), if not corrected at this stage, it progresses to the second degree.

(a) The pectoral muscles become short, thereby restricting the chest expansion.

(b) Longitudinal back muscles, rhomboids and the middle trapezius are unduly stretched and weakened with loss of tone.

(c) Posterior ligaments are lengthened with corresponding shortening of the anterior structures. This gives rise to increased posterior laxity and a typical kyphotic deformity.

(d) During the adolescent stage of the growth period, wedging of the vertebral bodies may occur.

Kyphosis can also occur due to tuberculosis, ankylosing spondylitis, Scheuermann's disease or congenital anomalies. Total assessment of the kyphotic deformity is to be done on the same lines as described for scoliosis.

Treatment

Physiotherapeutic management

As in scoliosis, early detection by screening forms an important part of

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its prevention. Other methods as described under scoliosis should be adopted. Physiotherapeutic management basically depends upon the stage of the condition and its ill effects.

First degree kyphosis: It is postural and should be detected early.

1. Relaxation of the body, especially the upper back.

2. Repeated stretching sessions of shortened anterior structures by bracing the shoulders.

3. Maintaining posture of the head, neck and shoulder during activity or rest in optimal position should be trained and checked.

4. Mobilization of the whole spine, particularly neck, scapulae and shoulders.

5. Diaphragmatic and costal breathing with emphasis on inspiration.

6. When precise mobility is attained, specific isometric and resistive exercises can be added.

7. Efficiency of home management programme is vital for good results. Therefore, it needs to be emphasized and checked regularly.

8. The efficiency of home management in the form of watchful monitoring and correction is important.

Second and third degree kyphosis: As wrong adaptation of the soft tissues is in the advanced stage, its active correction and maintenance are difficult. The Milwaukee brace is prescribed with

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pads applied on the posterior uprights.

Exercises: With the brace on, the patient is encouraged to apply maximum pressure over these posterior pads. It stretches the shoulders, shoulder girdles and the kyphotic curve. Sustenance of this active stretching is very important.

It is difficult to achieve enough correction but it certainly helps in preventing further deterioration of the curve.

Exercises to improve mobility and respiration reduce the overall impact of the deformity.

Surgery and postsurgical management

When surgery is undertaken, it involves gradual controlled halo traction for several weeks. Bone graft may be necessary to maintain the correction achieved through traction. In severe kyphotic curves, congenital or due to tuberculous lesions, spinal cord decompression and spinal stabilization may be necessary through anterior approach.

Besides gradual progression of the corrective mobilization and strengthening, special emphasis should be on prevention of postsurgical complications, especially the respiratory ones.

In the second stage of surgery, the spine is fused in the corrected position, and the regimen of physiotherapy is the same as described under spinal fusion.

Lordosis

Lordosis is the exaggeration of the anterior curve of the spine. Common sites of the lordosis are cervical and lumbar spine. The causes are (a) hip flexion contracture due to disorders of the hip, e.g., congenital; (b) positional or habitual tightness of hip flexors due to paralysis of abdominals or the flexors of lumbar spine; (c) it could be adaptive when it is developed to compensate for altered balance, e.g., pseudo-hypertrophic muscular dystrophy, ankylosing spondylitis, fixed flexion deformities at the hip or the knee; (d) congenital or

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acquired spinal deformities such as spondylolisthesis; (e) it could be due to habitual posture; and (f) obesity with protruding abdomen.

The forward tilting of pelvis produces compensatory exaggerated lumbar lordosis. This leads to stretching of the abdominal muscles and the anterior spinal ligaments. There is reciprocal shortening of the posterior ligaments and muscles. It may be associated with weakness of the glutei and lengthening of the hamstrings.

Treatment

It is mainly directed towards the following:

1. Mobilization of the lumbar spine.

2. Anterior stretching of the lumbar spine by concentrating on exercises to achieve posterior tilt of the pelvis.

3. Strengthening of the abdominals, glutei and hamstrings.

4. Training in graded correction of the pelvic tilt has to be emphasized. Active posterior pelvic tilting by contracting abdominals and glutei in supine position is initiated. It is progressed to sitting and standing. Maintenance of the corrected posture is vital. 'Make yourself as tall as you can' or toe touching in long sitting or forward bending sitting are simple procedures. To be effective, these should be repeated often.

Caution

Attitudes involving spinal extension or hyperextension should be strictly avoided.

Kypholordosis

This is a combination of the preceding two conditions, lordosis usually being the primary curve. Therefore, early detection and measures to treat primary lordosis can successfully prevent the occurrence of compensatory kyphosis.

Treatment

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The management on the whole remains the same. The only care one has to take is to restrict and localize the exercise to the exact segment, e.g., the thoracic spine must remain extended while exercising the abdominal muscles. The flexion of the lumbar spine should not produce flexion of the thoracic spine as well. Appropriate corrective braces should be applied, if required. The whole approach should be individualized.

As the corrective methods take longer time, emphasis on regular checkups and thorough evaluation is to be observed strictly.

Efficacy of the home exercise programme is of vital importance.

Flat back

This is a spinal deformity which is reverse of lumbar lordosis. The pelvis is tilted backwards with associated shortening of the hamstrings. There is flattening of the normal lumbar lordosis.

The aim of treatment here is to increase the lumbar lordosis, which results in forward tilting of the pelvis.

Maintenance of the arch by active holding and also passive support in sitting are effective in maintaining lordosis.

Mobility and strengthening exercises are important.

Caution

While treating spinal deformities, certain precautions should be observed, such as the following:

1. The holding or maintenance of the corrected position should not be continued beyond the point of muscle fatigue.

2. The patient should be taught to localize the corrective exercises. Careful monitoring of the effects of exercise on the deformity is necessary.

3. Necessary compensations or appropriate braces are necessary to square the pelvis.

4. Breathing capacity needs careful monitoring in the thoracic curves.

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Cervical syndrome

Pain in the neck and its associated complications is a regular feature to any orthopaedic clinic. The major contributory factor is bad postural habits.

Other causes

1. *Ischaemia*: The origin of ischaemia is in the soft tissues. Increase in the intramuscular pressure constricts the blood vessels, stops the internal circulation thereby causing stagnation of waste products which results in ischaemic pain.

2. *Inflammation*: Acute inflammation occurs in the superficial layers of the posterior longitudinal ligament and capsules of the apophyseal and interbody joints. It subsequently leads to chronic hyperplasia, resulting in narrowing of the intervertebral canals.

3. *Haemorrhage*: Acute traumatic bleeding can also lead to narrowing and compression of the nerve roots.

4. *Ligamentous and capsular instability*: After injury, the process of repair is extremely slow due to precarious blood supply to the ligaments. The repair may occur by the formation of scar tissue, with reduced tensile and elastic properties, resulting in stiffness.

5. *Disc lesions*: The incidence of cervical disc extrusion is less common due to the presence of lateral interbody joints.

6. *Degenerative changes*: These are common in the areas of maximum stress (C4–C6). This leads to joint pain and limitation of movements. However, thickening and fibrosis of the ligamentous and capsular structures further narrows the intervertebral canal, thereby precipitating the symptoms. Occasionally, osteophytes may be formed at these sites.

7. *Repeated muscular strains*: Certain muscle groups are exposed to

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repeated strain by performing one particular movement more often than the other. Sudden or jerky movement may also result in this type of strain.

8. *Bad postural habits*: Sustained, bad occupational posture or habitual wrong posture of the neck in relation to the thoracic spine and shoulder joints results in stretching of the soft tissues on one side and elongation or lengthening of the ones on the opposite side. This can cause irritation and strain of ligaments, muscles or joints, precipitating cervical pain.

Characteristics of pain

Pain originating from the ligamentous or muscular lesion can either be localized or radiating. The radiation however is diffused and without any precise trajectory (cervico-brachialgia). Neural pain (involvement of the nerve root) results in a radicular pain which radiates to a precise trajectory (dermatomal and myotomal distributions).

Neurovascular symptoms may be associated with neck pain as autonomic nerve fibres, and the vertebral artery runs in close proximity to the joints of the cervical spine.

Movements at the cervical spine

The anatomical configuration of the cervical spine allows remarkable freedom of movements to the neck in all the axes and planes. However, the following four movements are taken as the principal movements:

1. Flexion – in sagittal plane

2. Extension – in sagittal plane

3. Lateral flexion to right (R) and left (L) – in frontal plane

4. Rotation to right (R) and left (L) – in transverse plane

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The major part of mobility to the cervical spine occurs between the occiput, atlas and axis (occiput, C1 and C2) vertebrae.

Between the occiput and the atlas, the ROM is 35 degrees (10 degree of flexion and 25 degree of extension). In the movements of rotation and lateral flexion, the occiput and the atlas move as one piece.

The greatest movement of the cervical spine occurs between the atlas and the axis. Almost 50% of the movement of total rotation (approximately 80 degree) occurs at these joints, the rest 50% is contributed by the remaining cervical vertebrae.

The movements of lateral flexion and rotation never occur as isolated movements like flexion and extension. Both these movements are inter-related, occurring with the participation of all the intervertebral joints below the level of C2.

Flexion stretches both the cervical and the thoracic to the extent of the dura mater. It also compresses the anterior portion of the disc, resulting in opening of the intervertebral foramina, whereas extension results in their narrowing. The movements of lateral flexion and rotation bring about the closure of the foramina on the same side of lateral flexion or rotation, at the same time resulting in opening of the foramina on the opposite side.

The region between C4 and C6 interspaces is most mobile during the movements of flexion and extension. This is also the region of maximum stress. Therefore, it is the most susceptible site for wear and tear (cervical spondylosis) as these two movements are repeated several times in the ADRs.

Physical therapy management

To plan the appropriate therapeutic measures, a thorough physical examination of the neck, scapulae and arm is conducted. It consists of the following:

1. Observation

2. Active movements

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3. Passive movements

4. Resisted movements

5. Neurological examination of the upper extremity

6. Neurological examination of the lower extremity

Physical examination

1. *Observations*: The posture of the patient's head, neck and shoulders is critically observed when the patient walks, sits or lies down.

2. *Active movements*: Examination of the active movements gives information of the active ROM, muscle power and voluntary movement control.

3. *Passive movements*: The pattern of movements provides guidance in the assessment of the inert structures. The pattern of movement can be as follows:

(a) *Capsular* – where all the movements except the cervical flexion are limited.

(b) *Noncapsular* – ligamentous adhesions, where only the movements with adherent scar in a particular ligament are painful and slightly limited. Noncapsular pattern with internal derangement results in blocking of one or more movements with pain only at one side of the movement.

(c) *End feel* – overpressure at the completion of passive range tests the cervical joints' restrictions.

(d) *Presence of muscular spasm*

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(e) *Hypo- or hypermobility of the joint* – to assess hypomobility or the joint restrictions, passive accessory and intervertebral movement testing (central posteroanterior pressure) using Maitland's technique (1977) is extremely useful.

(f) *Quadrant test* (foraminal compression test) – put the patient's head in a combined position of rotation, side flexion and extension to one side. Then apply gentle axial compression by pressure over the top of the head (Fig. 32-17). In a positive test, this manoeuvre produces pain, which indicates interforaminal nerve root impingement. It also provides a clue to identify the localized capsular facet joint tightness.

4. *Resisted motion test*: It tests the following:

(a) The integrity of the cervical myotomes

(b) The lesions of the cervical muscles

(c) The strength of the cervical muscles

Pressure on the nerve trunk may cause paraesthesia but not pain, whereas pressure on the dural sleeve results in pain in the dermatomal distribution.

Passive flexion of the neck stretches both the cervical as well as the thoracic extent of the dura mater, eliciting pain in the disc lesion. Pain on the scapular approximation indicates affection of the thoracic spine.

5. *Examination of the upper extremity* (nerve root impingement test): A

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complete neurological examination of the upper extremity is done to ascertain the level of nerve root and the disc lesion (Tables 32-1–32-4).

6. *Examination of the lower limbs for cord signs*: Presence of a spastic gait, incoordination of lower limbs and extensor plantar response indicate a cord lesion.

FIG. 32-17 Quadrant test for cervical spine to detect interforaminal nerve root compression.

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Table 32-1

Movements of the Neck and Upper Extremity and Their Relative Level of Segmental Association

Movement	Level of Association
Neck rotation	C1
Shoulder shrugging	C2, C3, C4
Shoulder abduction and external rotation	C5
Elbow flexion, wrist extension	C6
Wrist flexion and elbow extension	C7
Wrist ulnar deviation, thumb motion	C8
Finger abduction/adduction	T1

Table 32-2

Level of Nerve Root Lesion and Cutaneous Analgesia

Nerve Root	Analgesia
C4	Trapezial ridge to the tip of the shoulder
C5	Upper scapula and deltoid; lateral brachial region and radial aspect of forearm
C6	Upper scapula, lateral brachial region, radio-volar aspect of the forearm and tips of the thumb and index finger
C7	Mid scapula, posterior brachial region, dorsum of the forearm, hand and index, middle and ring fingers
C8	Ulnovolar aspect of the forearm and ulnar border of ring and little fingers

Table 32-3

Guidance to Detect the Level of Lesion

Level	Root Involved	Motor Changes	Sensory Changes	Reflex Alterations
C4–C5	C5	Deltoid	Numbness over deltoid	Biceps ↓
C5–C6	C6	Wrist extensors	Dorsolateral aspect of thumb	Brachioradialis ↓
C6–C7	C7	Wrist flexion	Index, middle and dorsum of hand	Triceps ↓
C7–C8	C8	Finger flexion	Medial border of forearm (volar) ring and little finger	None

Note: Tendon jerks associated with nerve roots: biceps and brachioradialis C5–C6; triceps C7–C8.

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Table 32-4
Type of Lesion and the Symptoms

Lesion	Symptoms
1. Compression of the nerve trunk	Paraesthesia without pain
2. Compression of the dural sleeve	Pain in the dermatomal distribution
3. Disc lesion (cervical, thoracic)	Passive full ROM, neck flexion elicits pain (stretches the cervical and thoracic extents of the dura mater)
4. Lesion of the thoracic spine	Painful scapular approximation
5. Localized cervical facet joint restriction	Quadrant test positive on the involved side; unilateral scapular and arm pain after fatigue
6. Degenerative changes involving facet joints	Capsular pattern of movements. Limitation of movement is mild in flexion, moderate in lateral flexion and severe in extension; pain and stiffness in the neck; bilateral radiating pain in the arms; headache radiating from the occiput to the frontal area
7. Compression of the spinal cord	Presence of spasticity, incoordination and plantar extensor response

Treatment

Data thus recorded are correlated with the subjective symptoms and other clinical observations. Diagnosis is ascertained and a therapeutic plan is drawn which can include any or a combination of the following:

1. Physical agents and massage

2. Exercises

3. Cervical traction

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4. Manipulation

5. Cervical collar

6. Postural and ergonomic advice

Multicentre trial has shown better relief from symptoms with a combination therapy than with single modality (Brewerton, 1966).

Physical agents and massage

Various physical agents are routinely used mainly to:

1. control inflammation,

2. control pain and muscle spasm,

3. control stiffness of soft tissues and joints,

4. assist mobility,

5. increase blood supply and to relieve ischaemia.

Initial relaxation is achieved by the following:

1. Superficial thermotherapy modalities such as hydrocollator packs and infrared; later on, deep heating modalities such as short-wave diathermy, microwave and ultrasonics can be used.

2. Pain-reducing procedures of cryotherapy in the form of ice massage and ice packs, TENS, interferential currents and diapulse are useful.

Relaxation thus achieved can be useful in procedures such as mobilization, manipulation, general exercises or specialized exercise techniques such as PNF and cervical traction.

Massage: Deep and sedative massage manipulations such as effleurage, circular kneading and frictions to the localized areas effectively reduce the spasm and pain, and thereby induce relaxation.

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The relaxation thus achieved facilitates initiation of therapeutic programmes.

Exercises

The type and extent of exercises are to be planned according to the patient's needs, inabilities and comfort.

1. Relaxed passive movements – this includes manipulation and mobilization when the chief aim is mobilization.

2. Strong isometrics are indicated when mobility is contraindicated but strength, endurance and tone of the cervical muscles need to be improved (Fig. 32-18).

3. Active assisted movements – when the basic objective is to improve the weak muscles without exertion.

4. Active resisted exercises – to strengthen the cervical muscles.

5. PNF techniques ideally combine all the afore-mentioned four effects selectively.

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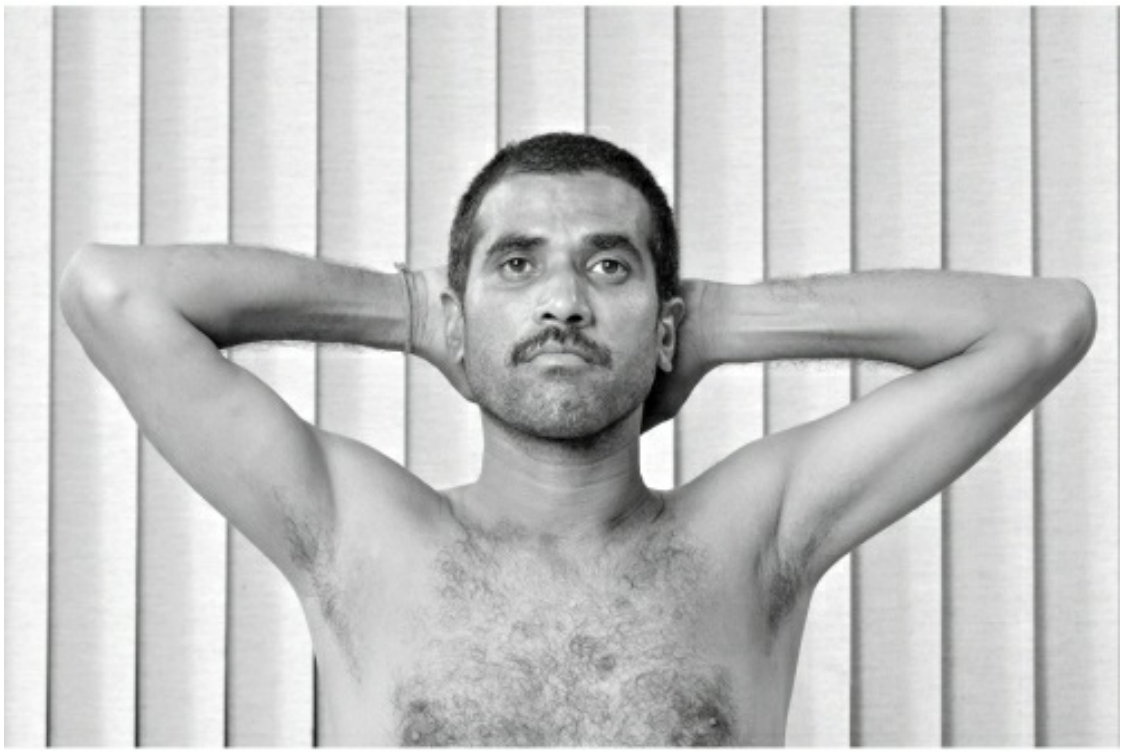
(A)



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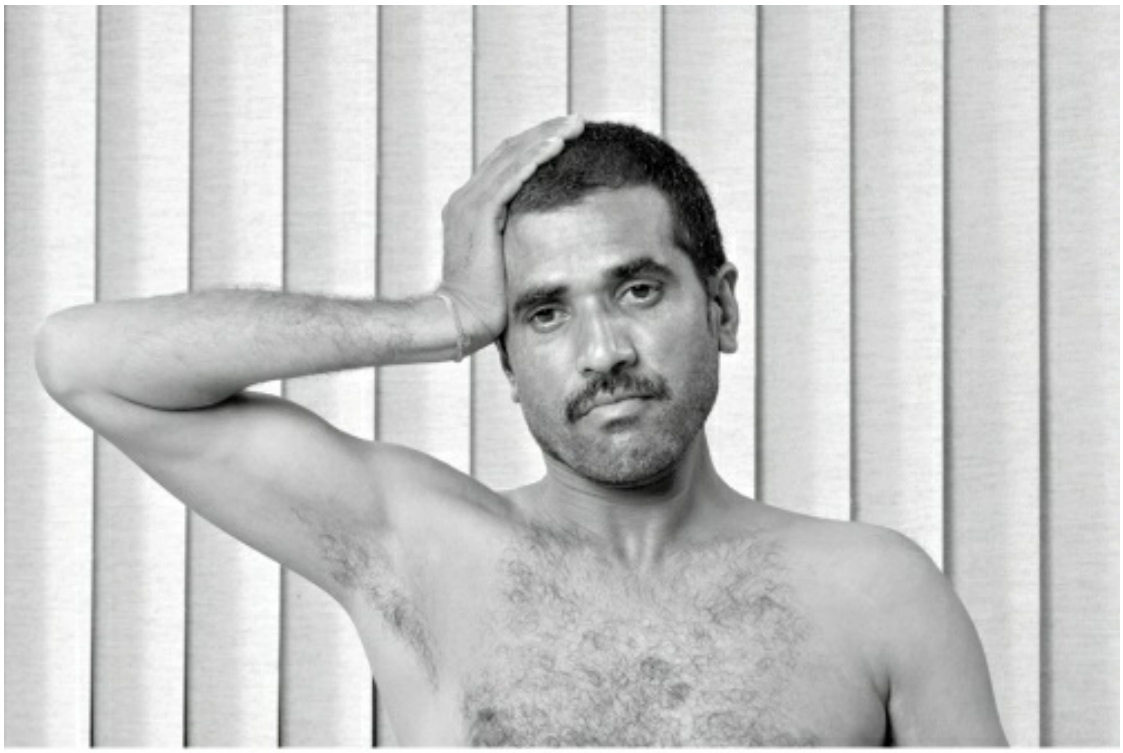

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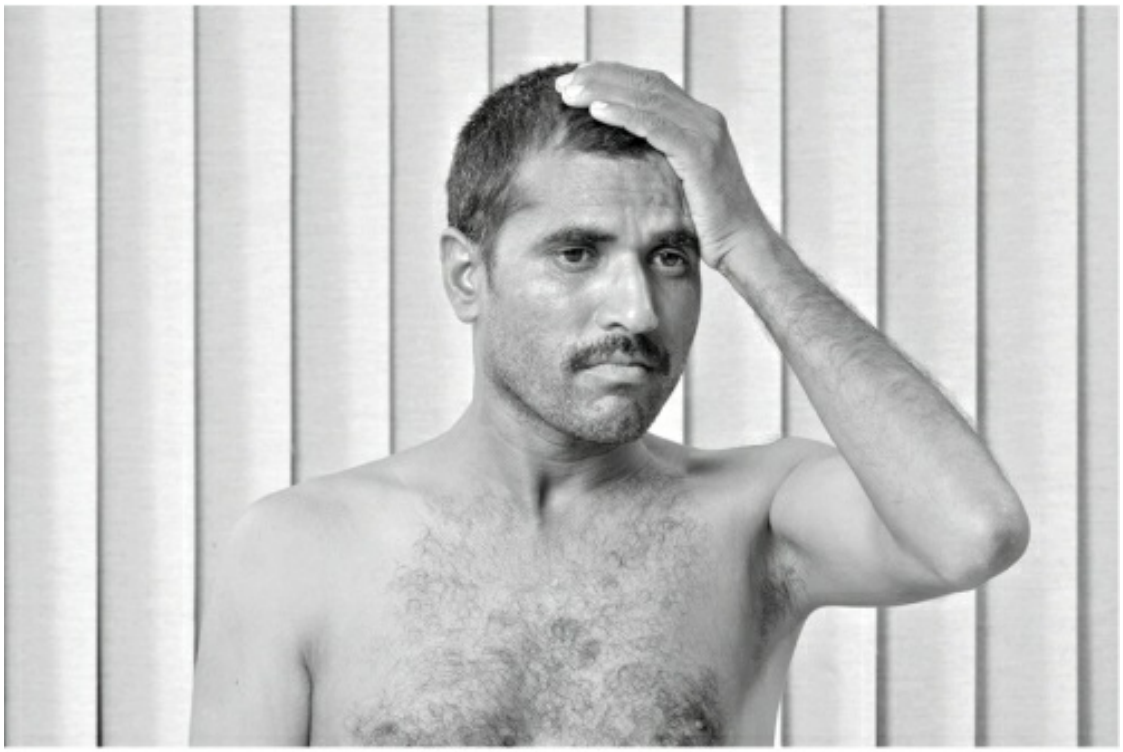

(D)

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FIG. 32-18 Self-resisted isometric neck exercise. **(A)** For flexors. **(B)** For extensors. **(C)** For lateral flexors. **(D)** For rotators.

The effects of exercises are as follows:

1. Elongation of the tightened soft tissues to their normal range

2. Minimize the periarticular fibrous contractures

3. Regain normal length of the muscles

4. Increase circulation to deeper neck tissues

5. Improvement of the posture and functions of neck

6. Provide encouragement and an overall feeling of physical betterment

Cervical traction

Cervical traction is a modality of choice for many cervical dysfunctions. It is applicable in a wide range of problems from sprain to fractures and dislocations of the cervical vertebrae.

Types of traction

1. Continuous

2. Static

3. Intermittent

4. Polyaxial

1. **Continuous traction**: The traction is usually continued for 24 h. The force of traction is minimal, i.e., 5–15 lbs.

(a) Sustained small pull for long hours induces relaxation

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of the muscle spasm and gradual vertebral separation. It relieves compression on the nerve roots or the spinal cord.

(b) It reduces the fractures and dislocations of the vertebrae.

(c) It offers immobilization.

(d) It may help the prolapsed disc to move back into its place.

It is, therefore, indicated in patients with fractures, dislocations, spinal cord or nerve root compressions and disc prolapse.

2. **Static traction**: Traction with a constant pull varying from 10 to 30 lbs is applied for 20–25 min. It is indicated in the presence of definite neurological signs, including radiating pain, not relieved by other conservative modes. It can also be given in minor disc prolapse. The signs and symptoms gradually improve with traction.

3. **Intermittent traction**: Traction with alternate phases of stretching (pull) and relaxation is the popular mode of traction. It produces the effects of massage on the muscular, ligamentous and capsular structures. It promotes circulation and reduces swelling, thereby reducing inflammation, spasm and pain. It also prevents adhesion formation between the dural sleeves of the nerve roots and may also help in breaking the adhesions.

4. **Polyaxial cervical traction**: Goodley (1981) invented a polyaxial system of cervical traction which exerts precise tractive force to a particular segment. It increases the effectiveness of the treatment besides having the advantage of being a patient-controlled technique. Its modified halter prevents pressure and pull over the

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temporomandibular joint.

Angle of pull of traction: The angle of head and neck in relation to the thorax plays an important role on the various segments of cervical spine.

Traction in flexion: Maximum pull and vertebral separation occur at the lower segments of the cervical spine. Traction in flexion of 24 degrees brings about greater intervertebral separation posteriorly, thus increasing the diameter of the intervertebral foramen, which is a common seat of compression over the nerve roots (Collachis & Strohm, 1966). Importance of traction in flexion for cervical radiculitis has been reported by Krusen (1955) and Crue (1957). The vertical diameter of C5–C6 vertebral foramen increased by 1.5 mm when the neck moved from 10 degrees of extension to 20 degrees of flexion. A small weight produced no clinical change when applied to an extended neck but it did produce relief when applied in flexion.

Traction in neutral: It offers maximum pull and intervertebral separation to the middle segments. It is indicated in herniated discs (Delacerda, 1979).

Traction in hyperextension: It exerts maximum pull and intervertebral separation at the upper segments of the cervical spine.

Duration of traction: It varies as per the requirements of the underlying pathology. Continuous traction may be needed for several weeks in cases of fractures, dislocations,

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prolapsed disc and pressure on the nerve root. Static traction may be needed for 20–25 min once a day or on alternate days. Intermittent traction is usually given for 15–20 min on alternate days.

Tractive force: Continuous traction is applied with smaller tractive force from 5 to 15 lbs. Static and intermittent traction is to be started initially with 10–15 lbs and to be increased to 30 lbs or more. The higher the force of traction, the lesser its duration and vice versa. Tractive force can vary between 1/10 and 1/7 of the patient's body weight.

Patient's position during traction: The convenient position of applying overhead traction in sitting position is a common practice. However, ideally, traction should be given with the patient in supine position (Fig. 32-19). Traction in supine position produces better relaxation, greater posterior intervertebral separation, decreased muscle guarding and increased stability. In supine position, lesser force is required to overcome the weight of the head, and at the same time the patient feels much more comfortable. A correct traction pull should be ensured, as pull under the chin forces the head into extension while a pull under the occiput forces the head into flexion.

However, the patient's response, comfort and reduction of the symptoms are the basic guidelines of applying traction successfully.

Application of traction: Traction should be applied in the position of greatest comfort. This position is detected by pretraction evaluation. It consists of applying gentle

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manual traction in various combinations of flexion, rotation and lateral flexion, using passive physiological intervertebral movement testing techniques.

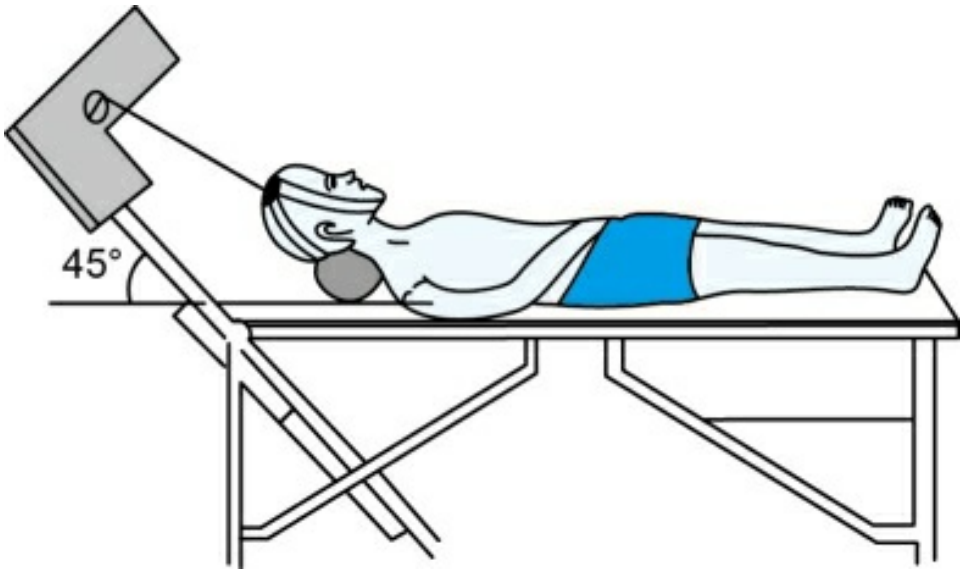

FIG. 32-19 Cervical traction in the most relaxed supine lying position with the rope pulled at 45 degrees of flexion.

Caution

Cervical rotation should never be given during traction. It produces extra stretching of the ligaments at the atlantoaxial level and is prone to produce traumatic inflammatory reaction and increased symptoms.

Contraindications to traction: Traction is contraindicated in the following:

1. Marked ligamentous instability immediately inferior to the specific traction level.

2. Malignancy involving cervical or thoracic spine.

3. Signs and symptoms of spinal cord involvement.

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4. Rheumatoid arthritis with necrosis of the ligaments adjacent to the traction level.

Manipulation

Reduction of the intra-articular displacement in cervical spondylosis by manipulation is very effective, provided the spondylosis is not too advanced. It is always carried out during strong traction.

Manipulation needs to be maintained correctly to prevent recurrence. Moulded cervical collar (thermoplastic material) supporting the mandible is given, with proper fitting of the occipital piece, not pushing the head forwards.

Contraindications to manipulation: It is contraindicated in the following:

1. Evidence of impaired pyramidal function.

2. Root palsy – excluding minor paraesthesia.

3. Primary posterolateral onset – where the symptoms appear in a reverse order, e.g., paraesthesia occurring first in the digits, followed by pain in the forearm, arm and then in the scapular region.

4. Cervical movements provoking brachial pain – instead of scapular region, the increased pain is felt in the upper limb.

5. Long-standing brachial pain – unilateral brachial pain for more than a 2-month duration.

6. Never attempt manipulation without thorough knowledge and practice.

Cervical collar

The use of a cervical collar nowadays is generally discouraged. It is advised for acute disc lesions following surgery or reduction of fractures and dislocations. However, it may occasionally be useful in mild cervical dysfunctions where temporary rest is needed, e.g.,

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during strenuous forward bending postures at work or riding or driving automobiles.

Functions of cervical collar

- Rigid immobilization
- Partial immobilization
- Support and relaxation of muscles and soft tissues
- Carrying out repeated isometric exercises
- Correction of deformity
- Conventional soft wrap around the neck using folded towel at night with correct height of pillow to maintain optimal neutral position of the neck in relation to shoulders is extremely effective in common neck pains.

Proper fitting of a collar is necessary, e.g., its fitting in flexion is advocated where separation of facets and opening of foramina is the aim.

Postural and ergonomic advice

Advice on the maintenance of posture of the neck in relation to the various body positions and ergonomics plays a predominant role in the majority of patients with cervical pain. Faulty posture also accelerates degenerative changes.

The correct posture of neck during working as well as rest (sleep) should be observed to avoid excessive stress (Fig. 32-20). Physiologically and mechanically the ideal posture is straight neck with the chin tucked in. Ergonomic advice is the single most important approach which can prevent recurrence of neck pain. Mass education on correct ergonomic principles is ideal to prevent common neck pains.

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(A)

(B)

FIG. 32-20 Ideal neck posture in lying. **(A)** Supine lying. **(B)** Side lying.

Osteoarthritis of the cervical spine

It is commonly known as cervical spondylosis, spondylitis, spondylarthritis or spondylarthrosis and begins as a degenerative

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process in the central intervertebral (body) joints. Subsequently, it affects the posterior intervertebral (apophyseal) joints (Fig. 32-21).

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FIG. 32-21 Cervical spondylosis. Note the narrowing of disc spaces with osteophytes (arrow).

Pain and stiffness at the neck are the primary symptoms. Often, there may be referred symptoms to the upper limb.

There occurs degeneration and narrowing of the disc, with bone reaction at the periphery resulting in osteophytes with wear and tear of the articular cartilage. Osteophytes may press on the cervical nerve root at the intervertebral foramina, leading to compression symptoms. Osteophytes may encroach upon the cord and cause pressure over the spinal cord in rare cases. The symptoms vary with the degree and site of compression (Table 32-4).

Repetitive movements or postural strains may give rise to pain on the posterior aspect of the neck over the trapezius. Stiffness and grating may also be present on movement.

Radiation of pain from the shoulder to the digits along the course of the nerve indicates nerve root compression. Paraesthesia in the form of tingling, pins and needles may be present in the hand. Muscular weakness or sensory impairment also happens in rare cases.

Diagnosis

Often, every neck pain is labelled as cervical spondylosis. This diagnosis causes unnecessary worry to the patient. Therefore, it is necessary to distinguish it from other causes of pain in the neck and upper extremity, which could be as follows:

1. Congenital: torticollis, malformations, cervical rib

2. Infective: tuberculosis and pyogenic infections of the spine

3. Degenerative: osteoarthritis, disc prolapse

4. Tumours: tumours involving the (a) vertebra and (b) spinal cord

5. Plexus lesions: injury, causalgia, distal nerve lesions, e.g., ulnar neuritis and carpal tunnel syndrome

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6. Miscellaneous: rheumatoid arthritis, fibrositis, heart disease (e.g., myocardial infarction)

7. Shoulder lesions: e.g., periarthritis

8. Elbow lesions: e.g., tennis elbow

Prolapsed cervical disc

Although uncommon, when present, it is accompanied with neurological manifestations in the upper extremities; in rare cases the signs of spinal cord compression may be present.

The disc rupture may occur as a result of intrinsic changes in the disc substance or an injury.

A part of gelatinous nucleus pulposus extrudes through a rent in the annulus fibrosus at the weakest part of the cervical spine. The C5–C6 or C6–C7 intervertebral levels are the common sites of disc protrusion (Fig. 32-22).

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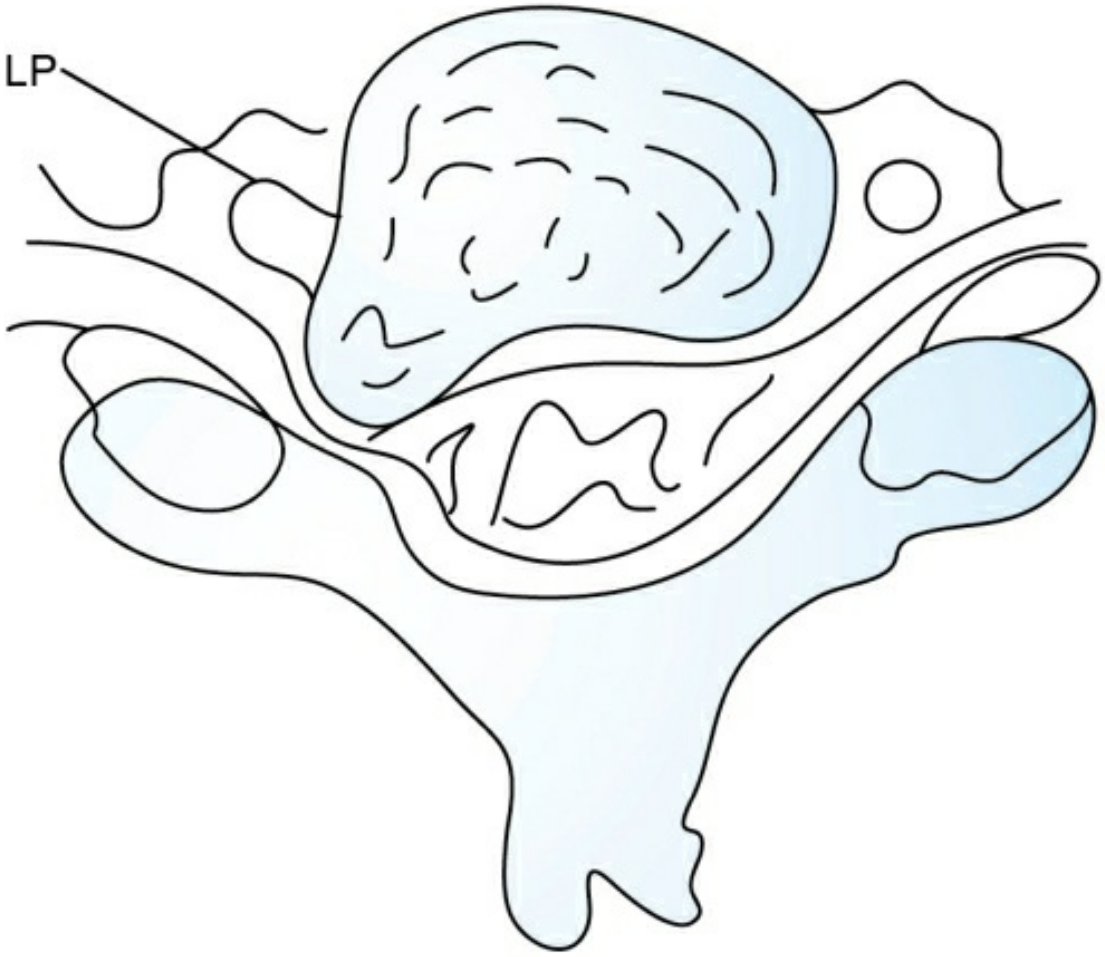

FIG. 32-22 Lateral prolapse of the cervical disc (LP).

The protrusion may be:

1. Mild – causing compression of the posterior longitudinal ligament, and localized pain.

2. Moderate – when it herniates through the posterior ligament and presses laterally on the emerging nerve root, causing lateral disc prolapse.

3. Severe – central protrusion compresses over the spinal cord.

The symptoms may be present in the neck and/or upper limb. A clinical and neurological examination with emphasis on the

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movements of neck, arm, muscle bulk, sensory status and reflexes will provide information regarding the extent, site and nature of the pathology (Fig. 32-23).

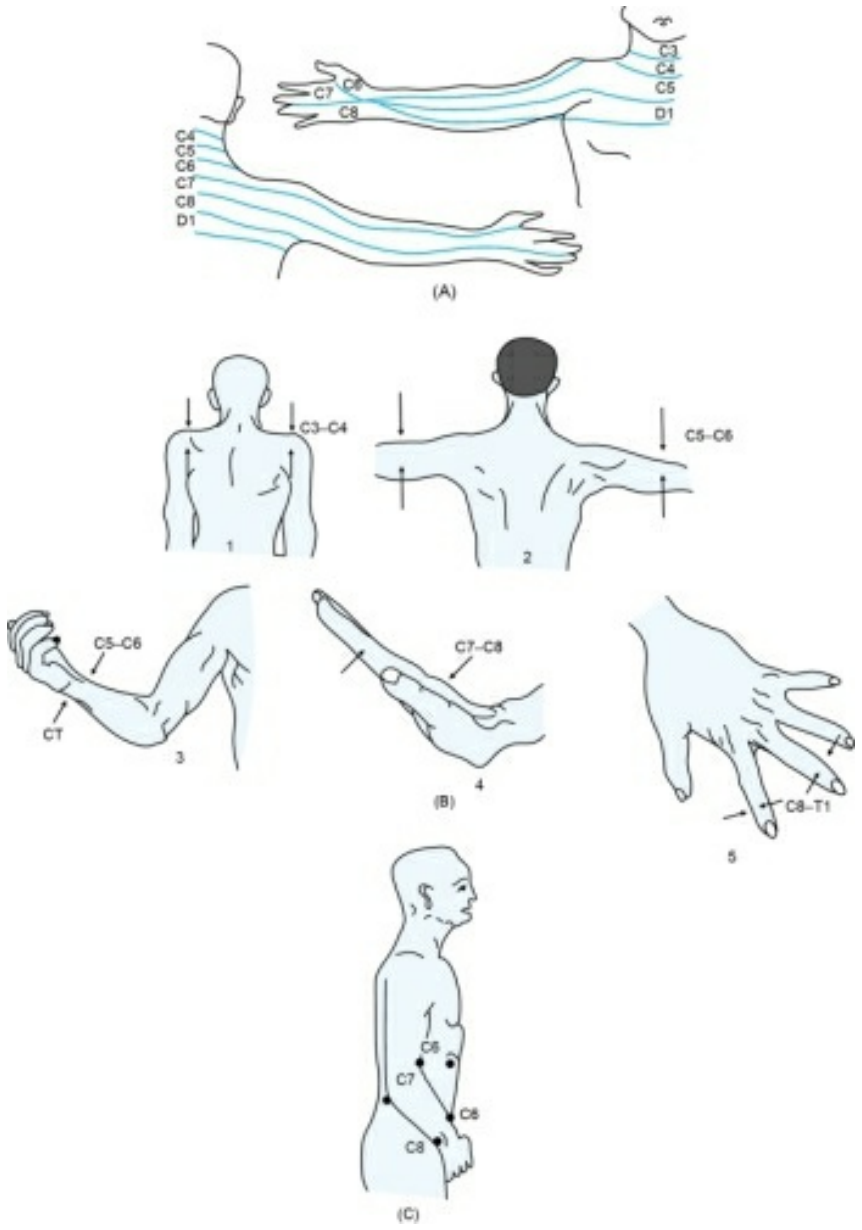

FIG. 32-23 Dermatomes and myotomes. **(A)** Dermatomes. **(B)** Myotomes. **(C)** Reflexes.

Treatment

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It depends on the severity of the condition. However, it is claimed that in disc prolapse, there is a tendency for spontaneous recovery.

- Mild symptoms can usually be controlled with rest in a conventional cervical collar, postural guidance and drug therapy.
- In severe cases, there is stiff and painful neck with positive neurological signs. Immobilization of the neck in a moulded or POP collar may be necessary for 6 weeks, or continuous cervical traction may be given till signs reduce or disappear.
- Disc lesion with rupture of annulus may be treated by manipulation (Cyriax, 1954).
- Traction is suited best for irreducible nucleus pulposus protrusion (Cyriax, 1954).

Physiotherapeutic management

During immobilization

1. Check the traction (positioning, line of pull and the magnitude)

2. Postural guidance with immobilization

3. Full ROM exercises for the shoulder joints

4. Maximum use of upper extremities

5. Scapular protraction–retraction and other shoulder girdle movements with sustained holds

6. Deep breathing and cycling motions without straining the neck

7. Isometrics to cervical muscles with mild tension

Mobilization

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1. Checking and training in the application of cervical collar

2. Relaxing thermotherapy modality

3. Stronger but pain-free isometric exercises

4. Intermittent cervical traction

5. Relaxed passive mobilization of neck

6. Gradually increasing ROM and strengthening exercises

7. Postural guidance to avoid excessive flexion attitudes; wearing collar during working and conventional soft collar at night

Cervical rib

It is a fibrous or bony overdevelopment of the costal process of the seventh cervical vertebra. It may be unilateral or bilateral. It is congenital and generally asymptomatic in the early years. During adult life, a person with this anomaly develops depressed and round shoulders. Neurological and/or vascular symptoms may appear.

Symptoms

Neurological symptoms

Usually the lowest nerve trunk of the brachial plexus may be pressed against the rib (Fig. 32-24).

1. There may be complete sensory anaesthesia in the forearm and hand over the area supplied by the lowest trunk of brachial plexus.

2. Pain and paraesthesiae may be present on the ulnar aspect of the forearm and hand; occasionally relieved by changing the position of hand.

3. Weakness of the finer movements of hand may be present.

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4. Atrophy may be present in the interossei, and the muscles of the thenar and hypothenar eminence at a later stage.

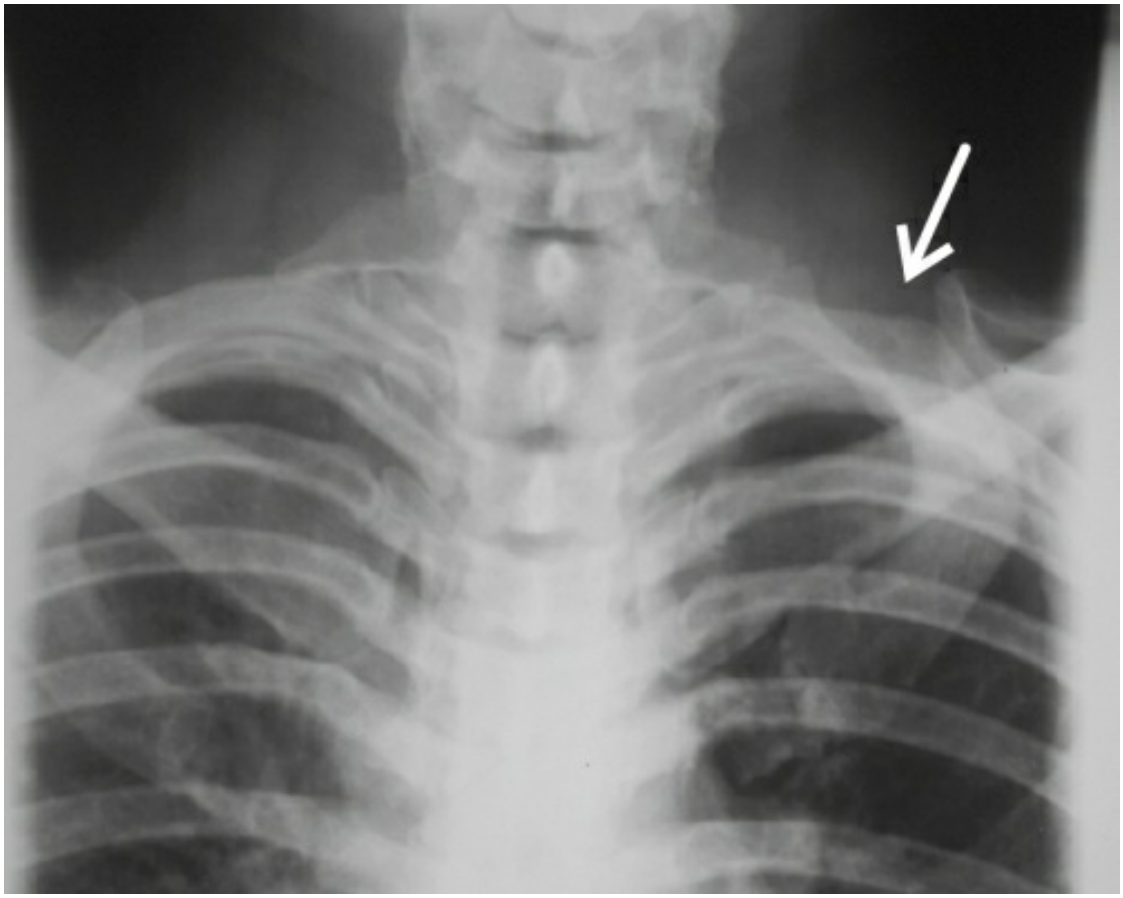

FIG. 32-24 Cervical rib on the left side (arrow).

Vascular symptoms

1. Absence or feeble radial pulse

2. Dusky cyanosis of the forearm and hand

Differential diagnosis

It is important to rule out peripheral vascular diseases such as Raynaud's disease. Certain other conditions such as syringomyelia, motor neuron disease, poliomyelitis and muscular dystrophy should

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also be kept in mind.

Treatment

Surgery is indicated in patients with established progressive vascular and neurological signs. It consists of removal of the pressure-causing elements, i.e., cervical rib and the associated fibrous band and occasionally dividing the scaleni group of muscles.

Physiotherapeutic management

The choice of therapeutic method depends upon the symptoms:

1. Postural guidance

2. Thermotherapy modality for pain relief

3. Exercises to improve distal circulation of hand and fingers

4. Exercises to improve tone, power and endurance of the whole arm in general and small muscles of the hand in particular.

The most important aspect is to carefully identify the movements which relieve symptoms. It is commonly noticed that the movements of the shoulder girdle such as retraction and raising the arm overhead with elbow extended wrist in neutral with interlocked fingers would relieve the symptoms. Axial traction is applied to both the arms, and holding for 10–30 s may bring spontaneous relief. Therefore, the following specific exercises to develop these muscle groups are extremely important:

1. Self-resisted scapular elevation (Fig. 32-25)

2. Self-resisted scapular adduction (shrugging)

3. Improving endurance of the muscles of the shoulder girdle by endurance training exercise

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4. Progressive resistance exercise (PRE) for the shoulder girdle muscles with weight belt (Fig. 32-26)

5. Maximum isometric holds

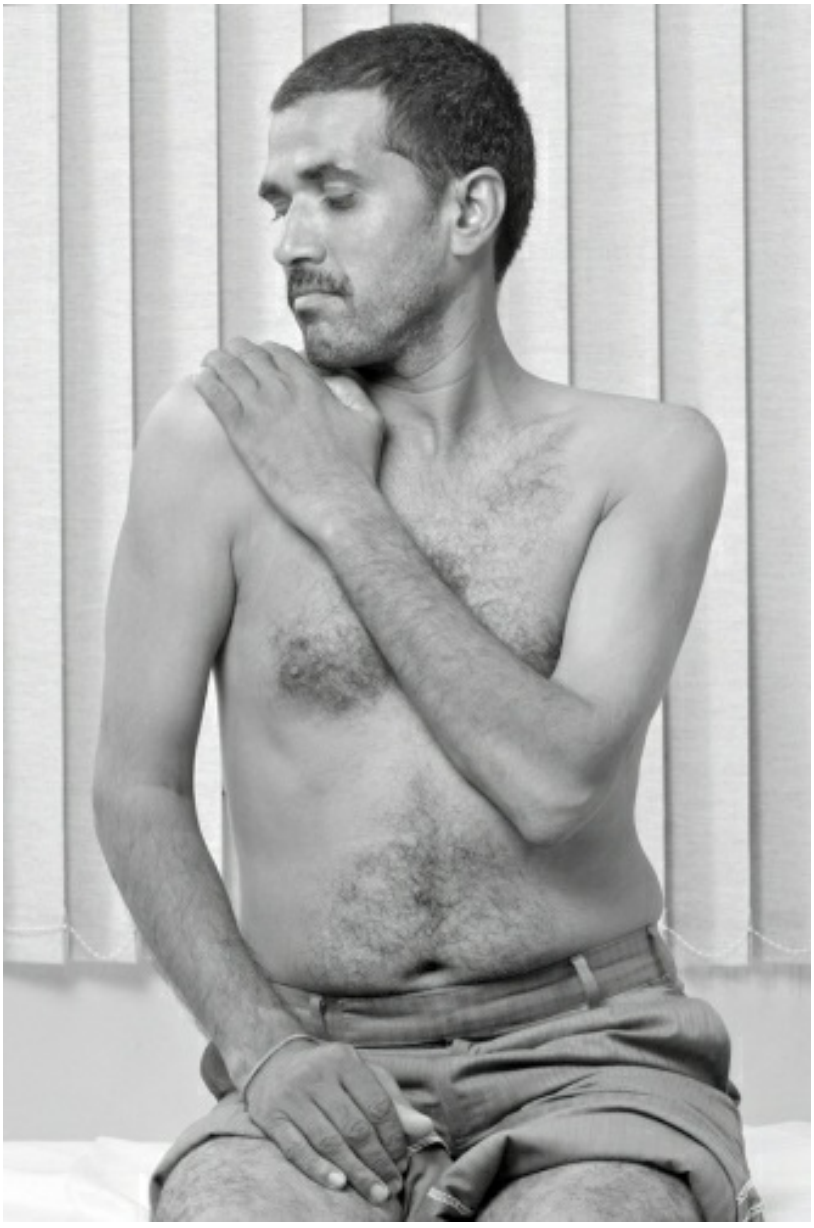

FIG. 32-25 Self-resisted scapular elevation.

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FIG. 32-26 Scapular elevation against the resistance of weight belt.

Caution

Thermotherapy for pain relief should not be used if there is complete sensory impairment.

Spasmodic torticollis

Typical torticollis posture presents with acute muscle spasm and pain. Malalignment of the neck posture at night is the predisposing cause of

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acute inflammation. It can also be due to hysteria. The inflammatory process can be controlled with appropriate drugs, thermotherapy and exercises.

Soothing superficial or deep heating modality may be used as an adjunct.

1. Relaxed passive movement of head in the opposite direction of spasmodic muscles gradually altered to active movement is the best form of exercise.

2. Controlled manipulation is beneficial.

3. The movements of rotation and side flexion are repeated in the painless direction under traction.

4. Other relaxed slow full-range movements are helpful.

A temporary soft collar is useful during working and sleep to maintain proper posture till acute pain subsides.

Vertebro-basilar syndrome

Two posterior cerebral arteries, which originate from the basilar artery, supply the temporal lobes and visual cortex in the brain. The vertebro-basilar artery passes through the foramina in the lateral masses of the cervical vertebrae. Osteophytes may cause pressure on the vertebral artery, particularly during the movements of extension and rotation of the neck. This, in turn, causes transient ischaemia of these areas of the brain. This results in vertigo.

Test for vertigo

A patient stands with the arms stretched out horizontally in front with the eyes closed. He is asked to rotate the head fully to one side and stay for 1 min. He is then asked to turn his head to the other side. Any straying of the arms away from the horizontal is suggestive of cerebral ischaemia.

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Management

1. Postural guidance to avoid sudden extension or rotation of the head and graduated slow changing of posture, all with eyes open; to first come to side lying and sit up in grades with arm supports.

2. Use of collar during working.

3. Strong isometric exercises to neck muscles.

4. Synchronization of eyeball movements with movements of the head.

5. Decompression of the vertebral artery.

Thoracic outlet syndrome

The classical feature of the thoracic outlet syndrome is the nocturnal appearance of pins and needles in the fingers which disappear when the patient changes position or sits up. The symptoms reappear on elevation of the arms overhead or elevation of the scapulae. Pressure on the lower trunk of the brachial plexus results due to drooping of the pectoral girdle. These symptoms occur when the space between the clavicle and the first rib is reduced.

Treatment

Conservative treatment

Postural guidance and strengthening exercises to the shoulder girdle muscles. Weight carrying, cycling, driving and swimming to be avoided.

Needs postural training in maintaining braced shoulders posteriorly, not allowing a common tendency of protruding them forward. A narrow osteomuscular space, traversed by neurovascular structures, including the lower trunk of the brachial plexus, is compressed. Repetitive performance of PNF scapular patterns with isometric hold is ideal.

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Surgical treatment

The indications of surgical treatment in cervical rib (thoracic outlet) syndrome are as follows:

1. Evidence of neuro and/or vascular disturbances.

2. Severe symptoms incapacitating the patient: The surgical treatment consists of removal of the cervical rib and the fibrous band which are causing abnormal pressure on the subclavian vessels and/or brachial plexus.

Occasionally, abnormal insertion of the scaleni muscles is responsible for the abnormal pressure, and thereby the symptoms. In such cases the insertion of these muscles is released to relieve the pressure.

Postoperatively, a small dressing is maintained for about 2 weeks.

Physiotherapy following surgery

Routine measures to control pain and inflammation are taken following surgery. Shoulder movements can be initiated after 8–10 days as relaxed passive or assisted active movements.

Active mobilization begins after 2 weeks and is intensified gradually along with functional re-education. Full function is restarted by 4–6 weeks.

Scalenus syndrome

It is a neurological manifestation of the cervical rib due to compression of the lowest trunk of brachial plexus between the first rib and the clavicle. This costo-clavicular compression occurs as a result of the presence of tough fibrous band in the body of the scalenus medius muscle.

The management proceeds on the same lines as described for the ‘cervical rib’.

Cervical spondylolisthesis

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Forward displacement of the upper cervical vertebra occurs in relation to the lower vertebrae (Fig. 32-27). It may occur as a result of the following three causes:

1. Congenital nonfusion of the dens (odontoid process) with the body of the axis; only fibrous tissue is present as a link.

2. Softening of the transverse ligament of the atlas as a result of an inflammatory lesion in the upper part of the neck.

3. Instability developed from previous injury or inflammatory reaction following rheumatoid or infective lesions of ear, throat or neck.

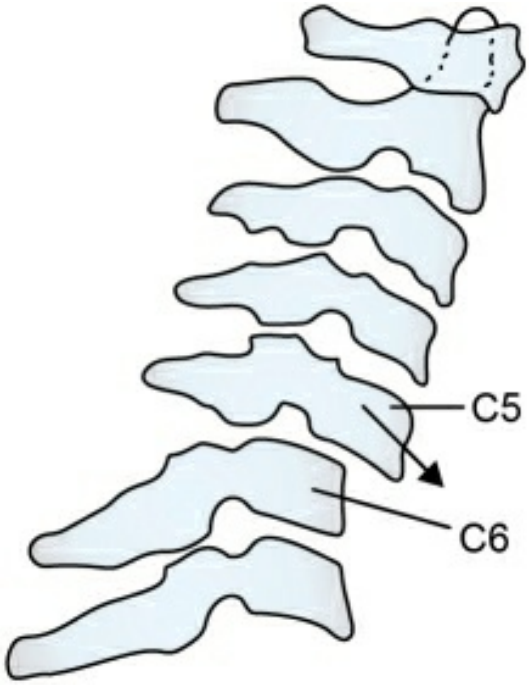

FIG. 32-27 Cervical spondylolisthesis showing subluxation of C5 on C6 cervical vertebrae.

Initial painful flexion deformity of the neck with stiffness may progress to nerve root symptoms or even spinal cord compression.

Treatment

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1. In the inflammatory type, the displacement is reduced by constant head traction. The neck is then immobilized in a plaster jacket in extension. If no relief is felt, atlantoaxial fusion may be necessary.

2. Congenital or post-traumatic instability – if the neurological signs are absent, treatment by moulded plastic collar is enough.

When the neurological symptoms and severe displacement are present:

(a) Reduction in displacement by skull traction is attempted.

(b) If no relief, fusion of the affected segments may be necessary.

Physiotherapeutic management

Following conservative management: Patients are treated with moulded collar or by constant bed traction:

1. Mobility of the legs and arms is maintained along with strengthening techniques.

2. Emphasis is placed on the shoulder girdle and scapular muscles.

3. Gradual mobilization of the cervical spine and progressive resistive techniques in the available range are given with emphasis on isometrics for the cervical extensor group of muscles.

Following surgical management: The same regimen as described for cervical disc prolapse is to be followed.

Caution

Overstretching of the fused segments of the cervical spine should be avoided.

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Studies reported on the survey of cervical syndrome by Basmajian (1976) and Patric (1978) can be summarized as follows:

1. Females are more prone to develop cervical syndrome.

2. There is a close relationship between cervical syndrome and the mental and psychic status of the patient.

3. Ultrasound therapy was found to be more effective in the treatment of patients with localized tender points and those with tension myositis.

4. Intermittent traction was found to be more effective than static mode of traction in relieving radicular pain.

High cervical pain

The pain may be felt over the occipital area and may occasionally radiate to the temporal region in the form of headaches (Fig. 32-28). The pain will aggravate with the movement of the high cervical spine (e.g., nodding). The site of emergence of the occipital nerves will be tender.

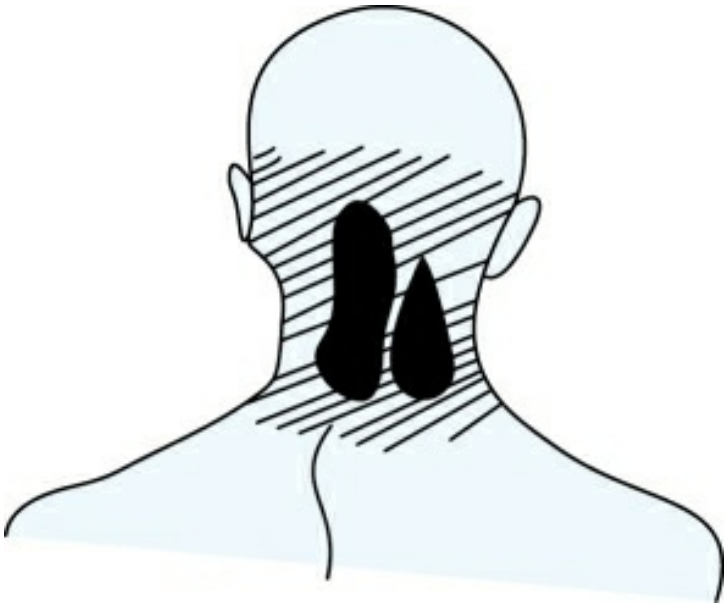

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FIG. 32-28 High cervical pain radiating to the occiput due to involvement of the cervico-occipital junction.

Test to identify the lesion at the cervico-occipital junction

Head is bent forward (flexed) at the cervico-occipital junction, keeping the rest of the neck straight (Fig. 32-29). The patient is then asked to rotate the head to right and left, preventing rotation of the inferior cervical spine. Occurrence or aggravation of pain on rotation confirms the origin of pain at the cervico-occipital junction.

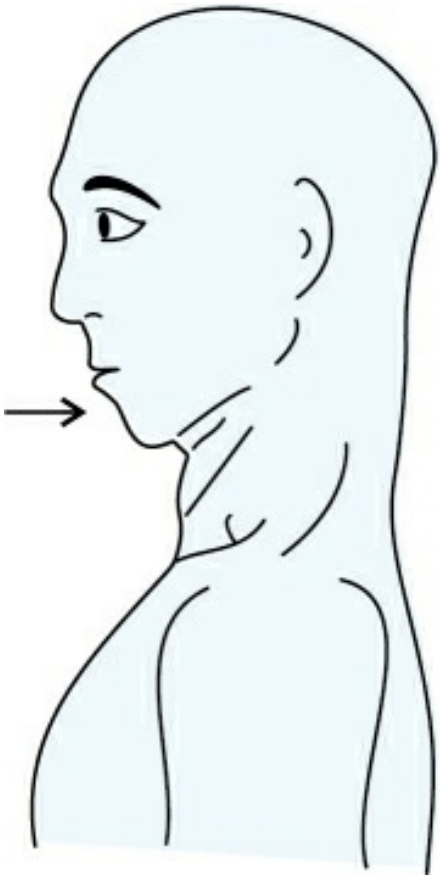

FIG. 32-29 Test to identify lesion at the cervico-occipital junction. Rotation of the head in atlanto-occipital flexion with straight neck.

Treatment

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- Rest in a soft cervical collar and analgesics or anti-inflammatory drugs
- Pain reducing electrotherapy modality
- Relaxed passive mobilization
- Graded mobilization avoiding sudden movements
- Manipulation

Levator scapulae syndrome

Certain repetitive movements, e.g., typing with a bad posture, sustained cervico-dorsal stooping posture, results in a habitual wrong posture. Psychological tension can also give rise to this syndrome.

On examination, contractions of the muscles inserted at the superomedial angle of scapula and at the superior portion of the cervical spine are noticed. In unilateral involvement, a clear-cut disparity is seen at the scapular level.

On palpation, tender nodules may often be felt.

Cervical disc lesion symptoms

- Unilateral or alternating scapular pain.
- Bilateral neck pain.
- Headache by extrasegmental dural reference.
- Unilateral scapulo-brachial pain with or without nerve root palsy.
- Pain in the upper limbs and paraesthetic hands as a result of bilateral protrusion.
- Paraesthesia in hands and feet as a result of central protrusion.
- Spinal cord compression with one or more root palsies in one or

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both upper limbs with spastic paresis in the lower limbs.

Osteophytic compression symptoms

- Pressure on one or more nerve roots, respective root symptoms.
- Compression of the spinal cord may cause paraesthesia of hands and feet.
- Compression of the anterior spinal artery may cause paraplegia.
- Kinking of the vertebral artery by an osteophyte on the superior articular process may cause impairment of basilar circulation and vertebro-basilar symptoms.
- Upper cervical pain or headache when there is involvement of the upper two cervical joints.
- However, osteophyte formation at the vertebral body or foramen, as well as narrowing of one or more disc spaces, could be symptomless. Therefore, it is important to plan therapeutic measures on the basis of clinical examination to identify the internal derangement, rather than excessive reliance on radiography (Cyriax, 1971).

Treatment

- Anti-inflammatory drugs
- Local infiltration by lidocaine or steroids
- Ultrasound and friction massage of contracted soft tissues
- Gentle mobilization of the neck, shoulder girdle and arms
- Posture training

Cervical disc syndrome: Surgical treatment

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Surgery in cervical disc syndrome is rarely indicated except in cases with cord compression.

The following surgical procedures may be performed:

1. *Discectomy*: Removal of the involved disc may be performed through anterior or posterior approach. When performed through the anterior approach, postoperatively a soft cervical collar is given for 2–3 weeks, after which mobilization may be started.

Disc excision through the posterior approach may require laminectomy. After laminectomy, a POP Minerva jacket or a four-poster collar is given for a period of 4–6 weeks (Fig. 32-30).

2. *Disc arthroplasty*: In cervical spine, the herniated disc is removed and replaced by an artificial disc (total disc replacement). The disc consists of an artificial end plate as well as a simulated nuclear core, which is inserted through an anterior approach.

3. *Spinal fusion*: Fusion of the spine is indicated after an extensive laminectomy is done for cord decompression and disc excision. Postoperatively, a POP Minerva jacket is given for about 3 months.

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FIG. 32-30 Four-poster cervical collar to immobilize the cervical spine.

Physiotherapeutic management

Preoperative evaluation: Preoperatively, careful and thorough physical examination is conducted to assess the following:

- Degree of pain
- Respiratory status (vital capacity)
- Neuro-musculoskeletal status
- Subjective influence of the dysfunction

The patient is to be trained on the postoperative regimen of physiotherapy with reassurance.

Postoperative management: The postoperative management proceeds

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on the same lines as for all the three surgical procedures of discectomy through anterior approach, posterior approach and spinal fusion. The only difference being the period of immobilization, which varies with the surgical technique, and thus the mobilizing procedures to the cervical spine.

During the early postoperative phase, chest physiotherapy, body positioning and resistive movements to the lower extremities and simple nonstrenuous movements to the upper extremities are initiated. Excessive stress on the shoulder joint and shoulder girdle should be avoided during arm exercises.

A thorough neuromuscular examination should be conducted and compared with the preoperative status. The neuromuscular status of the upper limbs forms the basis of the appropriate therapeutic programme.

Phase of mobilization.

As soon as the POP collar, four-poster collar or POP Minerva jacket is fitted, graduated mobilization begins.

Beginning with rolling mobilization, it is progressed to arm-supported sitting at the edge of the bed, standing balance and ambulation. The technique and the progress of mobilization depend upon the degree and the areas of neuromuscular deficits. Exercises to the functionally important muscle groups are made vigorous to assist early functional independence.

Graduated mobilization of the cervical spine is begun after 3 weeks in patients with discectomy through anterior approach, after 6 weeks in discectomy through the posterior approach and after 12 weeks in patients treated for spinal fusion.

Functional re-education should be planned, giving due consideration to the patient's daily routine activities and job requirements to achieve early return to job. Patients with spinal fusion need to be educated on the movement techniques based on ergonomic principles to compensate for surgically fused segments of the spine.

Low back pain

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The incidence of low back pain (LBP) has lately reached epidemic proportions. A number of population studies reported the incidence of LBP between 2% and 5%.

Since the time of acquiring the erect two-legged posture from the ancient quadruped state, the lumbosacral junction has remained weak due to its structural and biomechanical inadequacies. Fortunately, this has resulted in the presence of mechanical LBP in the majority of patients, whereas LBP due to prolapsed intervertebral disc (PIVD) and other causes requiring extensive treatment occurs only in about 1%–2% patients of LBP.

Structural and biomechanical considerations of the lumbosacral complex

- Clinical anatomy
- Pathophysiology
- Biomechanics

It is interesting to note that the structural composition of the whole vertebral chain is architextured in relation to the functional requirements of the individual vertebral unit (Table 32-5).

Table 32-5

Structural Composition of the Vertebral Chain as Related to the Functional Requirements of an Individual Vertebral Unit

Unit	Functional Requirement	Structural Composition
• Cervical unit (7, vertebrae)	• Free ROM through 180 degrees	1. Atlas with articular condyles forms compact head–neck unit 2. Cylindrical odontoid serves as an axis for freedom of rotation of head and neck 3. Nonobstructive anterior vertebral borders of C3–C7 vertebral bodies allow free movement of neck flexion
• Thoracic unit (12, vertebrae)	• Protects vital delicate organ systems in the chest viscera	• Posterior articulation with vertebral bodies form compact closed rib cage
•	• Offers freedom of	• The vertebral bodies are larger and stronger and interwoven

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Lumbar unit (5, vertebrae)	movement to the whole spine • Protects spine from injuries	with cancellous shock absorbing intervertebral discs
• Sacral unit (fused 5, vertebrae)	• Offers stability to facilitate freedom of movement to the whole spine • Forms compact envelope with broad pelvic bone offering protection to the delicate organ systems in the pelvic viscard	• Fusion with pelvis offers stability for the static and dynamic activities of the whole body
• Facet joints		
• Spinal ligaments	• Stability with safe-restricted mobility and strength to the spine	• Anterior and posterior longitudinal ligament protects the spinal cord on both the sides • Posteriorly placed additional short ligaments enforce posterior aspect of the spine, preventing injury and prolapse of the IV disc
• Muscles		
• On the anterior aspect	• Thoracic – loosely attached	• Provide anterior flexion force to the abdomen, and loose attachments accommodate abdominal organ systems without causing undue strain
• On the posterior aspect	• Tightly attached small posterior muscles	• Provide posterior protection from injury. • Provide strength, endurance with restricted mobility to the body
• Facet joints	• To allow restricted and safe mobility preventing injury to the spinal cord	• The short and more horizontally placed facet joint in the cervical spine gradually assumes vertical direction towards the lumbar unit. Therefore, the cervical spine is more susceptible for dislocation than fracture, whereas fracture dislocations are more common at the lumbar spine

Lumbosacral complex (fig. 32-31)

It is an important functional unit of the body. It consists of five lumbar vertebrae and the sacrum. The lumbar vertebrae, because of their weight-bearing function, are large and massive. They are characterized by the lack of foramen in their transverse processes, as found in the cervical region, and by the absence of articulating facets on the body itself, as in the thoracic region. The spinal canal in the lumbar region is smaller and triangular as compared to that in the cervical region. The short and strong pedicles that arise from the sides of the upper portion of the vertebral body proceed posteriorly to form

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the superior and inferior vertebral notches. The inferior portion of the pedicle above and the superior portion of the pedicle below form the intervertebral foramen, through which the spinal nerves pass. The space within the foramina is particularly vulnerable for impingement of the emerging spinal nerve by tumour, trauma or degenerative changes.

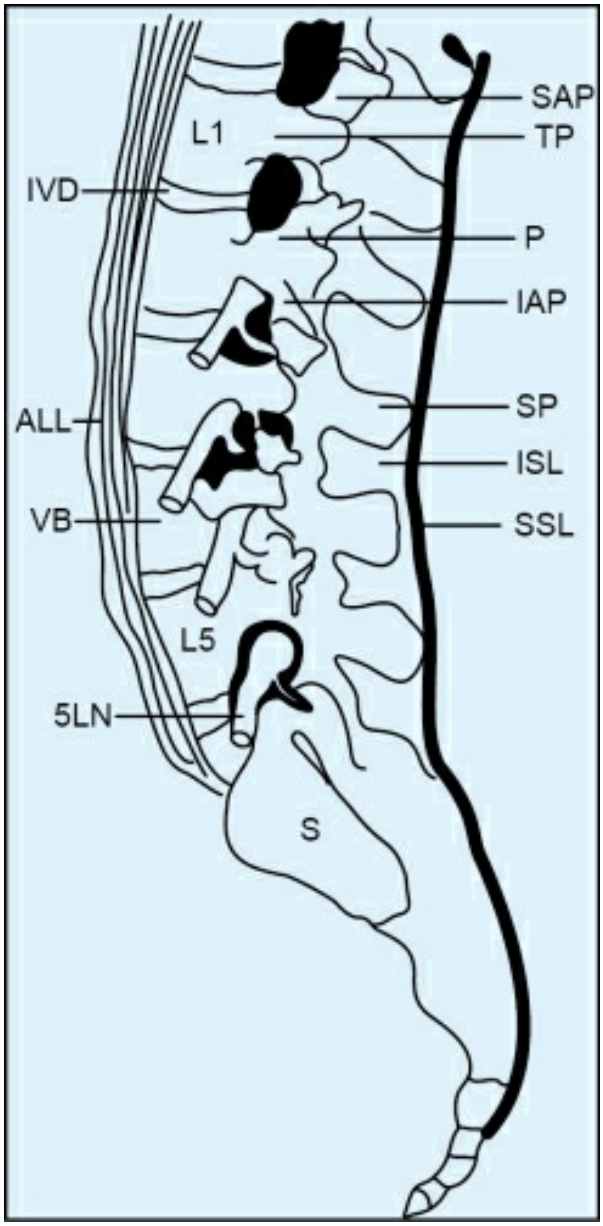

FIG. 32-31 Lumbosacral complex. SAP, superior articular process; TP, transverse process; IAP, inferior articular process; IVD, intervertebral disc;

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P, pedicle; SP, spinous process; S, sacrum; VB, vertebral body of L4; ISL, interspinous ligament; SSL, supraspinous ligament; ALL, anterior longitudinal ligament; 5LN, fifth lumbar nerve.

The facet joints which are formed by the inferior facet of the upper vertebra and the superior facet of the lower vertebra are true diarthrodial joints, complete with joint capsule and synovial lining.

Within each intervertebral space, there is an intervertebral disc with a central nucleus, surrounded by annulus fibrosus. The central nucleus pulposus has gelatinous qualities which dissipate mechanical stresses. The whole disc acts as a shock absorber and is repeatedly subjected to stress, and hence is vulnerable to early degeneration and displacement.

The whole complex consists of a series of joints, musculoligamentous structures, with neural elements in close proximity. All these structures are meticulously designed to offer controlled mobility. However, there are some structural deficiencies which contribute to its susceptibility to back pain in the absence of proper body mechanics and exercise.

Structural and biomechanical inadequacies of lumbosacral complex

Structurally and biomechanically the inadequacies in the following aspects at the L5–S1 intervertebral segment make it susceptible for injury or disc prolapse:

1. Bony configuration

2. Ligaments

3. Muscles

4. Blood supply

5. Nerves

6. Biomechanical factors

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1. **Bony configuration**

(a) The L5–S1 segment bears maximum weight as compared to any other intervertebral joint.

(b) The centre of gravity directly passes through these vertebrae.

(c) It is a site of transition between the freely mobile lumbar vertebrae and the relatively fixed pelvic girdle.

(d) There is a sudden change in the angle at these two vertebrae, making these susceptible for instability or slipping (spondylolisthesis, lumbarization or sacralization).

(e) Vertebral foramen becomes more triangular as it approaches the L5 level. As the pedicles at this level shorten, the space of the spinal canal is reduced, making it more susceptible to compression.

(f) 60%–70% of the spinal flexion occurs at the L5–S1 junction.

2. **Ligaments**

The stability to the lumbosacral and sacroiliac complexes is provided by the posterior longitudinal ligament, which is of special significance, as prolapse of the intervertebral disc usually occurs through a tear in this ligament. It occupies the middle portion and is deficient on either side. Therefore, central protrusion meets a strong barrier, and the protrusion has a tendency to shift laterally which is the

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zone of less resistance. Therefore, the laterally weak posterior longitudinal ligament is the main cause of the commonly seen lateral protrusion of the lumbar disc (Fig. 32-32). Excessive stress on this ligament is prevented by the physiological lumbar lordosis.

The anterior longitudinal ligament spans over the entire length of the vertebral column. It provides anterior stability and restricts excessive extension of the spine.

The supraspinous ligament extends up to the spinous process of L5. It certainly provides excessive mobility at L5–S1 segment at the cost of stability.

The other ligaments, e.g., sacrotuberous, sacrospinous, dorsal and ventral sacroiliac ligaments, interosseous and iliolumbar ligaments provide stability and strength directly to the whole sacroiliac complex and indirectly to the lumbosacral complex.

3. **Muscles**

The following muscles provide stability to the vertebral column, and strength and endurance to the back (Fig. 32-33):

(a) Errector spinae

(b) Intercostalis dorsi

Each muscle group has three parts. The erector spinae consists of the iliocostalis, longissimus and spinalis.

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The rectus abdominis provides remarkable leverage in flexing the spine and also offers anterior stability and cushioning effect by increasing intra-abdominal and intrathoracic pressures. However, ironically, the limb muscle, such as psoas, which originates from the spine, may produce instability of the spine by exerting anterior pull when it contracts strongly in a movement such as resisted hip flexion (especially in an unstable spondylolisthesis).

4. **Blood supply**

Spinal arteries are derived from the vertebral arteries of the cranial region. They proceed inferiorly as the anterior spinal artery and the paired posterior spinal arteries. They diminish in size as they run inferiorly, and alone they are insufficient to supply the caudal portion of the cord. They are reinforced at various levels by the branches of the lower intercostal or upper lumbar arteries. Spinal branches from one or more of these arteries give off a significant branch (radicular artery), which travels along the nerve root. The branch makes an important contribution to the spinal arteries. When this radicular artery is compromised, necrosis of the cord below that level may result.

5. **Nerves**

The major nerve supply is through the posterior and anterior primary divisions of the nerve roots and nerves of Von Luschka. Pain production involves the nociceptive systems of the musculoskeletal tissues of the vertebral column. The nociceptive system distribution in the tissues of the

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intervertebral segment gets triggered and its activation gives rise to the appreciation of pain. This system facilitates activity in the 'T' cells opening the gate. The nociceptive system of nerve endings is widely distributed in all the tissues of the whole complex.

Histochemistry: ATPase which breaks the ATP to produce energy has been reported to be deficient in patients with positive nerve root signs.

6. **Biomechanical factors**

Instead of being straight, the spinal chain assumes a typical curvacious posture. It has two lordotic curves at the cervical and lumbar spinal segments and a kyphotic curve at the dorsal region. These postural adaptations which occur under the impact of the gravitational force play a significant role in the distribution of the weight of the bony structures and the organs from head to pelvis besides offering free spinal mobility. The role of lumbar lordosis in reducing the LBP is well recognized.

Daily activities put tremendous repetitive, compressive and shearing stresses on the bony components of the back, and tensile stresses on the muscular and ligamentous components. The shearing stresses on the intervertebral ligament and the apophyseal joints of the lumbosacral junction are proportional to the angle formed by the superior surface of the sacrum with the horizontal surface. At a normal sacral angle of about 40 degrees, the shearing force is 65% of the superincumbent weight (Fig. 32-34A). This shearing force increases if the anterior tilt is increased,

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and diminishes when the back is flattened (Figs 32-34B and C). Therefore, a protective spasm of extensors occurs following strain which flattens the lumbar curve to diminish the shearing stress.

Intervertebral discs act as shock absorbers and provide hydraulic resistance to motion under high pressure. The lumbar spine is mounted on the sacrum at an angle of 45 degrees and is always eccentric in position, needing some external support for balance. This position produces larger shearing force on the lumbar spine. Maximum strain occurs on the lumbar ligaments during flexion. Greater activity from the lumbar spine results in variations in the intradiscal (ID) pressure. Nachemson (1966, 1976) and Nachemson and Elfastrom (1970) reported data on intradiscal pressures in different postures, activities and exercises. It is extremely important to understand the extent of load on the spine in different situations to guide and plan the precise therapeutic programme (Tables 32-6–32-8).

Active trunk flexion from the supine position raises intradiscal pressure tremendously. Intradiscal pressure of 100 kg during standing rises to 280 kg. Similarly, active hyperextension raises the intradiscal pressure to 180 kg. This needs due consideration before initiating these exercises.

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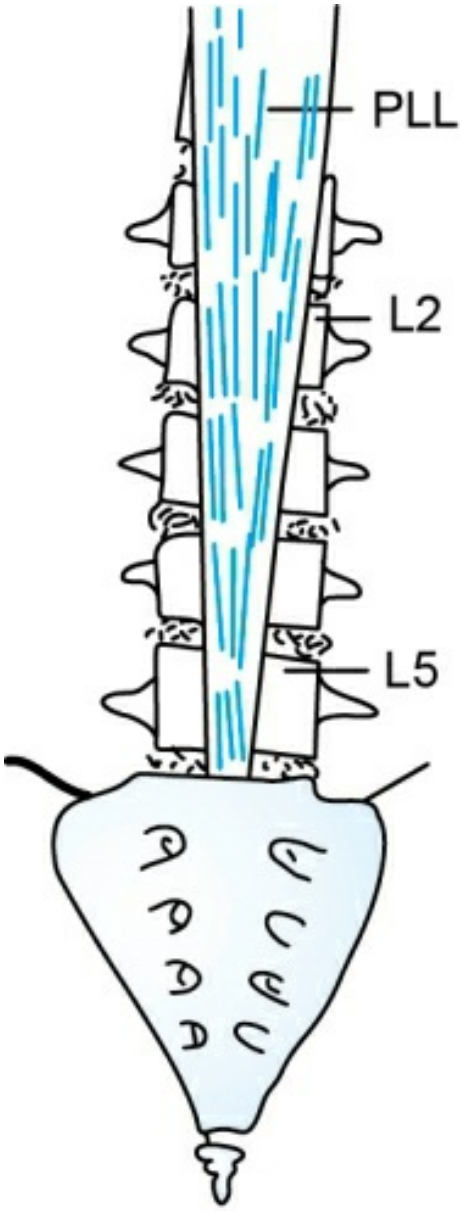

FIG. 32-32 Posterior longitudinal ligament: tapering, as it approaches L5 causing lateral deficiency, a common cause of lateral protrusion of disc at L4–L5 and L5–S1 levels.

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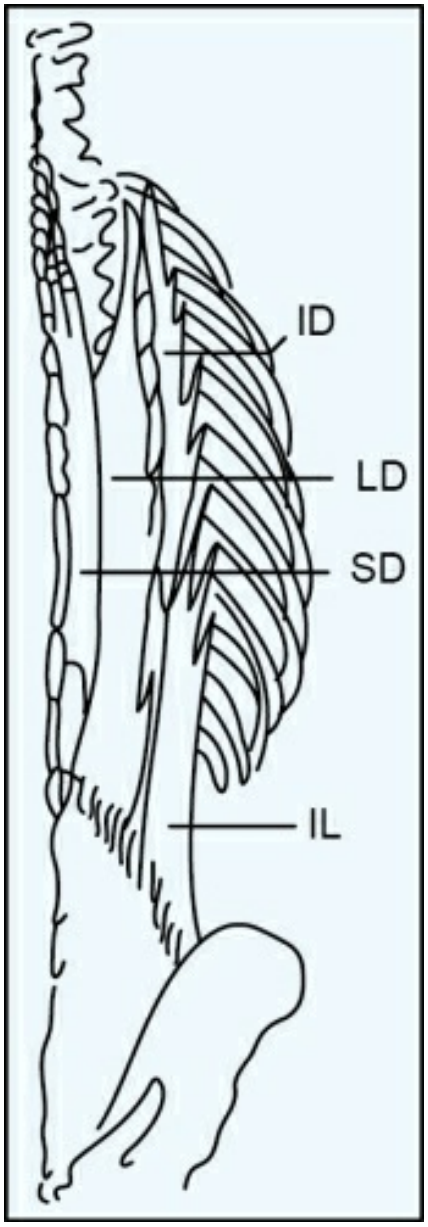

FIG. 32-33 Muscles over the lumbosacral complex. SD, spinalis dorsi; LD, longissimus dorsi; ID, intercostalis dorsi; IL, lliocostalis lumborum.

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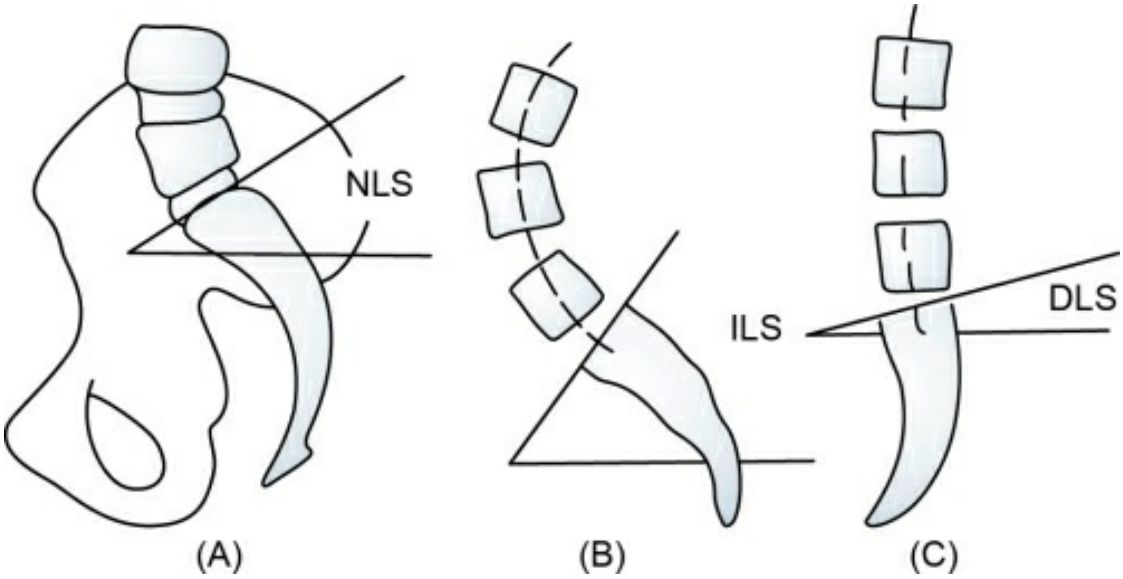

FIG. 32-34 Lumbosacral angle. **(A)** Normal angle (NLS). **(B)** Increased angle resulting in exaggerated lumbar lordosis (ILS). **(C)** Decreased angle resulting in flattening of the normal lordotic curve at the lumbar spine (DLS).

Table 32-6

Intradiscal Pressure Load in Various Body Positions (in a 100-kg Individual)

Position	Load (kg)
Standing still	100
Supine/prone	25
Side lying	75
Supine (leg rested with hip and knee bent to 90 degrees)	35
Sitting with back straight and unsupported arms hanging	140
Sitting forward stoop, back unsupported	185
Sitting forward stoop, lifting weight, back unsupported	275

Table 32-7

Intradiscal Pressure Load in Various Activities (in a 70-kg Individual)

Activity	Load (kg)
Walking	85
Twisting	90
Lateral bend	95
Coughing	120

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Laughing, straining	120
Lifting weight 20 kg (straight back, knees bent)	210
Lifting weight 20 kg (bent back, knees straight)	340

Table 32-8

Intradiscal Pressure (Load) on the Third Lumbar Disc during Various Exercises (in a 70-kg individual)

Position and Exercise	Load (kg)
Standing still	70
Supine	
In traction (30 kg)	110
Isometric abdominal exercise	110
Bilateral straight leg raising (SLR)	120
Sitting	
Sitting up with knees extended	175
Sitting up with knees flexed	180–210
Prone	
Back hyperextension (active)	150
Standing	
Bending forward by 20 degrees	150
With 10-kg weight in each hand	185

Recent observations

Forward flexion of the spine with 20 degrees rotation during standing increases the load on the lower lumbar segments by as much as 40 times (Kelsey et al., 1984; Punjabi et al., 1983). Therefore, an activity of bending forward with rotation to pick up an object (e.g. suitcase) precipitates acute lumbago or disc prolapse.

Thus, the structural and functional deficiencies of the lumbosacral complex and its correlation to the person's day-to-day work will not only be helpful in the diagnosis of the possible lesion but will also help in planning the appropriate therapy.

Aetiology of low back pain

The LBP can arise due to various reasons:

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1. Traumatic – sprain, strain, vertebral fracture

2. Discogenic LBP – due to the lesion in the IV disc

3. Structural defect – mainly in the vertebral spine (e.g., spina bifida, sacralization, scoliosis and spondylosis)

4. Functional defects – wrong postural attitudes, contractures at the hip and knee, limb length discrepancy, etc.

5. Degenerative – degenerative disc disease (DDD), osteoarthritis

7. Metabolic – osteoporosis, osteomalacia

8. Neoplastic – benign or malignant tumours

9. Referred LBP from the lesions in the viscera:

(a) Abdomen

i. Duodenal ulcer

ii. Aortic aneurysm

(b) GI system

i. Renal calculus

ii. WT infection

(c) Gynaecological diseases and genitourinary system

10. Miscellaneous causes:

(a) Functional backache

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(b) Habitual bad posture

(c) Pot belly, etc.

11. Idiopathic LBP

Pathology of low back pain

To identify the exact pathology of the LBP, extensive physical examination and evaluation is necessary and should include the following:

1. History

2. Examination of posture

3. Evaluation of pain characteristics

4. Palpation

5. Range and rhythm of spinal movements

6. Neurological examination

7. Diagnostic physical tests

8. Evaluation of functional status

History

Previous or present history related to the present problem, its treatment and the response: Clinical signs and symptoms indicating or suspecting the presence of infection, tumour, systemic disease, vascular disease, rheumatic affection and GI tract, endocrinal and gynaecological diseases should be carefully screened to rule out these, as they could be associated with LBP.

Vascular lesions, viscerogenic disorders, genitourinary disorders and gastrointestinal lesions are known to cause referred LBP.

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Information about the working posture or a leisure time posture adopted for longer periods (e.g., sedentary games and watching TV) should be noted in relation to the LBP.

Examination of posture

The normal physiological postural curves and gait should be observed from the front, back and the side.

Assessment of pelvic tilt: Deviation from the normal angle of pelvic tilt is assessed in standing position. The tilting of the pelvis could be anterior, posterior or lateral.

Anterior pelvic tilt: The anterior tilting of the pelvis may occur as a result of the protruding abdomen (e.g., in obese people), tight low back muscles, tight hip flexors, weakness in the abdominal muscles, tight hamstrings or in spondylolisthesis. When present, it puts excessive pressure on the posterior aspect of the vertebral bodies and the facets, as there is exaggeration of the lumbar lordotic curve.

Posterior pelvic tilt: Posterior tilt may result from tight or overdeveloped low back muscles. Weakness of hip flexors (psoas) or localized muscular spasm may result in the obliteration of normal lumbar lordosis into a flat back.

Lateral pelvic tilt: In lateral pelvic tilt, the pelvis drops on one side. It could be due to limb length disparity, unilateral lumbosacral strain, structural scoliosis or scoliosis due to unilateral muscular spasm. Reasons may also include muslce imbalances, such as weakness of gluteus medius, with strong hip adductors and lateral rotators on the raised side of the pelvis, with tightness of the adductors and TFL on the opposite side or unilateral PIVD.

Objective measurements of pelvic tilt: Anterior and posterior pelvic tilts are measured on a radiograph lateral view. The angle formed by a line parallel to the superior level of sacrum with the true horizontal line is measured. The normal angle is in the vicinity of 30 degrees. It increases in the lordotic curve (Fig. 32-34).

Lateral pelvic tilt is objectively measured by measuring leg length when there is discrepancy in one leg. It can also be assessed by measuring the difference in the true horizontal line and the horizontal

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line passing over the tips or the bony prominences of anterior or posterior iliac spines.

Evaluation of pain characteristics

The characteristics of pain type, site and its behaviour provide important clues to the diagnosis of LBP. The where, when and how characteristics of the pain should be noted (Table 32-9).

Where	–	furnishes the information about its location
When	–	indicates the time, duration, posture or activity precipitating the pain
How	–	relates to the position or activity aggravating, relieving and reproducing the pain

Table 32-9

Pain Characteristics Related to the Specific Spine Tissue Involvement

Tissue Involved	Pain Characteristics	Innervation (Pain Sensitivity)
Ligaments	Localized and deep pain	Posterior longitudinal ligament is richly innervated, other ligaments are innervated unevenly
Muscles	Localized dull ache	Extremely sensitive and have abundant innervation
Nerve roots	Pain over the dermatomal distribution or throughout the length of the nerve in inflammatory conditions	Richly innervated and highly sensitive
Blood vessels	Deep pain	Vertebral venous plexus is richly innervated and is extremely sensitive
Bones	Deep, often radiating pain	Periosteum is richly innervated and extremely sensitive
Facets joints	Dull diffuse pain with specific radiation patterns; Referred pain covering longer distance may be present	Joint capsule and ligaments have numerous nerve endings and are highly sensitive
Disc	Lumbago when posterior longitudinal ligament is compressed or sciatica when the nerve root is compressed	Depends upon the innervation and pain sensitivity of the tissue compressed by the disc

The type of pain such as sharp, stabbing or burning originates from the nerves; nonspecific and vague pain is present due to soft tissue inflammation; radiating pain could arise as a result of nerve pathology, whereas constant severe pain even during rest may indicate a tumour.

Areas of pain should be clearly marked on the body chart for easy

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reference (Fig. 32-35).

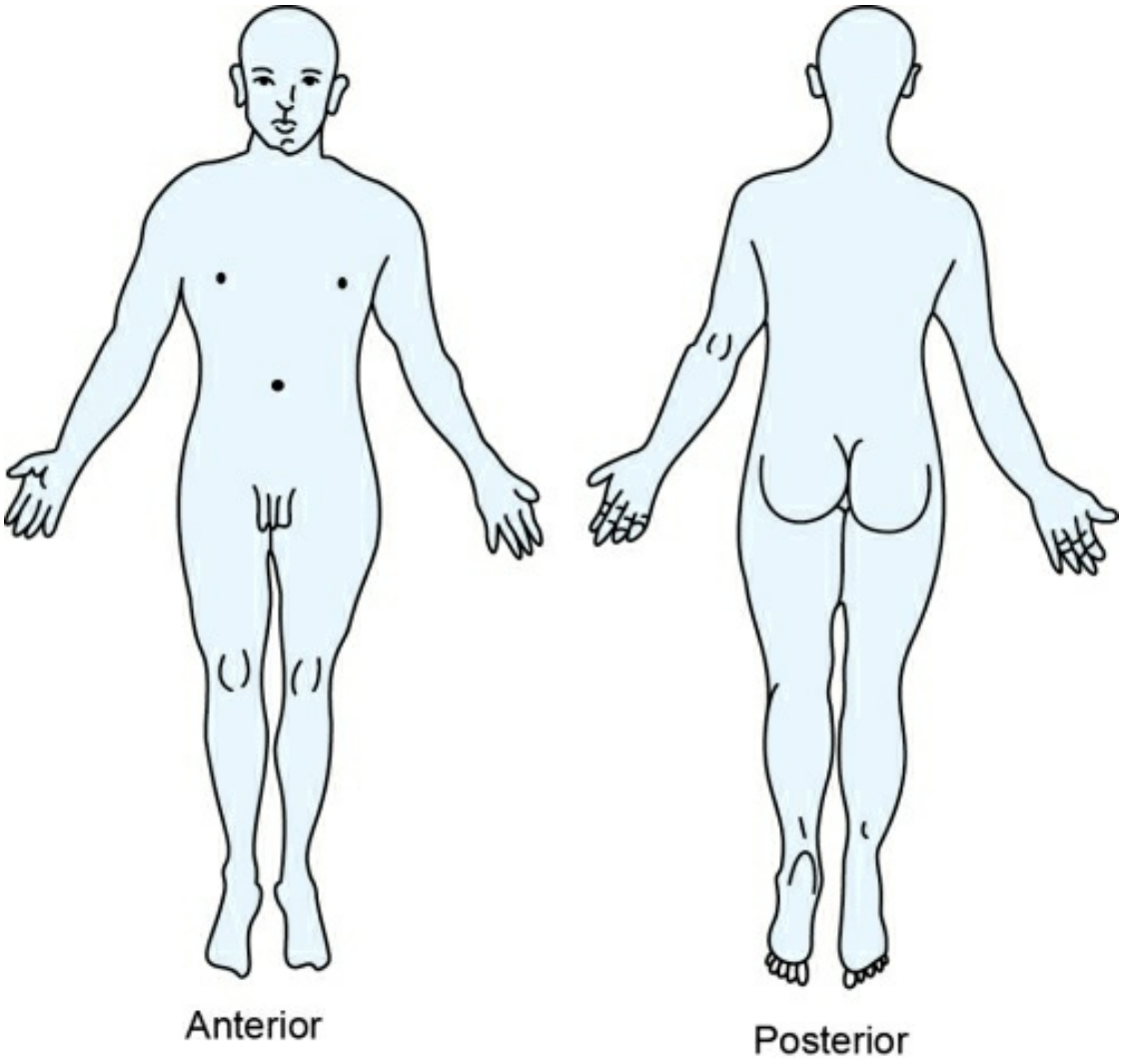

FIG. 32-35 Body charts to mark characteristics of pain.

The exact area of pain should be pinpointed by the patient on the bare body, and documented on the body chart.

Subjective recording of the gravity of pain should be made by using a visual analogue scale (Fig. 32-36) or the McGill pain questionnaire (Melzack, 1975).

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FIG. 32-36 Horizontal pain perception visual analogue scale (VA scale).

Palpation

Palpation helps in recognizing the specific tissues at fault. It can be done effectively in prone position. Each spinous process is palpated separately with firm pressure in the anterior and lateral directions. Bony tenderness is palpated over the paravertebral and interspinous areas, lumbosacral junction and sacroiliac joints.

Palpation is done to detect local muscular spasm and trigger points over the paravertebral region, posterior aspect of gluteal region, thigh and calf.

Percussion: Lightly percuss the spine from the root of the neck to the sacrum with the patient in forward bend position. Marked pain indicates tuberculosis or any other infection.

Localized muscular tenderness is examined by picking up and rolling manipulations of various muscle groups of the lower limbs. Documentation on the body chart can help correlate the myotomic distribution to detect the level of the lesions.

Nodules, when present, can be detected by picking up and rolling of the muscles over the paravertebral region.

Deep tenderness should be tested over the sciatic notch. Jabbing pressure with the heel of hand is applied to detect tenderness over the intervertebral joints. Compression test to the pelvis is employed to test sacroiliac joint pathology.

Intervertebral joint alignment is tested by palpating over the spinous processes. Undue prominences of the spinous process with a definite gap (step) and exaggerated lumbar lordosis indicate spondylolisthesis.

Palpation for temperature changes and sweating should be done with the back of the hand to detect local inflammation. Peripheral

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pulses should be palpated to assess the circulatory status. Gentle tap over the kidney area in the absence of localized signs and the presence of girdle pain indicate renal pathology.

Range and rhythm of the spinal movements

The movements of the lumbosacral complex include basically the movements at the intervertebral joints of the lumbosacral spine and the synchronized movement or stabilization of the pelvis in relation to the hip joint. The principal movements to be examined at the lumbosacral complex are flexion, extension, lateral flexion and rotation to either side.

Characteristics of movements

The aim is to reproduce the patient's symptoms by doing movement or by appropriate joint sign. Normally the movement should be of full range and pain free with overpressure. Sometimes sustained test for extension, lateral flexion and quadrant test towards the symptomatic side may be required to reproduce the symptoms.

The movements are tested as active ROM, resistive (isometric) small arc movements and passive movement with overpressure at the terminal range. Besides these, passive accessory intervertebral movements are tested at the early, mid and late ranges to elicit the 'joint sign'. A 'joint sign' is an alteration in active, passive, physiological or accessory joint mobility relative to pain, resistance or spasm which limits the ROM of the joint. The joint sign helps in detecting the exact vertebral level involved and also the status of the passive mobility of the intervertebral joints.

The restriction of active range indicates segmental soft tissue inflexibility of the functional units, facet capsules, ligaments and fascia. Resistance to movement will produce pain in the musculotendinous lesions. Pain on passive movement will produce compression in the joint – producing pain due to joint pathology or nerve compression.

Application of overpressure also increases pain at the site of the lesion and increased radiation.

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To find out the appropriate structures related to pain, the symptoms should be reproduced by performing movement enough to the point of first increase in symptoms.

Flexion (lumbar pelvic rhythm): It is tested by asking the patient to bend forward (toe touching) from stride standing without bending the knees. The movement involves synchronized movement of flexion at the intervertebral joints of the lumbar spine and rotation of pelvis around the hip joint. In this rhythm the lumbar lordosis gradually flattens and turns into a kyphosis at the terminal range of flexion (Fig. 32-37). This puts tremendous amount of compressive force and load on the anterior vertebral margins with opening up of the posterior vertebral margins.

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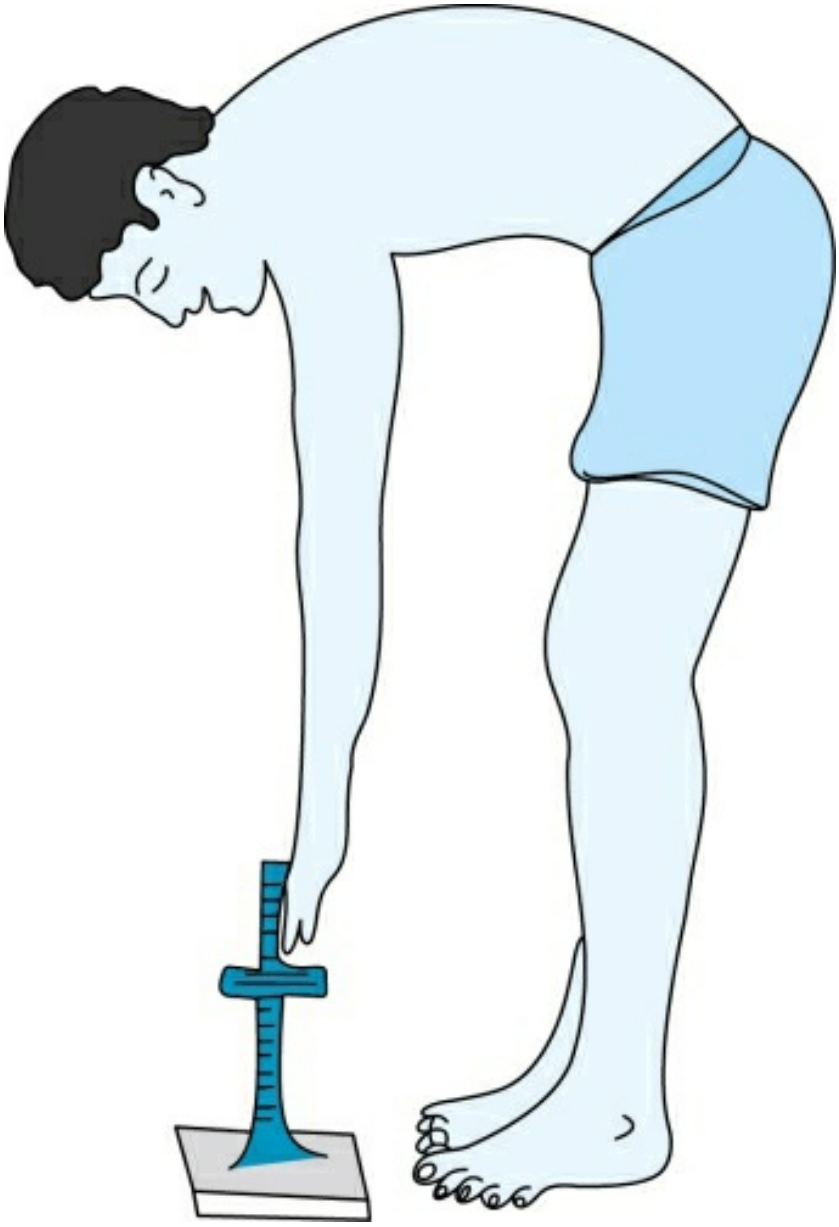

FIG. 32-37 Normal lumbar pelvic rhythm showing the normal lumbar lordosis turning into a kyphosis at the terminal range of flexion and its measurement by sliding ruler arrangement.

The restriction of flexion indicates the soft tissue inflexibility at the lumbosacral complex and/or pelvis due to protective reflex spasm from pain or guarding (tightness of hamstrings could also result in altered rhythm).

Occasionally, trunk flexion may be associated with rotation to one side. This indicates the presence of structural scoliosis, indicating

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lumbosacral facet tropism. It may be limited to the hip joint, the lumbar spine remaining rigid as in ankylosing spondylitis. Persistence of lumbar lordosis instead of kyphosis at the terminal range of flexion is an indication of hypermobility of the lumbosacral spine.

The patient gradually attains erect posture from flexion. This is achieved by reversal of lumbar pelvis rhythm, the movements of the pelvis on hip and lumbosacral spine. Derotation of pelvis occurs and lumbar kyphosis changes to lumbar lordosis. Normal range is 80 degrees.

Extension: From the erect stride standing posture, the patient is asked to extend the whole spine beyond midline to the maximum range (Fig. 32-38). This movement produces compression on the posterior vertebral bodies and facet joints with the opening up of the vertebral bodies anteriorly. It produces pain due to compression of the posterior structures. Normal range is 20–30 degrees.

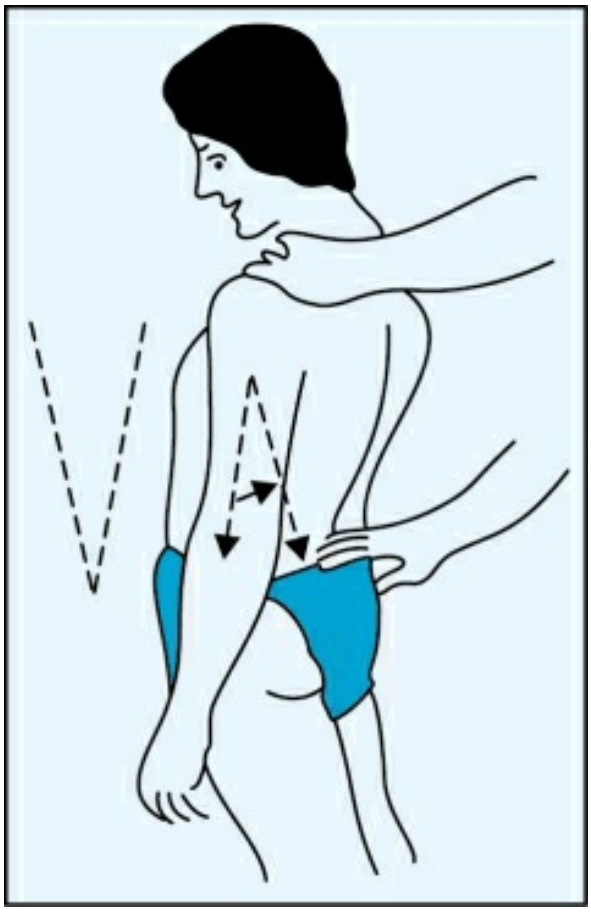

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FIG. 32-38 Spinal extension and its measurement by plumb line pointer.

Lateral flexion: A patient with knees straight is asked to bend the trunk to one side sliding his hand (finger tips) as near to the floor as possible from the lateral aspect of the leg. This movement compresses the tissues on the lateral side of the spine on the side of bending and causes stretching of the tissues on the contralateral side. If flexion towards the painful side aggravates the pain, the lesion could be either due to intra-articular pathology or a disc lesion lateral to the nerve root. If lateral flexion away from the painful side increases pain, then the lesion may be articular or muscular in origin; disc protrusion, if present, is likely to be medial to the nerve root. Normal range is 40–45 degrees (Fig. 32-39).

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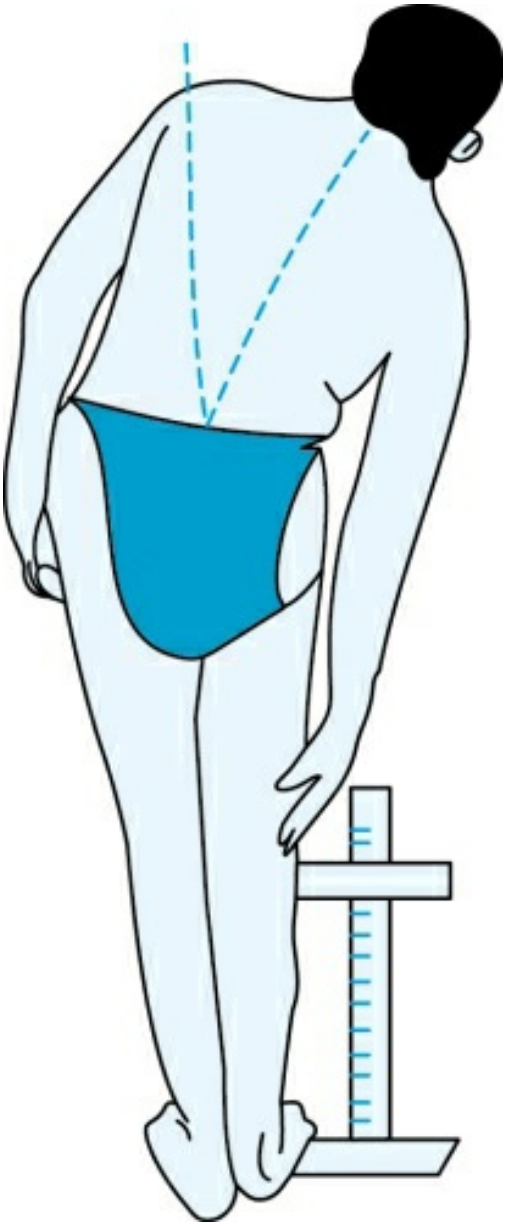

FIG. 32-39 Lateral flexion of the spine and its measurement by sliding ruler arrangement.

Rotation: Rotation is tested with the patient lying on the side or sitting with the hip and knee in flexion. The movement is tested on both sides (right and left). The site of pain is noted, and is assessed in relation to the other movements tested earlier.

Objective methods of measuring spinal movements

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Flexion

1. Macrae and Wright (1969) described the skin distraction method. Three ink marks are made. First at the lumbosacral junction over a line joining the dimples of venus. Other two marks are made at 5 cm below the first mark and 10 cm above it. The distance between the upper and lower marks before and after the movement denotes flexion (Fig. 32-40).

2. The same method can be used by putting marks on the spines of T1 and S1. The normal increase in distance is about 10 cm in adults.

3. It can also be assessed by measuring the distance between the middle finger tip and the floor in forward flexion. Normally, the fingertip touches the floor or remains within 7 cm from it (Fig. 32-41).

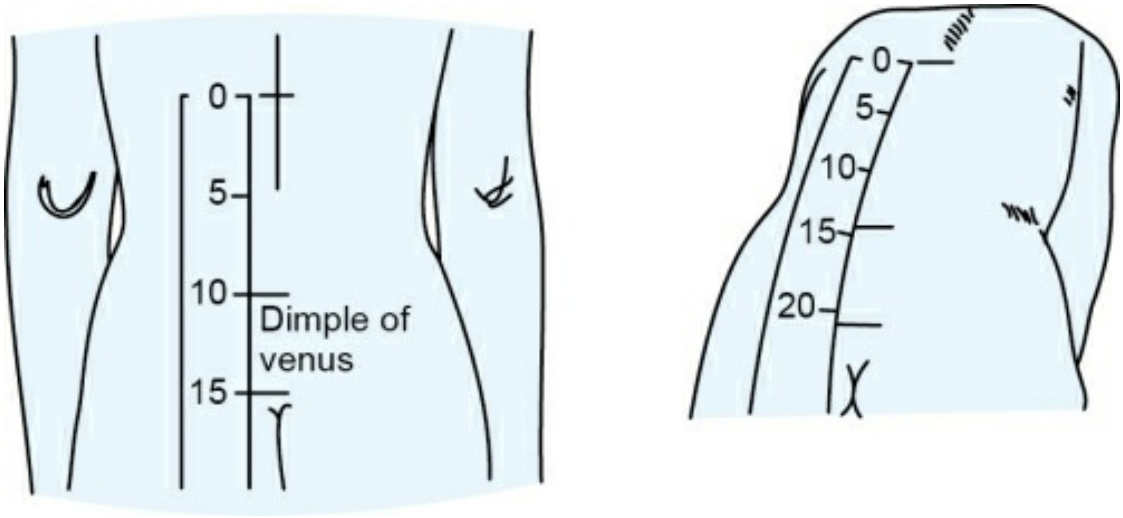

FIG. 32-40 A method of measuring lumbar flexion by skin markings.

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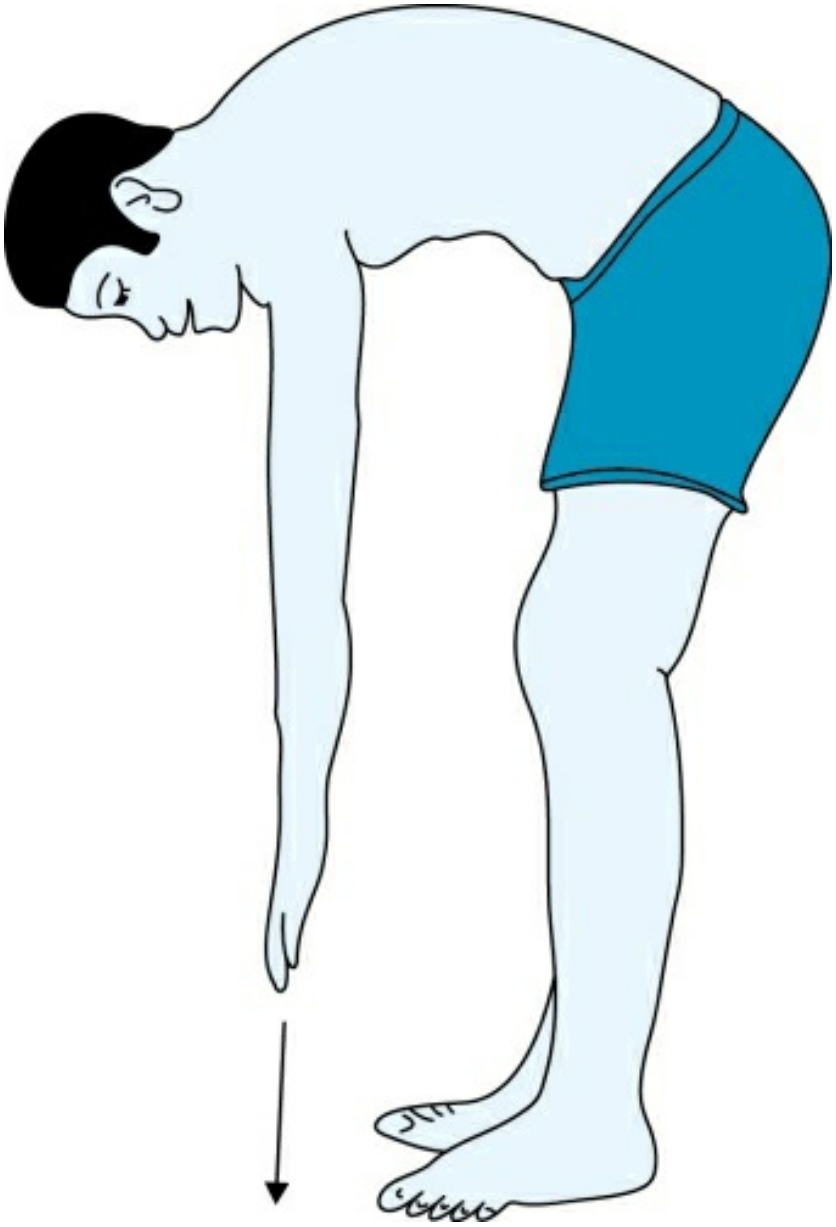

FIG. 32-41 Measurement of lumbar flexion by fingertip to floor distance measurement.

Extension

The distance traversed by the plumb line pointer held at the side of the trunk (see Fig. 32-38) provides a measure of extension (Moll, Liyange, & Wright, 1972). The upper mark represents the intersection of a horizontal line through the xiphisternum with the coronal line. The lower mark represents the intersection of a horizontal line

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through the highest point on the iliac crest with the coronal line.

Lateral flexion

1. The landmarks are the same as described for extension. The difference between these two marks in erect standing and after lateral flexion is measured.

2. It can be measured by fingertip to floor method while the patient is performing lateral flexion, the arm being held on the lateral side of the leg with the elbow extended (see Fig. 32-39).

3. It can also be measured by measuring the angle formed between the line drawn through T1, S1 and the vertical (see Fig. 32-39). The average range is 30 degrees.

Rotation

The subject lies on one side with hips and knees flexed to 90 degrees. The shoulders are rotated to prone position, and the head is rotated to the opposite direction. The surface inclination to the vertical is measured by placing a goniometer on the forehead and on T1, T12 and the sacrum. The regional spinal rotation can be calculated from distances between adjacent inclinations as described by Loebl (1973).

It can also be measured in sitting position. Ask the patient to rotate to one side. On completing the rotation, the angle formed between the planes of shoulders and the pelvis is measured (Fig. 32-42). The normal value of ROM is 40 degrees, mainly thoracic, the lumbar contribution is only of around 5 degrees (Macrae and Wright, 1969).

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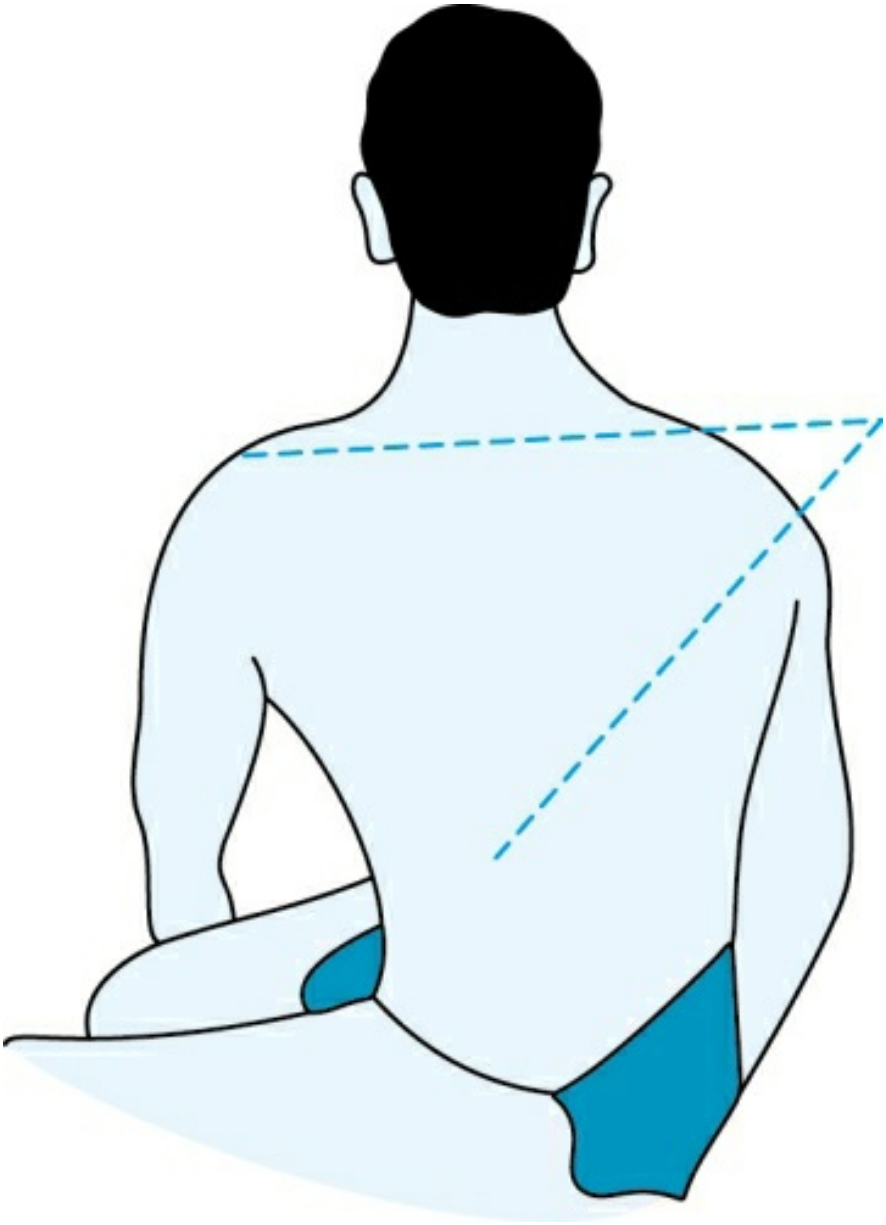

FIG. 32-42 Method of measurement of spinal rotation.

Spondylometer or inclinometer can also be used for objective measurements.

Chest expansion

It is necessary to measure chest expansion using measuring tape, especially in young males where ankylosing spondylitis is suspected.

Neurological examination

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Examination of the nervous system consists of checking the sensory status, the motor power, atrophy of the muscle groups, tenderness and the tendon reflexes.

Sensory status: The sensory supply is carried through various dermatomes representing particular nerve root or spinal segmental levels. Therefore, sensory paraesthesia in the distribution of a particular dermatome can detect the neurological level of the lesion (see Fig. 32-73A). Areas of sensory deficits should be marked on the body (limb) chart to identify the level of the lesion and to correlate it with the findings of the other tests.

Motor power: The muscles receive their motor innervation from specific nerve roots. Therefore, muscular weakness or atrophy of a particular muscle group is related to a specific nerve root.

The orderly sequence of motor innervation of the limb musculature (myotomes) provides information about the possible levels of the lesion (see Fig. 32-73). In general, each joint and muscle group is innervated by multisegmental roots. However, there are always predominant nerve roots for each muscle group (as shown in Tables 32-10 and 32-11). Thus, the dominating level can be identified. Predominant root involvement level can also be worked out by using adjacent segmental supply. For example, hip flexor and adductor groups receive their innervation from L2 and L3 segments, whereas quadriceps receive innervation from L3 and L4 segments. Thus, if the quadriceps is normal in the situation of hip flexor weakness, the predominant lesion could be at L2.

Manual muscle testing (MMT) is inadequate; endurance of a specific muscle group rather than strength is a more precise test. Muscle endurance is tested by repeated

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resistive isotonic movements (isokinetic) to the muscle or isometric hold. Early fatigue indicates lack of endurance. The myotomic representation of such a muscle group will indicate the level of the lesion. While testing muscular endurance, it may be remembered that weakness first appears in the extensor hallucis longus before the other dorsiflexors in a lesion of L4–L5 level. Similarly, flexor hallucis longus becomes weak before gastrocnemius in a lesion of L5–S1 level. Therefore, these muscle groups need special attention in the expected lesions at L4–L5 or L5–S1 level.

Muscular atrophy: It can be assessed by measuring the girth of the thigh (quadriceps) and leg (calf) or by volumetric method (water displacement technique).

The innervation of the major movements (the prince maers) is very useful (see Fig. 32-73).

Muscular tenderness: The presence of tenderness in the muscle groups can provide further confirmation of the level of the lesion (as described under palpation and in Table 32-12). The tender areas also need to be accurately marked on the body chart.

Tendon reflex test: It provides information about the integrity of the reflex arc in identifying the level of the lesion (Table 32-13).

Knee jerks or quadriceps tendon reflex: Done in sitting position with the legs hanging at the edge of the table, or in supine position with knee flexed. Patellar tendon is tapped with a hammer, which elicits involuntary knee extension.

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If it is sluggish or absent, it indicates lesion at L4 root involving L3–L4 disc.

Medial and lateral hamstrings reflex: It can be done in prone position with knee supported (relaxed) in flexion. Reduced or absent medial hamstrings reflex response indicates lesion at L5–S1 level.

Ankle jerks: It can be tested in sitting, supine or prone position, assuring relaxation of the ankle. Sluggish or absent ankle jerk indicates the lesion at S1 root involving L5–S1 disc.

Plantar response: Scratching of the sole of the foot produces sudden reflex contraction of the extensor hallucis longus. This pulls up the limb into flexion–abduction and internal rotation at the hip. Weakness or loss of plantar response indicates lesion at S1.

Cauda equina lesion: Impaired bladder function, loss of perianal sensation and rectal tone to be assessed, as they indicate massive herniation of the disc into the spinal canal.

Table 32-10

Segmental Innervation of Joint Movements

Joint	Movements	Segmental Spinal Innervation
Hip	Flexion, adduction, internal rotation	L2 and L3
	Extension, abduction, external rotation	L4 and L5
Knee	Extension	L3 and L4
	Flexion	L5 and S1
Ankle	Dorsiflexion	L4 and L5
	Plantar flexion	S1 and S2
Foot	Inversion	L4
	Eversion	L5 and S1
	Intrinsic	S1, S2 and S3

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Table 32-11

Segmental Supply of Lower Extremity Muscles

Muscle Group	Segment
Psoas, adductors of hip	L2 and L3
Quadriceps	L3 and L4
Tibialis anterior	L4
Tibialis posterior	L5 and S1
Extensor hallucis longus	L5
Flexor hallucis longus	S1
Peronei	L5 and S1
Toe extensor	L5 and S1
Calf, toe flexor	S1 and S2
Hamstrings and gluteus maximus	L5, S1 and S2

Table 32-12

Nerve Root Irritation and Muscular Tenderness

Nerve Root	Tender Muscle Groups
L4	Quadriceps
L5	Tibialis anterior
S1	Gastrosoleus
Emotional overtone	Subcutaneous surface of tibia

Table 32-13

Segmental Representation of Tendon Reflexes

Joint	Reflex	Segment
Knee	Quadriceps	L3 and L4
	Hamstrings	L5, S1 and S2
Ankle	Gastrosoleus	S1 and S2
	Plantar response	S1

Diagnostic physical tests

The data collected from history and physical examination are correctly interpreted. Specialized diagnostic neuro-musculoskeletal tests can be done whenever necessary to arrive at the exact diagnosis.

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Presence of sciatica: If there is unilateral trunk deviation giving rise to sciatica during trunk flexion, it is a diagnostic sign of possible unilateral disc protrusion. When the disc protrusion lies in the axilla of the root, the trunk is deviated towards the painful side, whereas if the protrusion lies lateral (shoulder) to the nerve root, the patient will try to prevent further root compression by deviating away from the painful side (Fig. 32-43).

Straight leg raising (SLR) or Laseque's sciatic nerve test: It is one of the important diagnostic tests. It is a protective reflex test which causes traction on the sciatic nerve, lumbosacral nerve roots and dura mater. It is a passive test done in supine position (Fig. 32-44). Appearance of pain in the distribution of the sciatic nerve up to 45 degrees of hip flexion with extended knee indicates positive SLR test. If the pain thus felt is aggravated by passive flexion of the neck and passive dorsiflexion of the foot, it is a 'positive neural sign' or positive SLR. The real stretching of the inflamed dura is possible only with all these three manoeuvres. While conducting SLR test, it must be remembered not to confuse it with hamstrings stretch due to straight leg raising, especially in patients with tight hamstrings confirmed by dull pain over the posterior aspect of the knee joint.

Performance of SLR on the contralateral side draws the dural tube downwards, exerting tension directly on the nerve root of the affected side eliciting back pain. It indicates nerve root compression (Fajersztajn test), and must be included.

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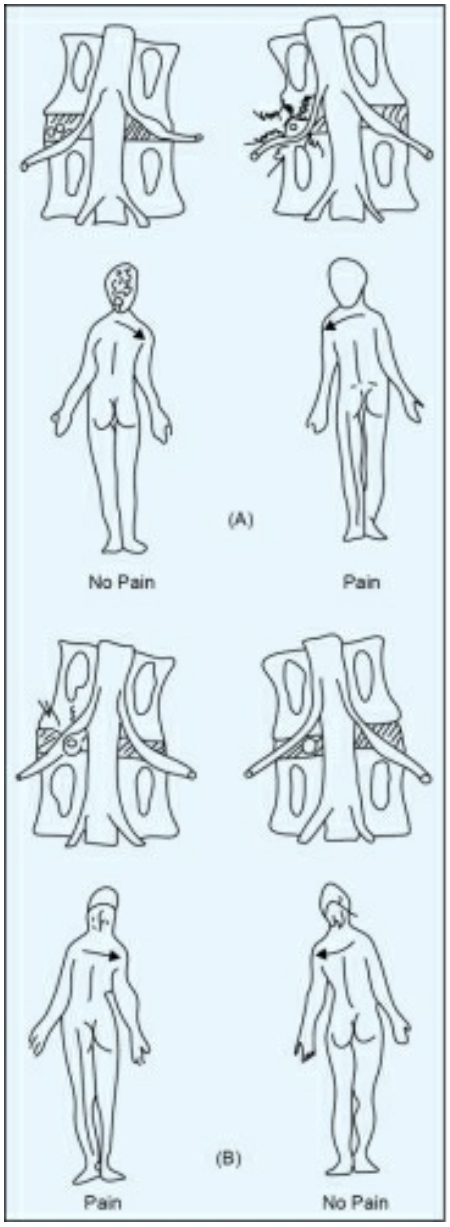

FIG. 32-43 Diagnostic sign of unilateral disc protrusion. **(A)** Disc protrusion lateral to the nerve root; the list appears to the side opposite to sciatica. **(B)** Disc protrusion medial to the nerve root; the list appears to the side of sciatica.

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FIG. 32-44 Straight leg raising (SLR) test. Pain in the distribution of sciatic nerve at 45 degrees of hip flexion with knee in extension indicates positive SLR. The tension on the sciatic nerve is increased further by a passive dorsiflexion of the ankle and foot.

Slr and the type of lesion

1. *Small protrusion*: Arc of SLR may be painful, or pain may be felt only at the extreme of SLR.

2. Moderate protrusion: Positive SLR but no neurological deficit. It indicates minor pressure near the intervertebral foramen, interfering with mobility but not with conduction.

3. Large protrusion: Positive SLR with neurological deficit indicating compression at the root sleeve as well as the parenchyma.

4. Elicitation of back pain on SLR: This is suggestive of central disc protrusion, whereas pain in the posterior aspect of the leg is suggestive of lateral protrusion.

Pitfalls of slr test

1. In the event of root atrophy, due to massive posterolateral protrusion, the nerve root becomes insensitive due to ischaemia. In such a situation, although the SLR may be negative, it is accompanied with numbness in the foot, an indication of progressive lesion.

2. The SLR test is valid only to test the mobility of the fourth and fifth lumbar nerve roots. It is not valid in the first three lumbar and the first sacral lesions.

Alternate SLR: Whenever there is doubt about the genuineness of the test, ask the patient to sit up with legs straight. If the sitting posture can be assumed without flexing the knee, the test is negative (Fig. 32-45).

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Prognostic value of SLR: When the disc protrusion is either mild or moderate, where SLR is positive without neurological deficits, usually conservative treatment is indicated. Under such circumstances, accurate measurement of the angle of SLR where the sciatic radiation begins is measured. Subsequent increase in the angle of SLR with lesser pain indicates good prognosis.

Bowstring sign: In this test the SLR is carried out until the pain is reproduced. At this point the knee is gradually flexed till pain disappears. The examiner rests the limb on his shoulder and places the thumb in the popliteal fossa over the sciatic nerve. Sudden firm pressure on the nerve reproduces pain in the back, or the pain radiating down the leg indicates positive bowstring sign or significant root tension (Fig. 32-46).

Slump test for mobility at the intervertebral foramen and the spinal cord: Passive neck flexion and straight leg raising help in detecting any reduction in the mobility of pain sensitive structures within the intervertebral foramen or the vertebral canal. If these prove negative, the ultimate test for mobility of these structures is done by the 'slump test'.

The patient is made to sit in a slouch sitting with knees in relaxed flexion at the edge of the table. The physiotherapist passively bends the head and the trunk forward, as much as possible, with total support, bringing the head down in between the knees. The patient is then asked to extend the knees alternately to the maximum, maintaining the foot in dorsiflexion. If pain is produced on attempting knee extension, the limiting range is noted. The positive test indicates interference of the mobility at the intervertebral foramen or the vertebral canal (Fig. 32-47). It may be noted that this test will also be positive in the presence of hamstrings tightness.

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Lumbar third nerve root test (reverse Lasegue test): The patient is made to lie in prone position, maintaining the hip in neutral extension. The knee is passively flexed. Pain in the distribution of femoral nerve indicates irritation of the third lumbar nerve root. The test is positive if the symptoms are aggravated on passively extending the hip (Fig. 32-48).

Test for pain of muscular origin (resisted isometric test): Applying increased resistance to the muscle action without producing movement builds up tension in the muscle. It would give rise to pain if the lesion is in the muscle. This test can be done on any muscle to diagnose muscular lesion.

Test for the pain originating at the articular structures: Full range passive movement is carried out with relaxation of the concerned muscle group. Pain due to slight overpressure beyond this point indicates joint pathology.

Test for sacroiliac irritation: Presence of tenderness on palpation at the sacroiliac joint is tested further to confirm the lesion at this joint by the following two tests:

1. *Gaenslen's test*: The patient is made to lie on the side of the unaffected hip joint and asked to flex the unaffected hip to the knee–chest position. He firmly holds the thigh against the chest. The examiner passively extends the other hip joint, keeping the knee straight. This produces rotary strain on the pelvis and tends to rotate half of ilium against the sacrum, eliciting pain at the SI joint in the presence of SI joint pathology (Fig. 32-49).

2. Pain is produced in the sacroiliac joint by pelvic compression or by attempting to 'open out' the pelvis. This is done with the thumbs hooked round the anterior

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superior iliac spines (Fig. 32-50).

Provocative test for acute disc herniation: Kopp, Alexander, Turocy, Levrini, and Lichman (1986) reported a test to detect whether the disc herniation is only intrinsic (with intact annulus bulging) or extrinsic (nucleus extrusion through the tear in the posterior annulus into the spinal canal).

In this test, the patient in prone position is asked to passively extend the lumbar spine by pushing up on forearms, and then on the hands by extending the elbows (Fig. 32-51). This forces the nucleus anteriorly. This test will be negative when the herniation is intrinsic but will be positive if it is extrinsic. Intrinsic extrusion can be treated successfully by conservative approach; however, extrinsic extrusion needs surgical intervention.

Test for root irritation: Presence of tenderness in the muscle is a positive sign of root irritation. During palpation, tenderness over quadriceps, anterior tibial group and calf muscles is a positive sign of the nerve root irritation at L4, L5 and S1 levels, respectively.

Test for root conduction: Impairment of nerve root conduction is confirmed by dermatomal sensory loss, myotomal motor weakness and impairment of the respective reflex response. In later stage (after 3 weeks of prolapse), muscular atrophy may occur in the respective muscle group.

Disc protrusion level: A disc herniation at L4–L5 level actually affects the fifth lumbar nerve root because of the upward migration of conus medullaris during development. Similarly, herniation between the fifth lumbar vertebra and the sacrum (L5 and S1) usually compresses the first sacral nerve root rather than the fifth lumbar nerve root.

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A central or midline disc protrusion of the fourth lumbar disc may cause compression of the fifth lumbar nerve root, first sacral nerve root or even all the sacral nerve roots due to the proximity of these nerve roots in the spinal canal. This will be confirmed by the involvement of the bladder and paralysis of foot muscles.

Test for hip pathology (Faber's sign):

1. Pain is felt in the hip joint on attempting hip flexion–abduction with external rotation.

2. The patient is placed supine with the hip held in flexion. Full range of passive external and internal rotation is attempted with slight overpressure at the end of the range. If there is pain-free normal ROM with overpressure, the hip pathology is eliminated (Fig. 32-52).

Test for back pain due to dorsal ramus syndrome (DRS): Low back pain radiating to the lower extremity with concurrent spasm in the back muscles may be due to disc pathology or mechanical irritation of specific tissues of the lower back (e.g., interspinous ligaments, multifidus muscle, zygapophyseal joints). Irritation of the dorsal ramus (Bogduk, 1980) can give rise to pain in the lower back region, radiating to the posterolateral aspect of the leg. However, the nature of pain due to the dorsal ramus syndrome is a deep and dull ache as against a sharp and precisely located pain due to disc pathology. The symptoms also have no segmental distribution.

The pain radiating down the leg and below the knee arises from disc levels at L4–L5 or L5–S1. The pain radiating from L3–L4 level or higher does not radiate below the knee.

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Lumbar flexion–extension test to differentiate between disc and facet joint pathology: This test is performed to differentiate between disc lesion and facet joint pathology. The movement of lumbar flexion increases the compression force between the two adjacent vertebrae anteriorly, causing the disc to move posteriorly, and increases the patient's pain as it causes nerve root compression. At the same time, it decreases the compression force between the adjacent facet joints and there is reduction in pain if it is due to compression of the facets joint.

Conversely, lumbar extension will increase compression force between the two adjacent vertebrae posteriorly, allowing the disc to move anteriorly, reducing pain if it is due to disc pathology, whereas it increases the compression force on the facet joints, increasing the pain if pathology exists in the facet joint.

Identification of functional LBP: There is discrepant motor weakness. Initiation of movement even against weak resistance is pretended to be not possible but, at the same time if taken passively, the patient has the ability to hold the same extreme position of the movement. Similarly, relaxation is jerky and irrespective of the resistance. This is usually seen in psoas (hip flexion). The patient may complain of constant pain, but there is marked discrepancy in all the tests.

Identification of nerve root tension: *Sciatic nerve root tension*: Pain reproduction by applying stretch to a peripheral nerve, e.g., reproduction or aggravation of pain by forced dorsiflexion of ankle at the limit of slow passive SLR. Pain is relieved by passive knee flexion. If, however, the pain persists or increases on further hip flexion, emotional imbalance or hip joint pathology could be suspected.

Relationship of list to the severity of condition: When list is present,

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it is important to find out if it is correctable. If the symptoms are reproduced (e.g., whole leg pain and foot paraesthesia) by the passive correction of the list by 25%, the presenting condition is severe and irritable.

Recent tests: The following tests predict the prognosis and the possible therapeutic planning:

1. Use of lumbar extension

2. Hip, knee 90–90 test.

(a) *Use of lumbar extension*: Based upon the clinical and experimental work of Mckenzie (1981) and Nachemson (1976), Kopp et al. (1986) reported the following test: The patient in prone lying position is asked to hyperextend the spine on the forearm support; it is then gradually progressed to hand support. If he succeeds in attaining 30 degrees of hyperextension within 3–5 days of therapy, the lesion is not a true prolapse, and perhaps does not require surgery. Therefore, an early response to extension therapy is an indication of conservative management (see Fig. 32-51).

(b) *Hip, knee 90–90 test* (Cotrel & Lossing, 1986): Patient lies in supine position. Examiner bends both knees of the patient to 90 degrees with the thighs vertical. By keeping the arms under the thigh supporting the weight of the legs, examiner raises the bent legs and buttocks vertically upwards, elevating the pelvis. This tilts the pelvis posteriorly, overcoming the lumbar lordosis and flattening the lumbar spine. This manoeuvre opens up the intervertebral foramina, stretches the paraspinal

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muscles and aligns the facet joints. If it relieves pain, the lesion is not a true prolapse and the patient is suitable for conservative management and the treatment by 90–90 traction (Fig. 32-53).

FIG. 32-45 Alternate SLR: assuming sitting posture without flexion at the knees indicates negative test.

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FIG. 32-46 Bowstring test: appearance or increase of pain on sudden firm pressure on the sciatic nerve in the popliteal fossa indicates positive test.

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FIG. 32-47 Slump test: patient in slouch sitting, head passively flexed between the knees, active knee extension with foot dorsiflexion reproduced symptoms when the test is positive.

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(A)

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(B)

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FIG. 32-48 **(A and B)** Reverse Lasegue test: Passive extension of hip with knee in flexion causes pain in the distribution of femoral nerve indicating positive test.

FIG. 32-49 Gaenslen's test: Pain at SI joint on passive extension of hip with knee in extension and normal lower leg in knee–chest position indicates SI joint pathology.

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FIG. 32-50 Pelvic compression test for SI joint pathology: Passive compression or opening up of the pelvis with firm pressure elicits pain at the SI joint.

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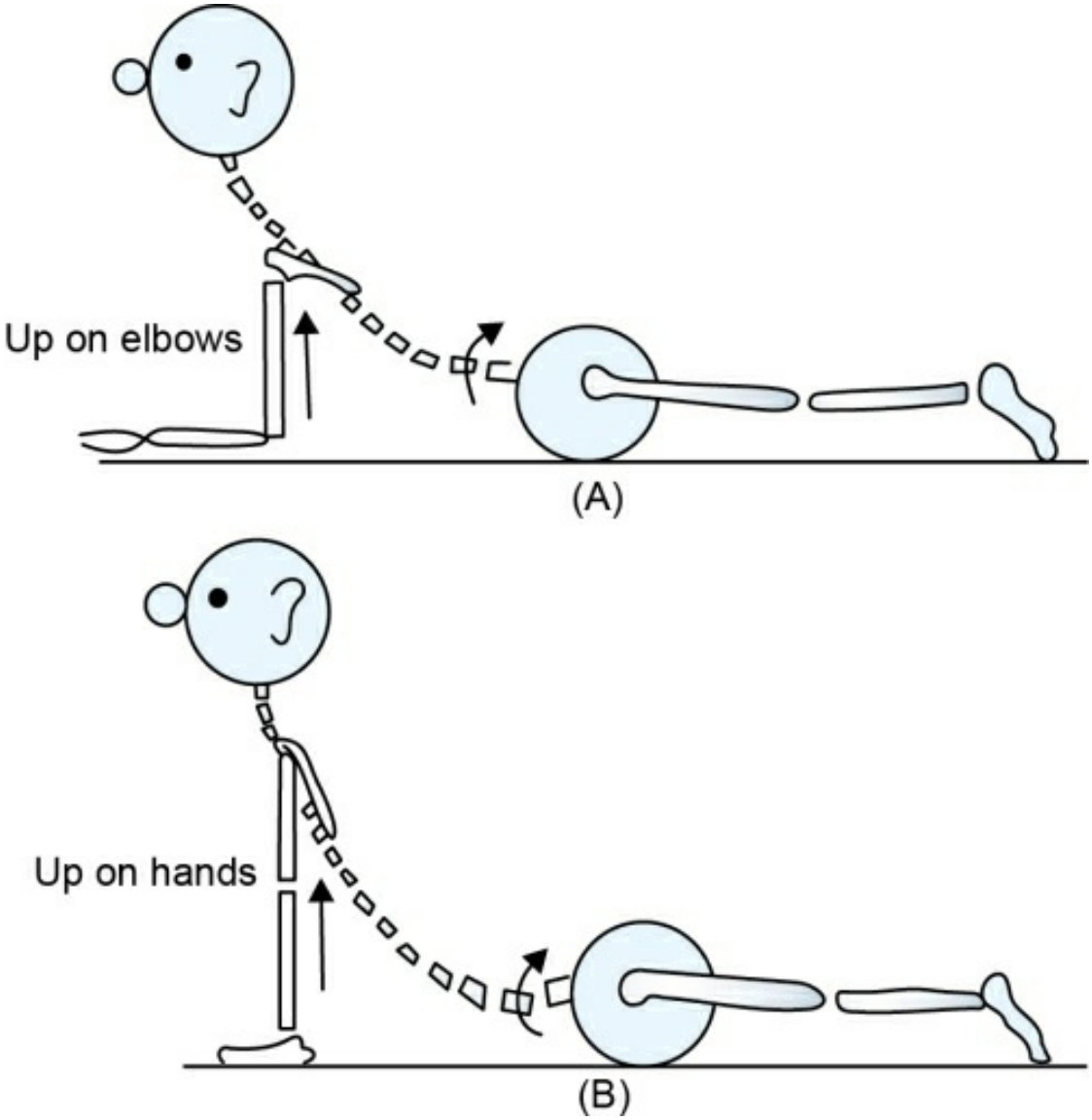

FIG. 32-51 **(A and B)** Provocative test for acute disc herniation: graded passive back hyperextension provokes symptoms in the presence of nuclear extrusion.

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FIG. 32-52 Faber's test (sign) to detect the presence of hip joint pathology as a causative factor for LBP.

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FIG. 32-53 Hip–knee 90–90 test. When passive raising of pelvis with hip and knee in 90 degrees of flexion relieves symptoms, pelvic traction in this position is effective.

Other investigations

- Laboratory investigations are necessary when LBP is suspected because of malignancy, metabolic disorder or infective disease.
- Plain radiographs (AP and lateral) done as a routine.
- CT scan and MRI are ideal in fractures and soft tissues pathology respectively.
- Bone scan – in metastatic diseases and tumour suspicions.
- EMG – in localizing nerve root lesions.
- Rectal and pelvic examination.

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The data thus collected through subjective and objective examinations should be correlated with the other investigations to arrive at the final diagnosis.

Evaluation of functional status

Early initiation of guarded functional activities in the management of LBP is gaining more popularity. Therefore, it is important to objectively evaluate the activities of daily life and the functional levels of each patient.

Evaluation of ROM, muscle strength and endurance constitutes the index of activities of daily living and should be rated on a graduated numerical scale. They can be divided into five grades from 0 to 4 depending upon the degree of assistance required in carrying out each activity.

The functional activities to be evaluated are as follows:

1. Personal hygiene.

2. Dressing.

3. Rising from sitting position to standing and reverse.

4. Level walking.

5. Walking up steps and inclines, and coming down.

6. Running.

7. Gait involves rotation of the pelvis and lateral bending which are reduced because of pain, thereby resulting in decreased speed. Objective evaluation of gait is hence necessary (time and distance parameters).

8. Maintenance of a static posture: In the functional positions, static hold can be made objectively by recording the period (time) of holding that position before the symptoms appear. If there is no difficulty, weight can be added to test the holding position. Whenever

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feasible, activities such as jogging, jumping and running should also be objectively assessed and documented.

The scoring scale for the functional activities is as follows:

0	= Unable to perform the activity
1	= Able to perform only with adequate assistance
2	= Able to perform with minimal assistance
3	= Able to perform independently but has pain while performing
4	= Pain-free, normal activity

General plan of examination

1. Patient standing	
Observe	General body built, physiological spinal curves, spinal alignment, pelvic obliquity, buttock crease (sag may be present in S1 joint lesion)
Document	Site, size, nature and the degree of pain
Palpate for	Local muscular spasm, trigger zones, myofascial nodules, sciatic nerve tenderness, prominence of spinous processes
Test	Range and rhythm of spinal movements of flexion, extension, lateral flexion and rotation; document the movements aggravating and relieving pain. Muscle endurance:
	Tip-toe walking tests gastrosoleus (S1 lesion): If knee buckling occurs, quadriceps weakness should be suspected (L4 lesion)
	Heel walking: To test active dorsiflexion and great toe extension (L4–L5)
	Compression test: To test sacroiliac joint tenderness
Measure	ROM of spinal movements, angle of pelvic tilt
Look for	Limb length disparity (block measurement)
2. **Patient supine**	
Observe	General posture
Palpate for	Flattening of the lumbar lordosis during leg raising
	Abdomen: Listen for bruit, intra-abdominal mass
	Inguinal: Listen for bruit
	Peripheral pulses and skin temperature for vascular insufficiency
	Muscle tenderness: Hip flexors (L2–L3), quadriceps (L4) and foot dorsiflexors (L5)
Test	Passive spinal movements and end feel for flexion and rotation
	Hip flexor tightness and hamstrings tightness
	Full ROM hip movements (to exclude hip pathology)
	Passive SLR: Foot dorsiflexion at the end (sciatic nerve root tension and dural sheath tension)
	Bowstring sign (root compression): Passive neck flexion (mobility of dura mater)
	Passive neck flexion with SLR (involvement of the spinal cord with L4–L5 nerve roots)
	Contralateral SLR (massive disc herniation medial to the root), SI joint: Pelvis opening up and compression test (to exclude SI joint pathology), pelvic examination in females
Sensory status	Lower limbs (respective dermatomes)

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Muscle endurance	Abdominals (upper and lower)
	Hip flexors, knee extensors and foot dorsiflexors, extensors and flexor hallucis longus
Measure	Leg length (tape measure)
Reflex	Medial hamstrings reflex (L5)
	Plantar response (S1)
3. **Patient side lying**	
Test	Muscle endurance: gluteus medius, S1 joint pathology by:
	Lateral compression test
	Rectal examination
4. **Patient prone**	
Palpate for	Vertebral alignment, muscle spasm, local tenderness, nodules, renal tenderness, gluteus maximus hamstrings and calf tenderness
Test	Intervertebral accessory movements
	Femoral nerve stretch test
Muscle endurance	Hip extensors, spinal extensors and hamstrings
Sensory status	Dermatomes on the posterior aspect from buttocks to feet
Reflex	Ankle jerk (S1)
Measure	Thigh and calf girth for atrophy
5. **Patient sitting**	
Test	Muscle endurance:
	Hip flexors (L2–L3), quadriceps (L3–L4), extensor hallucis longus (L5)
	Flexor hallucis longus (SI)
	Hamstrings for tightness
Reflex	Knee jerk (L3–L4)
Measure	Calf circumference, chest expansion

Working diagnosis of low back pain

Such an extensive and elaborate physical examination, although ideal, is not always feasible in all patients of LBP. A quick working diagnosis can be made by examining certain major characteristics of signs and symptoms chosen from the general plan of examination to identity and rule out the serious underlying pathology.

The presence of a serious pathology can be identified by keen observation as the patient walks into the room and relates the history of his episode. On the basis of this, priorities in the physical examination can be chosen to arrive at the working diagnosis such as the following:

1. *Severe degree pain at rest*: Infectious or neoplastic lesion may be

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present.

2. *Acute pain radiating to leg; list, positive neurological signs and positive SLR or cauda equina syndrome*: Major disc lesion, fracture or infectious disease may be suspected.

3. *Pain relieved by rest*: Lesion most probably be of mechanical origin.

Treatment

Physiotherapeutic modalities in the management of low back pain

A number of studies have been reported to find out the most effective modality in the treatment of idiopathic LBP. None of the studies so far has proved the definite superiority of a particular modality. The objective findings of various studies can be summarized as follows:

1. Properly controlled exercise programme is a common effective modality with any of the therapeutic approaches.

2. Manipulation has a definite edge over the other approaches in selective cases.

3. Maximum benefit was observed in patients treated early (within the first month of the onset).

4. Postural guidance during rest and at work (back ergonomics) is very important.

5. The results are better in patients treated with a combination of more than one approach, rather than those treated with a single modality.

The following modalities, single or in combination, are generally employed in the conservative management of LBP:

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1. Spinal exercises
2. Physical agents
3. Spinal traction
4. Role of lumbar spinal supports
5. Specialized techniques

Before discussing the rationale of each of these modalities, it is necessary to highlight the importance of ergonomic advice which consists of educating the patient on postural adaptations (static as well as dynamic) to reduce strain on the back.

Role of spinal exercises

A great deal of controversy still exists regarding the exact indication and the type of exercise for a particular aetiology of LBP. Specific optimal regimen of exercise is nonexistent.

If the purpose is reduction of pain, exercise should be limited to the point of discomfort. However, if the purpose of the exercise is to regain mobility, the movement has to be carried well into a perceptible pain and maintained in spite of little discomfort; it should be performed often and be progressive. The exercise programme aims to:

1. decrease pain,
2. strengthen weak muscles,
3. improve endurance of muscles,
4. decrease mechanical stress to spinal structures,
5. stabilize hypermobile structures,

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6. improve posture,

7. improve mobility and flexibility and

8. improve fitness level to prevent recurrence.

Effects of exercises

1. They increase strength of bones, ligaments and muscles.

2. They improve nutrition to joint cartilage, including intervertebral disc.

3. They enhance oxidizing capacity of skeletal muscles.

4. They improve neuromotor control and coordination.

5. They increase the level of endorphin in the cerebrospinal fluid (CSF) and blood, which is found to be reduced in patients with LBP. Endorphin has been proved to have a significant pain-modifying effect.

6. Exercises have tremendous psychogenic effects and reduce the symptoms of depression and anxiety.

7. They promote the feeling of well-being, as there is an increase in the alpha wave activity, producing central and peripheral relaxation and decreasing the muscle tension (Colt, Wardlao, & Frantz, 1981; De Vries, 1968; Edgerton, 1976; Farmer et al., 1978; Fraioli et al., 1980; Hammand and Froelincher, 1986; Tylor, Sallis, & Needle, 1985). Exercises have been shown to be more effective than a dose of meprobamate in decreasing muscular tension (De Vries, 1968), in addition to their positive response in inducing sleep.

Supervised activation, sometimes even beyond the pain limit but with controlled biomechanical activities, seems to be a more effective modality than any other therapeutic procedure (Cathlove & Cohen,

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1982; Choler, Larson, Nachemson, & Peterson, 1985; Nachemson, 1983).

The exercise programme should be minimal and as specific as a drug needed in proper dosage. The authors feel that it is high time to develop a scientific approach rather than blindly treating all patients of backache with hyperextension exercises.

It is important to understand the effects of a particular type of exercises on the spine and its periphery. It is also highly improper to hand over one standard manual of back care and home exercise programme to all the patients irrespective of the cause of LBP.

1. ***Flexion exercises***: Williams (1965) advocated trunk flexion exercises for the following aims:

(a) To open the intervertebral foramen and facet joints, reducing compression on the nerves.

(b) To stretch (tight) back extensors, reducing stress on the lumbar spine.

(c) To strengthen abdominal muscles.

(d) To increase endurance of abdominal muscles.

(e) To free posterior fixation of lumbosacral articulation.

(f) To protect the lumbar disc from excessive posteroanterior pressure through the development of intra-abdominal pressure (Bartelink, 1957; Morris, Lucas, & Bresler, 1961). However, internal and external oblique muscle groups have been found to be instrumental in generating the reflex intra-abdominal pressure (IAP). They also have an added advantage of avoiding range of true flexion, and hence need special attention.

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Caution

It must be remembered that the excessive participation of the rectus abdominis and obliques results in compressive forces, and hence are to be avoided (Valsalva manoeuvre). Graded shoulder lift sit-up with rotation of the trunk in hook lying position is the ideal exercise to emphasize the action of oblique muscles (Fig. 32-54). Flexion without rotation strengthens the rectus abdominis (Figs 32-55A,B and C). Graded holding of knee–chest position (Figs 32.55D and E) stretches tight spinal extensors responsible for exaggerating the lumbar lordosis.

FIG. 32-54 Exercises for external and internal oblique muscles by graded shoulder lift with spinal rotation.

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(A)

(B)

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(C)

(D)

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(E)

FIG. 32-55 **(A–C)** Graded rectus abdominis exercise. **(D)** Initial phase of single knee–chest position. **(E)** Final knee–chest position of bilateral full ROM knee flexion which maximally stretches posterior soft tissues, opens up posterior intervertebral disc spaces and opens up facet joints.

Contraindications

1. In acute disc prolapse, as exercises exert excessive load on the lumbar discs and open the posterior intervertebral space.

2. After prolonged rest, when the disc is hyperhydrated, it is more susceptible to injury (Nachemson, 1980).

3. When the postural LBP is due to posterior pelvic tilt.

4. In the presence of a lateral trunk shift/list (McKenzie, 1979).

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5. In patients with osteoporosis, where incidences of compression fractures and wedging have been reported (Sinaki & Mikkelsen, 1984), as these exercises will increase compressive forces on the vertebrae.

2. ***Extension exercises***: Effects of extension exercises are as follows:

(a) They promote normal physiological lumbar curve of the spine, allowing it to withstand axial compression force (Kapandji, 1979; White & Punjabi, 1978), thus facilitating lifting loads.

(b) They improve the motor recruitment, strength and endurance of the extensor muscles of spine and hip (Sinaki & Mikkelsen, 1984).

(c) In postural LBP patients, where the extensors develop tightness due to the prolonged flexion attitude of posture in sitting or standing position.

(d) They unload the disc and allow the fluid influx; therefore, important in patients with suspected posterior or posterolateral discs.

(e) They are the main muscle groups in postural holding and in the eccentric control of trunk flexion (Pauley, 1966).

(f) They improve the mobility of the spine.

(g) They improve tone in the extensor muscles, which is often reduced because of the maximum natural flexion attitude of the human body.

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(h) Rare incidence of LBP in patients with strong extensors (Davies & Gould, 1982), and decreased endurance in patients with LBP suggests the important role of strong extensors (De Vries, 1968).

Extension exercises are of two types:

(a) Extension to neutral: It involves concentric contraction of the back extensors from the flexion of 40–45 degrees of the trunk. The advantage of this exercise is that it involves eccentric contractions of the extensors when the trunk returns to its initial position of 40–45 degrees of flexion (Fig. 32-56A). Controlled assistive support needs to be given over the chest or shoulders.

(b) Hyperextension exercises: In prone position, the patient extends the spine beyond the neutral position up to 15–30 degrees of hyperextension (Fig. 32-56B).

Contraindications

1. Acute disc lession.

2. Pathological conditions such as spinal stenosis, spondylolisthesis (Kapandji, 1979).

3. In a multioperated back where sufficient disruption of the extensor muscles and spinal mechanics have occurred.

4. Patients with limited forward mobility following scarring from previous surgeries (Mckenzie, 1982).

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3. ***Rotational exercises***: Exercises involving the movement of rotation are important due to the following reasons:

(a) The movement of rotation of spine forms the basic component of mobility for functional efficiency.

(b) The external and internal oblique muscles provide anterior stability to the lumbar spine and flexion of the spine without excessive compression (Halpern & Bleck, 1979).

(c) The rotators contribute significantly to the development of intra-abdominal pressure and are effective in maintaining anterior and posterior balance of the trunk, which is disturbed in LBP. They are also important in performing controlled rotatory activity of the spine.

(d) The rotational movement of the intervertebral segment provides overall relaxation to the spinal muscles, reducing tightness, spasm and pain.

4. ***Mobility exercises***: Functional efficiency of the lumbar spine depends upon its flexibility (Farfan, 1978). Similarly, pelvic mobility is needed for various activities such as bending and lifting (Gracovertsky, Farfan, & Lamy, 1981). Apophyseal joints of the spine require mobility or movement to facilitate nutrition and to prevent degeneration of the articular cartilage (Enneking & Horowitx, 1972). Therefore, mobility exercises are the main contributors to the mechanical efficiency of the spine and the whole body.

Mobility exercises can be passive or active and should include all the movements. Relaxation of the concerned muscles and joints is important to improve mobility. The

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speed and the arc of movements need to be progressed only when enough relaxation is achieved. The effective exercises improve relaxation and mobility of the lumbosacral complex which can be achieved by self-assisted pelvic rotation and chest roll performed by the patient.

In supine lying with hips and knees bent and the feet resting on the treatment table, the patient initiates a small range of pelvic rotation on either side. As relaxation is induced, further range can be gained, progressing to complete rotation of the pelvis (Fig. 32-57). Alternately, chest roll in either supine or sitting position may be included to improve the mobility of the whole spine (Fig. 32-58). These exercises, before the passive mobilization technique, facilitate the process of manipulation and mobilization. Ideally, these relaxed mobility exercises should be initiated as soon as one wakes up, in the bed itself, to overcome the stiffness of night rest.

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(A)

(B)

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FIG. 32-56 **(A)** Active assisted spinal extension from 40 to 45 degrees of flexion. **(B)** Active spinal hyperextension.

(A)

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(B)

FIG. 32-57 Rotational exercises to the spine: pelvic rolling. **(A)** Starting position. **(B)** Position of extreme rotation of pelvis to the left.

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FIG. 32-58 Rotational exercise to the upper spine (chest roll).

Caution

Mobility exercises are contraindicated in (a) the presence of segmental hypermobility and (b) acute disc lesions.

5. ***Stretching exercises***: These are of two types:

(a) General stretching exercises

(b) Specific stretching exercises

(a) *General stretching exercises*: They offer stretching to all the soft tissues and the spinal joints which remain contracted when one type of posture is sustained for a long time. Generalized stretching is needed to avoid adaptive shortening of the soft tissues, good posture, mobility and, above all, the feeling of well-being and

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alertness.

(b) *Specific stretching exercises*: They are of special significance when the basic cause of LBP is the adaptive soft tissue shortening. Long sessions of low intensity sustained stretching techniques may be required.

6. ***Self-correction and its maintenance***: Proper and adequate education on self-corrective techniques of incorrect postural habits may be necessary. Maintenance of the postural self-correction forms an important part of this technique.

7. ***Exercise specificity:*** Once the type of exercise has been selected, the specificity has to be decided on the basis of the findings of examination. The exercise must not be PAINFUL. The major types of exercise techniques are as follows:

(a) Isometric

(b) Isotonic

(c) Isokinetic

The efficiency of the selected exercise technique is to be checked at regular intervals.

8. ***Aerobics:*** Gradual introduction of aerobics is proving extremely effective in the control of LBP. These should be started gradually so that there is no undue strain. Activities such as brisk walking, jogging, swimming, cycling, rope jumping and dancing have been found to be very useful in controlling as well as preventing LBP. They need to be supervised and controlled biomechanically by the physiotherapist. They must begin with relaxed free movements of the whole spine.

Efficacy of exercise programme: As an optimal regimen of exercise

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is nonexistent, it is important to monitor the efficacy of the exercise programme right from day one. Changes in the intensity of pain and its location provide valuable guidance.

1. Centralization of pain to the centre of the back is an important clue to the correctness of the therapeutic programme. Incorrect posture, improper exercise or wrong activities cause pain to move away from the centre of the spine to the periphery (Table 32-14).

(a) Rotational exercise, added gradually only when pain free.

(b) Aerobics – only after cardiac clearance and rapid longer duration movements are possible.

2. At the initial exercise session, slight increase in pain is expected. The pain should decrease in the subsequent sessions with centralization. However, increase in the intensity of pain and its migration to the periphery is a warning to stop exercise immediately and seek further advice.

3. Approach to the exercise should be cautious when even gentle exercise or graded positioning of the body is uncomfortable.

4. In situations where tightness or weakness of muscles and fascia is the cause of LBP, increase in pain is expected due to repeated stretching and muscle fatigue.

5. Initially, new pain may be noticed as a result of corrective procedures of the established wrong postural attitudes in postural LBP.

6. The response may be slow and the improvement may be delayed in patients with longer duration LBP. It may take even 10–15 days for a noticeable relief.

Table 32-14

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Guidance to Select Flexion versus Extension Exercise on the Basis of Pain Reduction or a Relief

Flexion Exercises	Extension Exercises
Relief of pain on • Sitting • Forward bending Has lumbar lordosis Has fixed lumbar lordosis with forward bending	• In lying position • On walking • Decreased lumbar lordosis • Repeated back bending
Or	
Increase of pain on • Standing still • Sustained bending forward • Repeated backward bending	Pain unchanged on stopping forward • Sitting • Driving • Raising to standing from chair • Forward bending or stooping • Repeated forward bending

Exercises to be avoided: Certain exercises should either be totally avoided or be initiated with extreme caution. Examples of such exercise are as follows:

1. Forward bending and trying to touch the toes in sitting and standing positions.

2. Bilateral straight leg raising in supine lying position.

3. Prone lying, lifting both the arms overhead and both the legs with knees straight, and arching the back posteriorly.

4. Backward bending in standing position.

All these exercises put tremendous stress on the concerned tissues.

The lumbar extensor group of muscles, being antigravity muscles, are stronger right from younger age. They remain so unless they are incised during surgery. As such, strengthening procedures are not really needed for these muscles unless they are for a specific purpose. The strengthening may lead to their shortening and limitation of trunk flexion. This should be considered in planning the exercise programme and during training to attain normal lordotic lumbar curve and its maintenance.

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Physical agents

Various types of physical modalities can be applied as adjuncts in the treatment of LBP. Selection of a modality depends upon the mode of action of the modality to suit symptomatology and the nature of tissue involvement. The objectives of using various physical agents are as follows:

1. To control pain and spasm.

2. To reduce inflammation.

3. To facilitate the use of specialized techniques such as mobilization, traction and exercise.

4. To reduce depression, tension or any other psychological factor.

The various physical agents are discussed below.

1. ***Ultrasound***: Ultrasound has been in use since the 1950s and is definitely advantageous in the following situations:

(a) It can be given in acute as well as chronic phases of LBP.

(b) It can be used for driving the medications such as hydrocortisone and xylocaine into the skin over the targeted tissues by phonophoresis.

(c) It increases cortisol present in the spinal nerve roots and lumbosacral plexuses, thereby improving mobility by decreasing pain (Touchstone, Griffin, & Kasparow, 1963).

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(d) It increases extensibility of the connective tissues such as tendons and joint capsules (Lehmann, 1970). This particular action of ultrasound is important, as it can improve the accessory movements in the apophyseal joints. Therefore, it is ideal before applying mobilization techniques.

(e) It has been found to reduce spasm in lumbar radiculopathy (Clarke & Sterner, 1976).

Although the dosimetry of ultrasound is based on tolerance, an output intensity of 1.5 W/cm^2 with continuous mode of application for a period varying from 5 to 10 min is a standard pulsed ultrasound ideal for acute LBP.

2. ***Cryotherapy***: It is a simple and effective procedure which reduces muscle spasm and inflammation in the acute phase. Ice massage with ice cubes for 3–5 min or with ice bag for 15 min can be used directly over the painful areas; it also acts as an analgesic and provides the most needed compulsive rest.

3. ***Transcutaneous electrical stimulation***: Transcutaneous electrical stimulation (TENS) over the trigger points or acupuncture points has been reported to be effective in both acute and chronic conditions (Ersek, 1976). It reduces the perceived pain by:

(a) elevating endogenous opiate levels in the brain and spinal cord (Bonica, 1979), and

(b) continuous stimulation of cutaneous afferents which blocks pain in the substantia gelatinosa of the spinal cord (Melzack & Wall, 1965).

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Frequency of 2–4 Hz, output intensity of 50 MA, pulse rate at 2 pulses/s and pulse width between 30 and 60 min have been reported to be an effective mode of application in chronic as well as acute conditions.

4. ***Moist heat***: Moist heat in the form of hydrocollator packs reduces pain and spasm in the acute phase. It can be used as an effective adjunct before applying specialized techniques or even before TENS, short-wave diathermy (SWD) or ultrasonics because of the comfortable heat along with forced rest for a longer period.

5. ***Electroacupuncture***: It has been reported to be an effective pain controlling modality but needs special equipment. It also needs specific knowledge of the theory of acupuncture and is difficult to practise as a routine therapy (Santiesteban, 1980).

6. ***Diathermy***: Diathermy is preferred for deep heating of the tissues over larger areas. However, drum electrodes or induction electrodes can be used where superficial heating is advisable (Griffin & Karselis, 1978).

Of the two modes of diathermy – (a) continuous and (b) pulsed or nonthermal – the latter is ideal in dealing with acute conditions or after surgery. In chronic LBP, a continuous modality is preferred.

Various new modalities such as interferrential currents, diapulse, megapulse and laser beams are added to physical therapy. Helium–neon laser has been reported to be significantly effective in the control of back pain with

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musculoskeletal trigger points (Synder-Mackler, Barry, Perkins, & D'Soucek, 1989).

7. ***Electrical stimulation***: High intensity electrical stimulation over the trigger area may respond favourably, especially in LBP of psychogenic origin.

8. ***Massage***: Gentle soothing massage is instrumental in reducing local muscular spasm. It helps in removing nociceptive substances by improving blood circulation. It also gives a feeling of betterment by inducing relaxation.

The efficacy of a particular modality should be evaluated periodically during the course of treatment. The selection of a particular physical agent should be done as per the underlying pathology.

Spinal traction

It is a popular modality in the management of LBP.

Range of traction force: There exists a great deal of variation in the spectrum of the effective traction force. To overcome the force of friction, a force equivalent to the body weight is necessary. Therefore, the traction force required to produce distraction in the vertebrae ideally should be of at least half the body weight. The range of traction force may vary from 37 to 91 kg (Hickling, 1972; Judovich, 1955; Mathews, 1972).

As a result of traction, the range of vertebral distraction as reported in various studies varies from 0.3 to 4.0 mm. The maximum distraction reported is 2.0 mm (Harris, 1960).

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Effects

1. Traction produces relaxation of tight muscles and tautening of viscoelastic ligaments.

2. It increases the intervertebral distance, allowing reduction in disc protrusion.

3. It relieves pressure on the nerve roots and their dura.

4. It offers positive decompression, drawing the protrusion towards the centre by suction and brings about separation of the facet joints.

5. Traction has been found to be effective in the presence of dural signs and root palsy.

Direction of traction: The direction of pull must be underneath the pelvis so that there is posterior tilting of the pelvis, decreasing the lumbar lordosis (Fig. 32-59).

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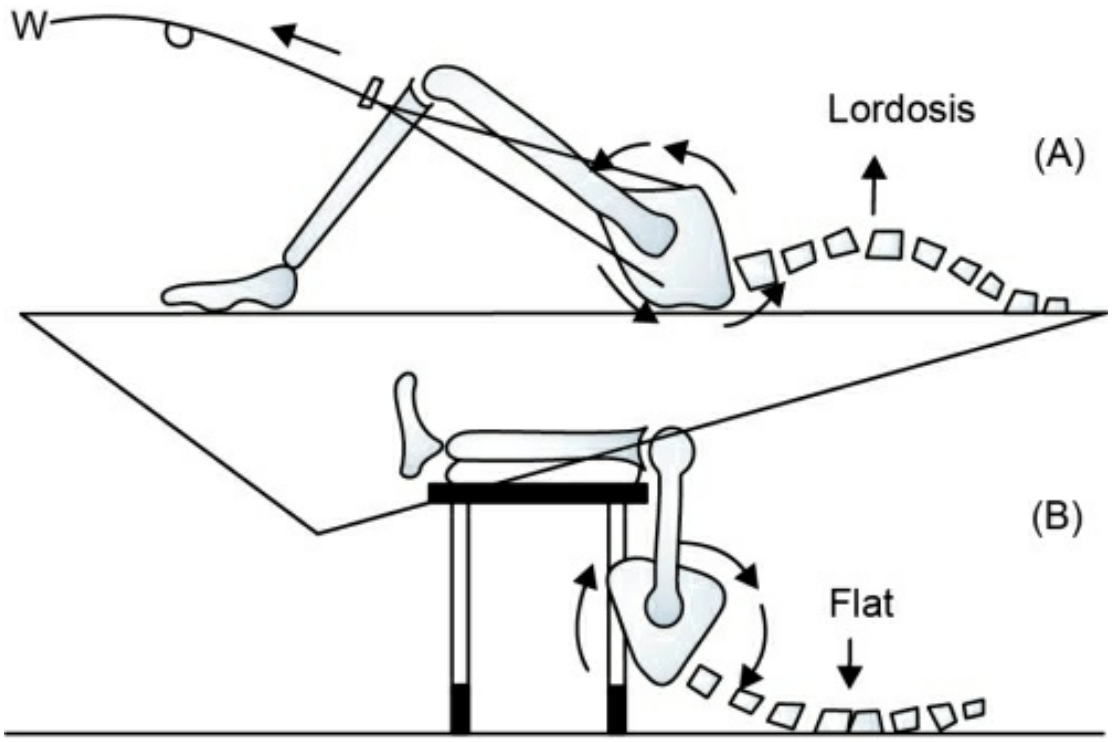

FIG. 32-59Lumbar traction – direction of tractive force. **(A)** Incorrect tilting of pelvis anteriorly results in exaggeration of lumbar lordosis. **(B)** Correct tilting of pelvis posteriorly results in flattening the lumbar curve.

However, whatever method is used, one must remember that the effectiveness of traction does not depend upon the magnitude of the tractive force. The criterion for selecting traction as a treatment modality is the reduction of the symptoms.

Types of spinal traction

1. *Continuous traction*: Continuous traction provides stability and muscular relaxation. It is advocated in patients complaining of excruciating localized or radiating pain. A traction force in the range of 10–25 lbs is adequate for pain

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relief. It is applied for several hours with the foot end of the bed raised to provide counter traction. The pulley system of the traction should be 10 inches above the mattress. The force of traction rotates the pelvis backwards and maintains the lumbar spine in neutral position (Kottke, 1961).

However, continuous traction sometimes produces pain due to muscle fatigue. On such occasions the traction should be discontinued temporarily.

If supine lying is painful, sustained traction can be given in prone position, provided the patient is comfortable and indicates relief. Disc protrusion can be treated effectively with the patients in prone position (Saunders, 1983).

2. *Sustained traction*: In supine lying, the static traction with tractive force of not less than 50%–60% of the body weight is applied for 20–30 min. If more distraction is needed, heavy but tolerable weight is applied for a short duration. It is advisable in sciatic type of pain.

Indications

1. Disc protrusion.

2. Degenerative disease with osteophytes exerting pressure on the nerve root or dural sheath (heavy traction for 30 min).

3. Unilateral lumbar traction when stronger force is desired on one side of the spine (e.g., unilateral joint dysfunction, sciatic scoliosis).

4. Pain arising as a result of secondary disc lesion in

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spondylolisthesis.

5. First and second lumbar disc lesions secondary to lumbar arthrodesis or failed manipulation.

6. Recurrence of pain following surgery, e.g., laminectomy.

3. *Intermittent traction*: Alternate application of traction and its release is the most popular method of applying lumbar traction. It has vascular massaging effect, and relaxation is produced in the tight soft tissues. The combination of alternating stretch and release promotes relaxation. It is well accepted by the patients as compared to sustained traction.

Indications

1. Disc protrusion accompanied by stiff back (60-s hold, 20-s rest).

2. Joint dysfunction or degenerative disc (shorter hold and rest period).

4. *Manual traction*: Traction is applied manually for a few seconds by the physiotherapist. However, it is not commonly used as the patient cannot anticipate the amount of tractive force, and thus fails to relax during traction.

5. *Positional traction*: If only one side of the spinal segment is involved, the patient is positioned in lateral bending by using sandbags, pillows or blocks.

6. *Autotraction*: A special traction table provides a facility to angulate or rotate an individual segment of the spine. The

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patient can manoeuvre the direction and magnitude of the traction. It needs constant supervision. Although it is self-monitored, it has not gained popularity in practice.

7. *Gravity lumbar traction*: It is a traction where the body is vertically suspended by a special vest securing the rib cage. Gravity and weight of the hips and legs provide the traction force on the lumbar spine (about 40% of body weight).

Gravity traction in inverted position has been reported with straps securing the pelvis or boots (Gianakopoulos Waylonis, Gant, Tottle, & Blazek, 1985; Nosse, 1976). Here the weight of the upper body, head and arms provide a tractive force (about 50% of the body weight).

However, these types of gravity tractions are not generally used because of their inability to attain relaxation in vertical hanging. Secondly, one has to constantly watch for the obvious effects of inversion on the patient's cardiopulmonary systems (Gianakopoulos et al., 1985).

Ideal methods of spinal traction

1. *90–90 position* (Fig. 32-60): Cotrel and Lossing (1986) have described a method which appears to be ideal for the following reasons:

(a) The patient is in supine position.

(b) The legs are bent 90 degrees at the knees and hips and supported on a chair at a proper height.

This position reduces the intradiscal pressure at the lumbar

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spine to the maximum (Splatts, 1977) and offers relaxation to the lumbar area. Gradual traction in this position promotes opening of the intervertebral foramina, aligns the facet joints and provides even stretching of the paraspinal muscles. It is not suitable when there is painful limitation of extension.

2. *Neutral position of the lumbar spine*: The patient is placed in supine position with a pillow under the knees. This position puts the lumbar spine in neutral.

FIG. 32-60The 90–90 position: resting in supine with hip and knee joints supported in 90 degrees **flexion reduces intradiscal pressure.**

Chest and pelvis harnesses are applied and the traction force is gradually increased to an adequate level.

Ideally, the traction should be preceded by an appropriate

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modality such as hydrocollator pack or diathermy to induce relaxation. The newer traction tables also have microwave units for simultaneous use.

Precautions

1. Constant supervision is necessary, when the patient is under traction, to detect any difficulty in breathing or other GI or cardiopulmonary complications.

2. Gradual increase of tractive force to be regulated to the level of comfort and reduction in the symptoms. Release of traction should also be gradual.

3. Bouts of cough and sneeze during traction can aggravate pain. Therefore, before applying traction, make sure that the patient is not having cough or cold. If present, he should avoid jerking the back.

Contraindications

1. Acute lumbago following acute strains, sprains and inflammation.

2. Patients with impaired cardiac or respiratory functions, e.g., cardiac failure, emphysema and asthma.

3. Instability of the spine.

4. Marked osteoporosis, hiatus hernia, claustrophobia, pregnancy.

5. In structural disease secondary to tumour or infection.

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6. In vascular compromise, and in any condition for which the movement is contraindicated (Yates, 1972).

7. Massive disc prolapse causing sciatica with neurological deficit (Weber, 1975).

8. Patients with pain during rest, indicating root interruption.

9. Spinal infections, i.e., osteomyelitis, tuberculosis.

10. Malignant disease, metastatic or local.

11. Rheumatoid arthritis.

Role of lumbar spinal support

The present trend is to discourage the use of lumbar/lumbosacral support in LBP. This is because it reduces the muscular activity, resulting in weakness, atrophy and reduction of tone. However, it is beneficial under certain situations. The advantages of lumbar spinal support are as follows:

1. It enhances the natural splintage effect, as it maintains the physiological lumbar curve which is the basis of treatment of LBP these days (e.g., McKenzie's technique).

2. It provides partial immobilization, and thus protects the lumbar spine from stress of movements. Immobilization helps in reducing pain due to muscle spasm. Restriction of movement allows early safe mobility, which is preferred to

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rest and immobilization.

3. It allows transmission of the forces of gravity and weight, facilitating early ambulation.

4. It provides support and reassurance to the patient.

5. It is especially beneficial in acute lumbago or disc lesions.

6. It facilitates the natural splintage effect provided by the abdominal and spinal muscles.

7. It uplifts and supports the abdomen, thereby unloading the effects of gravity on the discs.

Indications for lumbosacral support

1. Acute vertebral pain

2. Acute disc lesion

3. Spondylolisthesis

4. Following spinal surgery

5. During work activity to patients who were mobilized earlier

6. Chronic recurrent LBP

The physiotherapist must first check the fitting of the corset, and educate the patient on the correct methodology of its application and maintenance. Emphasis has to be laid on the early but graduated weaning of the corset to avoid its ill

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effects.

Specialized techniques

1. McKenzie's approach

2. Manipulation and mobilization

Mckenzie's approach

The basic principles of this approach can be underlined as follows:

(a) McKenzie (1981, 1982) utilizes the response of the patient to the repetition of all four basic movements of the lumbar spine. Identification of the movement which reduces pain or brings about its centralization (i.e., peripheral pain is moved towards midline of the spine) forms the basis of the therapy. Hence, it is called *movement therapy*.

(b) He also stresses the importance of maintenance of the normal physiological curve of the lumbar lordosis in all the body positions and activities, besides back ergonomics.

Prolonged flexion posture elongates the posterior tissues such as posterior longitudinal and supraspinous ligaments, the facet capsules and posterior annular fibres of the disc, putting excessive compression over the anterior surfaces of the vertebral bodies. This forces the nucleus pulposus posteriorly, causing nuclear bulging, or some herniation, whereas lordosis at the lumbar spine is 'physiological', which forces the nucleus anteriorly, away from the neural

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contents of the spinal canal. Therefore, his approach lays emphasis on the maintenance of the lumbar lordosis.

He categorized the origin of LBP basically because of three principal pathological conditions, and termed them as follows:

1. Derangement syndrome

2. Dysfunction syndrome

3. Postural syndrome

1. ***Derangement syndrome:*** In derangement syndrome, anatomical disruption or displacement occurs within the intervertebral disc. In younger age group, there is displacement of the annulus complex or fluid nucleus, whereas in older age group degenerated annulus or fibrosed nucleus may be present.

The disc derangement may be:

(a) minor or major posterior disc disturbance;

(b) minor or major posterolateral disc disturbance with impingement of nerve root and dural sleeve with sciatica with or without deformity;

(c) anterior or anterolateral disc disturbance.

Symptoms of various disc displacements are presented in Table 32-11.

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Patients with ipsilateral shift or in whom the trunk is listed towards the painful side, with sciatica and neurological signs, are resistant to mechanical therapy.

The basic approach of mechanical and movement therapy in posterior derangement syndrome is as follows.

2. ***Dysfunction syndrome:*** The incidence of LBP due to dysfunction syndrome is common in the age group of 30 years. Lack of exercise, poor postural habits or organization of fibrous collagenous scar tissue during the process of repair may be the precipitating factors.

Pain is felt adjacent to the spine only at the extreme range of movements because of the overstretching of shortened soft tissues, and never during movements.

The treatment consists of extension in lying, flexion in lying or side gliding in standing positions. As it involves stretching of the contracted soft tissue, some pain is expected. To be effective, exercises are performed long enough to maintain stretched positions. They should also be performed in various positions, e.g., for flexion dysfunction if the improvement is not achieved with flexion in lying, change it to flexion in standing or may be to flexion in step standing.

Rotation manipulation combined with mobilization may be necessary if the patient ceases to improve.

3. ***Postural syndrome***: Postural syndrome is common in younger age group (below 30 years). Pain is present adjacent

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to the spine. The cause is the overstretching of the normal tissues because of poor sitting or standing postures or lack of stretching exercises in sedentary professions.

The basis of treatment is the training of self-corrective postural exercises. This may be associated with 'new pains' due to adjustments to the new postural attitudes.

It must be remembered that in all the techniques of this approach, back care programme on biomechanical principles and maintenance of lumbar lordosis are essential. Mckenzie's method has gained popularity and has been proved objectively effective in various conditions (Vanharanta, Videman, & Mooney, 1987).

Methodology of mckenzie's approach

1. The patient is taught self-correction of his bad posture with emphasis on maintaining normal lumbar lordosis in all the situations.

2. Exercise programme begins as an extension exercise, flexion attitudes are incorporated later (by 2–3 weeks) or only when acute pain subsides.

Extension to restore normal lumbar lordosis:

1. Prone lying: Brief periods of prone lying for relaxation of the back muscles (Fig. 32-61).

2. Prone lying in extension with forearm and elbow support: In this position, the elbows are placed in line with the shoulder joints. Trunk is raised in extension by leaning on

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the forearm and curling of shoulders and upper back (Fig. 32-62).

Progress to exercises 3 and 4 when the constant pain is relieved.

3. Prone lying extension on hand support: In this position, hands are placed in line with the shoulder joints, and trunk is gradually extended by leaning on the hands (Fig. 32-63).

4. Standing extension: Stand upright, keep hands over the small of the back. Bend trunk backwards as much as possible.

FIG. 32-61Relaxed prone lying with pillow under the legs.

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FIG. 32-62Prone lying with forearm support.

FIG. 32-63Prone lying: further progression of spinal extension to hand support without lifting the pelvis.

Progression of exercises from 1 to 4 is done in stages. Exercises 1 and 2, if pain free, can be given in acute pain. Extension exercises are not enough unless the ways and means of maintaining normal lordosis of the lumbar spine by

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self-corrective methods is taught.

When there is no relief even by 3–4 days of extension exercise and the pain is only on one side, shift away the pelvis from the painful side; relax in this position (Fig. 32-64) and then perform exercise 1 in this altered position. Progress to exercise 3 in this modified position. Centralization or even distribution of pain following this manoeuvre is an indication of its efficacy.

FIG. 32-64Relaxation with the left pelvis away from the painful right side.

Flexion exercise – to improve flexibility – begins after 2–3 weeks or when the acute pain has subsided:

1. Flexion in supine lying with both the knees bent: Bend one knee, hold with both the hands, swing it rhythmically in a graduated manner to knee–chest position and hold to 10 counts. Repeat the procedure with the other knee. Then bring both the legs to knee–chest position. First give slow

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rhythmic swings and hold with hands in the maximally stretched pain-free knee–chest position to the count of 30 or 10 s or more.

2. Flexion in sitting: Long sitting with feet apart and firm on the ground; gradually bend forward. Initially, hands supported on thighs are brought forward gradually towards feet and held in the maximally stretched position without pain to reach just above the ankle joints (Fig. 32-65). Then, progress further to reach tiptoes. Hand support can be waned gradually once the pain-free lumbar–pelvic rhythm is achieved.

FIG. 32-65Supported trunk flexion in long sitting.

Spinal manipulation

Manipulation is a very specialized technique which involves skilled, gentle, precisely passive movements of a joint either

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within or beyond its active range of motion by manual force. A small and firm but gentle force is applied to restore the lost movement by producing a desired 'joint play' or to achieve unlocking. It can be carried out successfully only by thorough training and practice based on sound knowledge of the neurophysiological and biomechanical processes as applied to a specific joint and its movement. A beginner should undertake manipulations only under supervision of an experienced colleague. Unskilled attempted manipulation on the basis of theoretical knowledge alone can be disastrous.

The aims of manipulation are to:

1. relieve pain

2. promote increased function

Effects of joint manipulation

1. Mechanical: It improves the extensibility of the connective tissue elements of the capsule, ligament, muscle and fascia.

2. Neurophysiological: It blocks the centripetal transmission of nociceptive (pain) pathways through sensory input, which could be cutaneous, muscular, articular or auditory.

3. Sensory stimulation: Skilled evaluation of the joint mechanics and soft tissues itself provides enough sensory stimulation and encouragement to the patient.

Indications of manipulation

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1. Vertebral malposition

2. Abnormal vertebral motions

3. Abnormal joint play or end feel

4. Soft tissue abnormalities

5. Muscle contracture or spasm

6. Severe nerve root pain

7. Chronic spondylotic changes

8. Chronic discogenic pain

Techniques: There are four basic techniques.

1. *Oscillation technique*: It is employed in a *recently injured joint* where minimal movement is indicated to retain its function.

2. *Stretch technique*: *Joints presenting restriction* due to capsular or myofascial changes are benefited by 'stretch manipulations'.

3. *Thrust technique*: *Joints demonstrating sudden hard stop to a movement* in one direction due to adhesions will respond better to a thrust technique.

4. *Rotation and side bending technique*: *When there is restriction of the facet joint mobility.* During the movements of forward, backward or side bending, the facets slide on each other. During rotation, the facets distract from each other.

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Restrictions in the mobility of lumbar facet joint instantaneously respond to rotation and side bending manipulation techniques (Haldeman, 1983; Maitland, 1977; Paris, 1983).

Contraindications

1. The most important contraindication is the unskilled manipulator

2. Patients with prolapsed disc (acute discs with advancing neurological signs)

3. Instability, spondylosis and fracture

4. Fever, influenza, rheumatoid arthritis

5. Active inflammatory joint disease

6. Advanced osteoporosis and diseases of bone

7. Bleeding disorders

8. Pregnancy

Support modalities such as heat, massage, ice, ultrasound and TENS relax the soft tissues and may be used as an effective adjunct before and/or after manipulation.

Treatment of idiopathic low back pain

In idiopathic LBP, it is necessary to recognize the nature of the LBP syndrome. It may be static or dynamic; static when

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pain is present during stationary position, and dynamic when it appears during movements. The complex nature of the origin, symptomatology, the individual's perception of pain and its overall influence lead to marked variation to the therapeutic approach (Table 32-15). The basic therapeutic regimen during the acute and subacute stages is outlined as under.

Table 32-15

Therapeutic Approach for Treatment of Idiopathic Low Back Pain

Cause of LBP	Clinical Signs and Symptoms
• Cauda equina compression	• Bilateral sciatica, saddle anaesthesia, bladder and bowel incontinence
• Abdominal aneurysm	• Tearing, throbbing back pain, syncope, dizziness or hypotension • Pulsatile mass, abdominal bruits, decreased peripheral pulsation
• Infective disease affecting lumbar spine	
• Bacterial infection	• Persistent pain even at rest, exacerbated by movement, stiffness

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	with acute toxic symptoms
• Tuberculosis and fungal infections	• Loss of body weight, pain over the affected vertebrae with reflex spasm
• Discitis with pyogenic sacroiliitis	• Postlumbar disc surgery, acute symptoms fever, SI joint pain and tenderness
• Tumours • Benign • Malignant	• Nocturnal and pain even at rest • Localized pain, stiffness, involves mostly posterior elements of involved vertebrae • Diffused pain, systemic symptoms and mostly involves anterior vertebral elements
• Inflammatory spondyloarthropathies • SI joint arthritides • Ankylosing spondylitis • Reiters disease	• Long lasting morning stiffness, persistent pain • Localized SI joint pain and tenderness, iritis, gradually increasing stiffness (whole spine) • Associated with conjunctivitis, urethritis pain localized to lumbar spine

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• Psoriatic spondylitis	• Psoriatic skin patches, localized pain lumbar region
• Metabolic bone diseases: • Osteoporosis	• Midline bony tenderness, pain over affected vertebrae, dorsal kyphosis, vertebral compression fracture
• Degenerative joint diseases • Osteoarthritis • Degenerative disc disease (DDD) • Articular degeneration	• Localized pain and tenderness • Mild morning stiffness • Increased pain while performing spinal extension or standing
• Referred LBP: Viscerogenic disorder • Vascular lesions • Genitourinary lesions • Kidney	• Dull diffused, deep pain in the abdomen or may radiate to hips or thighs • Constant pain over costo-vertebral angle • Colic pain or dull flank pain • Pain centred round sacrum or

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• Urethral • Bladder infection	girdle pain along the belt line
• Gastrointestinal • Pancreatitis • Peptic ulcer • Colon or rectal disorders	• History of excess alcohol consumption • Pain relieved after eating • Peristaltic colic pain
• Polymyalgia • Rheumatica	• Proximal shoulder or hip joint stiffness in 75-year-old individual with ESR level
• Fibromyalgia due to: • Chronic fatigue • Irritable bowel syndrome • Psychotic	• Diffused muscular pain • Widespread tender areas or trigger points • No other relevant clinical or laboratory finding

Note. Before planning treatment do not forget to eliminate disabling disorder causing LBP and rule out the cases of

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referred LBP.

Acute phase: This is the phase of excruciating pain. Therefore, reduction of pain, spasm and inflammation assumes priority over all other symptoms.

1. Muscle spasm: Spasm is protective in nature during the initial stage. Therefore, stretching of the muscles should be avoided. However, it must be remembered that if it is allowed to persist, it may lead to contracture of the soft tissue elements such as erector spinae muscles, lumbosacral fascia, ligaments and facet joint capsules. Therefore, early attempts to release spasm through relaxation techniques are of primary importance. Cryotherapy/steam packs are effective in relieving the spasm.

2. Bed rest for first 3–5 days or well-guarded relaxed movements only in the pain-free range.

3. Proper back care avoiding strain.

4. Frequent change of posture 'in bed'; preferably lying prone whenever possible, may be with assistance.

5. Analgesics and anti-inflammatory drugs.

6. Pain relieving physiotherapeutic agents to control pain and inflammation.

7. If the pain is radiating in nature, light lumbar traction (continuous) may be indicated, which mainly serves as immobilization rather than traction. If the symptoms persist for over 5 days, patients may need prolonged bed rest with

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or without gentle traction.

8. However, the modern concept of treating acute LBP advocates earliest return to controlled activities rather than bed rest. Activities should be performed only in the pain-free range.

Subacute phase: When the symptoms improve, further relief can be achieved by gradual mobilization through relaxation.

1. *Continuous relaxed rhythmic passive movements*: They have been proved to be beneficial in further reducing pain and improving nutrition of the disc (Choler et al., 1985).

2. *Relaxation techniques*: (a) Use of appropriate physical agent to induce relaxation; (b) initiation of relaxed pelvic and chest rotation; (c) use of PNF techniques (Voss & Knot, 1968) only if pain-free.

3. *Specific corrective exercises*: Once relaxation is achieved, specific exercise programme, depending upon the patient's problem, has to be started based on biomechanical principles. The specific technique is aimed at not only correcting the faulty elements but also maintaining the corrected posture. Sometimes, LS support may be needed to ensure the maintenance of the normal lumbar lordosis. (The specific exercises for a particular postural fault are elaborated separately on the rationale of causative factors.)

4. *Mobilization*: Early initiation of mobilization, conditioning and fitness programme, sometimes including even aerobics,

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has proved effective.

The exercise programme should be aimed at gradual loading associated with initiation of activity of larger muscle groups. These exercises not only promote healing of the cartilage, ligaments and tendons but also influence the chemical modulating system. They increase the level of endorphin in the blood and cerebrospinal fluid, reducing the sensitivity to pain (Salter, 1982; Woo et al., 1981).

5. *Activities of daily routine*: Initiate the activities the patient is supposed to carry out in the daily routine at the earliest possible opportunity. Early but gradual and biomechanically controlled return to the activities of daily routine has proved to be the best method of treatment (Nachemson, 1983).

Low back pain due to faulty postural attitudes

Faulty habitual postural attitudes often give rise to LBP. The abnormal pelvic tilt is a common feature, which could occur as a result of various musculoskeletal imbalances. Habitual wrong posture results in muscular tightness, eventually leading to fixed deformity. Pelvic tilt or trunk flexion deformity due to such wrong postures may precipitate LBP (Table 32-16). The pelvic tilt is of three types (Kendall, Kendall, & Boyton, 1960):

1. Anterior

2. Posterior or

3. Lateral

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1. **Anterior pelvic tilt**: It puts undue compression stress on the posterior part of the vertebral bodies and articulating facets. At the same time there is increased stretch or tension on the anterior longitudinal ligament. This results in the exaggeration of lumbar lordosis. This is found commonly in obese individuals with a protruding abdomen.

Anterior pelvic tilt could result from any of the following muscle imbalances:

(a) Weak abdominal muscles (upper or lower)

(b) Tight low back muscles

(c) Tight hip flexor muscles

(d) Weak hamstrings muscles

(a) *Weak abdominal muscles*: The pain presents as fatigue or ache which becomes worst as the day passes on and is relieved by rest or back support. The strength of the abdominals should be carefully evaluated by recording isometric holding time or any other technique. Tightness in the low back muscles and hip flexors can be detected by passive tests.

(b) *Tight low back muscles*: Tight low back muscles give rise to dull ache which increases on attempted lifting and is present during movement as well as rest. This type of back is mechanically weak but the back muscles are strong and rather overdeveloped.

(c) *Tight hip flexor muscles*: The tightness of hip flexor muscles

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results in exaggerated lordosis in standing or supine lying with hips and knees in extension. Pain is present during standing and is relieved by sitting or supine with hips and knees in flexion. The relief in pain is due to the reduced tension on the hip flexor muscles. The tightness in hip flexor muscles can be easily detected by the Thompson test in supine position (Fig. 32-66).

(d) *Weak hamstring muscles*: This is a rare phenomenon but in association with abdominal weakness it exaggerates the anterior pelvic tilt and lumbar lordosis. Static posture of standing with knees hyperextended and pelvis tilted anteriorly puts tension on hamstrings, causing gradually increasing stretch weakness of the hamstring muscles. Therefore, it is essential to differentiate between weakness and tightness of hamstrings for planning the treatment programme.

2. **Posterior pelvic tilt**: It may give rise to the following:

(a) Rigid flat back with tightness and overdevelopment of the low back muscles. Forward bending movement gives rise to acute strain and pain.

(b) The lumbar spine assumes a position of flat back or there may be slight kyphosis when it is associated with weakness of hip flexors (psoas).

(c) The positions of standing, sitting and bending put undue strain on the anterior surfaces of the bodies of lumbar vertebrae, posterior spinous ligaments and muscles of low back.

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3. **Lateral pelvic tilt**: It usually presents as a unilateral lumbosacral strain with tenderness over the articulating facet of the 5th lumbar vertebra on the dominant side. The lateral pelvic tilt produces muscle imbalance. On the raised side of the pelvis, there is weakness of the gluteus medius, stronger hip adductors and lateral trunk muscles, while on the opposite side there is tightness of hip abductors and tensor fascia lata.

Pain may be present in the lower back region or legs.

When the cause of LBP is muscular imbalance, it needs to be treated with specific exercises to correct these imbalances along with ergonomic advice.

Leg length disparity must be checked, as it could result in lateral pelvic tilt.

FIG. 32-66Test for tight hip flexors on the right side.

Table 32-16

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Deformity and the Probable Cause

Deformity	Causative Factor
1. Pelvic tilt	
Anterior	Weak abdominals
	Tight low back muscles
	Tight hip flexors, tensor fascia lata
	Weak hamstrings
Posterior	Tightness and overdevelopment of low back muscles
Lateral	Scoliosis (structural or sciatic)
	Limb length disparity
2. Trunk flexion deformity	Cartilaginous locking in flexion to accommodate posterior protrusion

Specific exercises for backache due to muscular imbalance

For weak upper abdominal muscles: Supine with a small pillow under the knees. Initially, tilt the pelvis to flatten the back. Maintaining the pelvic tilt with arms extended forward, raise the head and shoulders high enough to clear the scapulae off the table (Fig. 32-67). Hold this position. Alternatively, without hold, bring the shoulders down slowly but not enough to make contact with the table. Repeat till fatigue sets in. Record the time of hold or the number of lifts at a time.

For weakness in the lower abdominals, pelvic tilt to flatten the back with strong lower abdominals is ideal. Bilateral

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straight leg raising can be an alternative exercise, provided there is no back pain.

For tight lower back muscles: Sit with back against a wall, keeping a small pillow under the knees. Reach forward towards the toes by tilting the pelvis and bending at the lower back. Stretch should be felt at the lower back and not the knees or upper portion of the back (see Fig. 32-65).

FIG. 32-67Exercise for weak upper abdominal muscles.

Caution

Exercises or positions promoting hyperextension are contraindicated, e.g., hyperextension exercises in prone lying, double leg raising or sit-ups.

For weak/tight hamstring muscles: Accurate diagnosis is necessary to ascertain whether the hamstrings are weak or tight. Weakness in the hamstrings is often associated with

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weak abdominals giving rise to anterior pelvic tilt and exaggerated lumbar lordosis. Therefore, exercises to correct anterior tilt of the pelvis relieve tension on the hamstrings. Self-resistive knee flexion exercises in sitting are preferred as they can be easily repeated by the patient several times.

For posterior pelvic tilt: Hyperextension exercises with localization at the lumbar region – prone lying with hands over the lumbar region. Lifting head and shoulders with lumbar extensors, avoiding strain at the neck and upper thoracic region. Hold and then bring the shoulders down in a small range to lift them again with extra efforts (Fig. 32-56).

If there is an associated weakness in the psoas, strengthening hip flexion exercises in sitting position should be added.

For lateral pelvic tilt: Basically, heel raising is needed on the side of dropping of the pelvis. Exercises to strengthen the weak gluteus medius are needed on the side of the raised pelvis. Exercises to stretch tight abductors on the side of the dropping of the pelvis are to be taught.

For stretching tensor fascia lata: To stretch the left tensor fascia lata, the patient assumes the right-side lying position with hip and knee bent. Pelvis on the right side should be stabilized firmly. Draw the left thigh slightly backwards on the table. Inward rotation at the knee due to tight tensor fascia has to be avoided. It can be done in prone lying position, stretching the hip into extension with knee in flexion. Extension of the hip should be in the neutral position of abduction and adduction.

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For stretching of the tight heel cord: Occasionally, there may be unilateral or bilateral tightness of the heel cord. This puts excessive strain on the hamstrings and lumbosacral spine. It is noticed in forward bending. Unilateral heel cord tightness may cause pelvic rotation and lateral flexion.

During physical examination, many a times, alterations may be observed in the normal curves of spine, e.g., exaggerated dorsal kyphosis with round shoulders. These also need appropriate corrective exercises and ergonomic advice.

Physiotherapeutic management of chronic low back pain

The treatment of chronic LBP is a complex problem. Pain is a perception which reflects not only bodily events but also thoughts and emotions. At times the cause of chronic LBP may be psychosomatic. Disorders such as peptic ulcer, allergic rhinitis, asthma, colitis, migraine, tension headache, idiopathic cardiac palpitations, angio-neurotic oedema, neurodermatitis, eczema and psoriasis may give rise to LBP. Peptic ulcer alone accounts for about 72% cases of psychosomatic LBP. It is believed that these disorders originate in the limbic nuclei and are mediated through the autonomous nervous system. *Tension myositis* is also one of the common basic factors in chronic LBP (Sargent, 1946; Sarno, 1976). Its typical characteristics are as follows:

1. Minor trauma is enough to precipitate acute, excruciating LBP.

2. Sudden shifting of the back pain from one leg to the opposite leg which is contrary to the true radiculopathy of

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spinal origin.

3. Long standing pain without any obvious neurological deficit or objective parameters.

4. Patient complaining of pain simultaneously in the muscles of the upper and lower back.

5. Persons with certain personality characteristics such as overambitious, compulsiveness, perfectionism, depression and over anxieties are more prone (Blumer & Heibronn, 1982; Sternbatch, 1977).

As the localization of pain usually does not fit in any typical area of distribution, it can be easily diagnosed as tension myositis. A questionnaire that includes dermographic information can be used. Ask the patient to draw painful areas (pain drawings) on the body chart. In certain cases, it may be necessary to get a psychological evaluation done without the patients' awareness (Deyo & Diehl, 1983). The physiotherapist with his psychological background and with the help of various treatment modalities, is the right person to deal with this problem.

To be successful, the physiotherapist has to change the patient's attitude towards pain. Planning of treatment schedule, choosing appropriate modality, initiating therapy – all have to be done, giving due importance to the patient's acceptance.

Physiotherapeutic schedule

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1. *Awareness of diagnosis*: For an effective management, the first important responsibility of the physiotherapist is to gradually convince the patient to accept the diagnosis.

2. *Choice of the correct modality*: There is no study about the efficacy of a particular modality of physiotherapy. However, TENS has been reported to be effective in 83.8% of patients with chronic LBP (Fried, Johnson, & McCraken, 1984; Loeser, Black, & Christman, 1975).

3. *Exercise*

(a) Gradual active mobilization: Psychogenic effects of exercises in reducing anxiety and depression are well documented (Blair, Jacobs, & Powel, 1975; Tylor et al., 1985). Similarly, the ill effects of inactivity have been adequately demonstrated in psychosomatic conditions as well as in other chronic LBP patients. Excellent results have been reported by the use of active mobilization in patients even after failure of surgery (Mayer et al., 1985).

(b) Strengthening exercises: Exercises to strengthen the back extensor muscles play an important role in the control of chronic LBP. Improved tone of the erector spinae gives a feeling of better physical fitness.

(c) Endurance exercises: Improvement in endurance of the larger muscle groups also plays a decisive role. These exercises increase the level of endorphin in blood and CSF, which has been reported to be diminished in chronic LBP (Puig, Laorden, Maralles, & Olason, 1982).

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(d) Isometrics: Strong isometric exercises are effective in chronic back pain, especially of myofascial origin (Wong & Burlingame, 1986).

(e) *Progressive mobility and active exercises*: Progressive mobility exercises are important to improve flexibility of the body and ease of function.

(f) Physical fitness through aerobics: Positive correlation between physical fitness through aerobics is an efficient method of decreasing muscular tension. Aerobics increase alpha-wave activity, producing central and peripheral relaxation response (De Vries, 1968; Farmer et al., 1978). Aerobics preceded or succeeded by relaxation techniques such as *shavasan* should be ideal in inducing freshness and a feeling of well-being. Aerobic exercises are also well accepted, being a popular craze of the present time. Aerobics such as swimming, cycling and brisk walking need to be emphasized as they also provide diversion from pain.

4. *Specific exercises and body mechanics*: When recurring strain is the cause of chronic LBP, advice on biomechanically controlled body mechanics and back care programme should be emphasized.

Lesions of the intervertebral disc

Pathology of disc lesions

Discogenic low back pain

The intervertebral disc is a hydrodynamic system with

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centrally placed nucleus. The nucleus is surrounded by inner and outer annular collagen fibres (Fig. 32-68), which restrain the contents of the nucleus within its central region. The disc is basically aneural. However, the extreme outer layer of the annulus is innervated and could well be the site of nociceptive stimuli. Vascularization, inflammation, autoimmune responses and stimulation of the nerve endings can occur as the annulus tear progresses. The disc allows some compression, flexion and rotatory torque and acts as a shock absorber protecting the neural elements. Besides soft tissues, such as muscular and ligamentous structures, the disc is protected by the facets. The disc separates the vertebral end plates, maintaining the patency of the spinal canal and the intervertebral foramina. Therefore, any impairment in the integrity of the disc is enough to precipitate LBP and its related symptoms, depending upon the extent of the disc lesion.

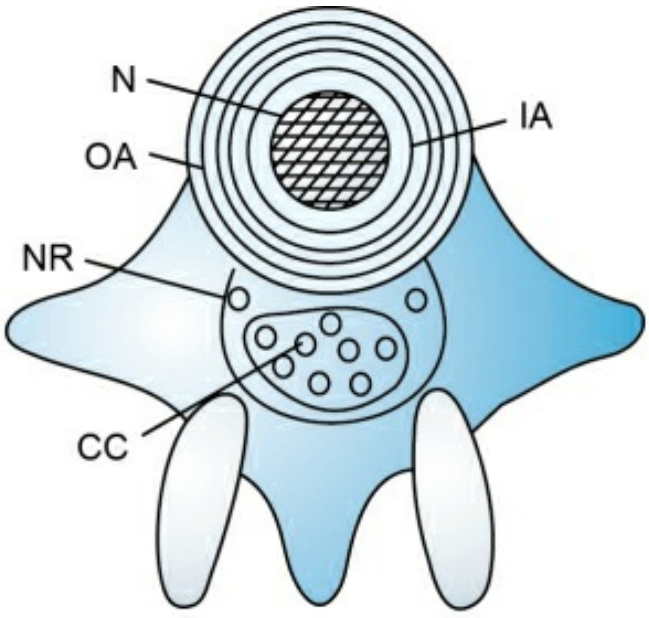

FIG. 32-68Intact intervertebral disc. OA, outer annulus;

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IA, inner annulus; N, nucleus; NR, nerve root; CC, central canal.

Disc lesions

The disc, basically a soft fibrocartilaginous structure, is entrapped in between hard vertebral bodies, and therefore remains susceptible to extrusion with compressive forces.

Before discussing various disc lesions, it is important to know the possible cause of LBP, whether it is discogenic or due to muscular or joint dysfunction. Mennel (1960) provided guidelines to identify the offending tissues precipitating LBP (Table 32-17). If the lesion is due to disc pathology, it is important to identify the type, extent and site of the lesion (Tables 32-18 and 32-19). Provocative nuclear test as described by Kopp et al. (1986) is done. In this test, passive maximum hyperextension in prone lying position is tested first on elbows, progressing to hands. Passive hyperextension of the lumbar spine forces the nucleus anteriorly. Therefore, when the lesion is self-contained, there is no increase in the symptoms. However, when there is herniation into the canal, it is compressed further, reproducing or increasing the symptoms, such as radicular pain. Thus, it identifies the patient who is likely to respond to conservative mode of treatment or else may need surgery.

Table 32-17

Characteristics of Low Back Pain Due to Joint Dysfunctions, Musculotendinus Dysfunction and Disc Lesions

Joint	Muscle

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Characteristics	Dysfunction	Dysfunction	Discogenic
Onset	Sudden	Sudden	Sudden
	During movement	With lifting	With stressful movement
	With snap or lock	With feeling of tearing	With lock
Effect of rest	Relieving	Stiffening	Relieving
Effect of activity	Aggravating	Aggravating	Aggravating
Location (tenderness)	Over L5–S1 junction or sacroiliac joint	Over muscle	Over intervertebral junction
Architectural changes	Segmental alteration of normal curve	No change in spinal curve	Segmental alteration of normal curve
	Curve convex on side of pain with iliac crest raised on side of pain		Curve concave on the side of pain with iliac crest lower on the side of pain
Mobility	Localized loss	Less well localized	Localized loss
Percussion	Short sharp pain	–	Short sharp pain, often with radiation
Obvious	One joint	No joint	One junction

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Physical signs	One level	No area	Same level joint
General	Pain may be referred	Pain in muscle	Radiating pain
Observations	No neurological sign	No neurological sign	Mixed neurological signs
	Patient lies still	Patient varies position	Patients lies still
	No signs of systemic disease	No signs of systemic disease	No signs of systemic disease
	No fever	No fever	No fever
X-ray findings	Negative	Negative	Negative except with special techniques (MRI)
Laboratory findings	Negative	Negative	Negative except increased protein content in the CSF

Table 32-18

Symptoms Related to the Type of Disc Displacement

Disc Displacement	Location	Pain	Deformity

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Pain		Radiation	
• Posterior disc displacement	Central or symmetrical across L4/L5 region	May radiate to buttock or thigh	No deformity, or flat or kyphotic lumbar spine
• Posterolateral disc displacement	Unilateral or asymmetrical across L4/L5	May radiate to buttock or thigh	No deformity, or lumbar scoliosis
• Posterolateral disc displacement with impingement of nerve root and dural sleeve	Unilateral or asymmetrical pain across L4/L5	Intermittent or constant sciatica with buttock or thigh pain	Sciatic scoliosis
• Anterior or anterolateral disc displacement	Symmetrical or asymmetrical pain across L4/L5	May radiate to buttock or thigh	Accentuated lumbar lordosis

Notes: Features of L1–L2 nerve root involvement:

- Cauda equina lesion
- Groin or testicular pain
- Positive stretch test

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- Late stage – atrophy of the involved limb

Table 32-19

Differential Diagnosis of Lumbar Canal Stenosis and Herniated Disc

Spinal Stenosis	Disc Herniation
1. Onset is comparatively at old age	More incidence in younger age
2. Chronic pain	Acute pain
3. Lumbar lordosis usually maintained	Lumbar lordosis flattening is common
4. Sciatic tilt is less common	Sciatic tilt common
5. Gluteal muscles unaffected	Loss of tone with drooping of the gluteal fold is common
6. Less restriction of spinal movements	Marked restriction of spinal movements
7. Symptoms usually bilateral and less restriction of SLR	Marked restriction of SLR, and symptoms usually unilateral

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8. Bilateral involvement of more than one nerve root	Unilateral involvement is more common
9. Even minimal hyperextension causes pain	Hyperextension relieves pain
10. Walking uphill is easy; walking down the hill is painful	

The commonly affected discs in the lumbar region are the fourth and the fifth discs. Basically, there are two types of disc lesions:

1. Self-contained disc lesion

2. Disc lesion with nuclear extrusion

1. **Self-contained disc lesion**: In the self-contained disc lesion, the disc and the nucleus pulposus remain intact within the confines of the disc. The outer annulus fibres which are longer and occupy a more distant place from the axis of rotation may be exposed to excessive stress (torque force) during rotation, and thus tear occurs more easily. When the tear of the outer annulus fibres is minimal, the rest of the intact annulus fibres are sufficient to prevent nuclear extrusion or the extrusion of the annulus fibres into the canal (Fig. 32-69). Similarly, the tear may occur at the inner annulus fibres causing some extrusion of the nucleus.

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However, when sufficient outer annulus fibres are intact, the extrusion of the outer annulus (bulging) into the canal is prevented (Fig. 32-70).

2. **The disc lesion with nuclear extrusion:** The lesion is characterized by the extrusion of disc material into the central (posterocentral) or foraminal canal (posterolateral). This lesion is of two types:

(a) *Inner nuclear extrusion with protrusion of the outer annulus*: The central or posterolateral extrusion of the nucleus (Fig. 32-71) causes external protrusion of outer annulus (annular bulge). The protrusion encroaches through the rent in the longitudinal ligament and impinges on the emerging nerve root. The neurological tests specific to that nerve root are positive.

Diagnostic tests such as discograph, CT scan, myelography and MRI may reveal the bulging disc.

(b) *True herniation* (Fig. 32-72): The extrusion of the nucleus occurs through the ruptured outer and inner annulus into the central or foraminal canal. The signs and symptoms will depend upon the site and extent of the extrusion of the nuclear material. The extrusion may be:

i. *Central extrusion*: The extrusion of the nuclear material presses the posterior longitudinal ligament, giving rise to LBP, which may involve the lumbosacral area and buttocks. The lumbar spine assumes antalgic posture. Nuchal flexion aggravates the pain.

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The radiograph will show obliteration of the lumbar lordosis. CT scan, myelograph or MRI may indicate bulge without the displacement or encroachment of the nerve roots.

Both the flexion and extension attitudes are contraindicated for a week or so to avoid further herniation. Corset may be useful.

ii. *Posterolateral extrusion*: Herniated nuclear fragment, when encroaches on the passing nerve root through a rent in the longitudinal ligament, may damage the nerve. The symptoms specific to the impingement of a nerve root may be identified by the pain, point of specific tenderness, sensory (dermatomal), motor (myotomal) and other neurological tests as related to its segmental representation (Figs 32-73A, B and C).

The classical signs and symptoms are as follows:

1. Trunk flexion is painful and limited; when it is attempted, there is no reversal of lumbar lordosis. The flexion occurs only because of the rotation of the pelvis on hip joint. Sciatic scoliosis (list) will be present.

2. Straight leg raising will be positive with positive dural sign. When there is significant entrapment of the involved nerve root, contralateral SLR may also be positive.

3. Sensory impairment over the dermatomal distribution, and motor weakness over the myotomal distribution of the involved nerve root will be present.

4. The reflexes will be either sluggish or absent.

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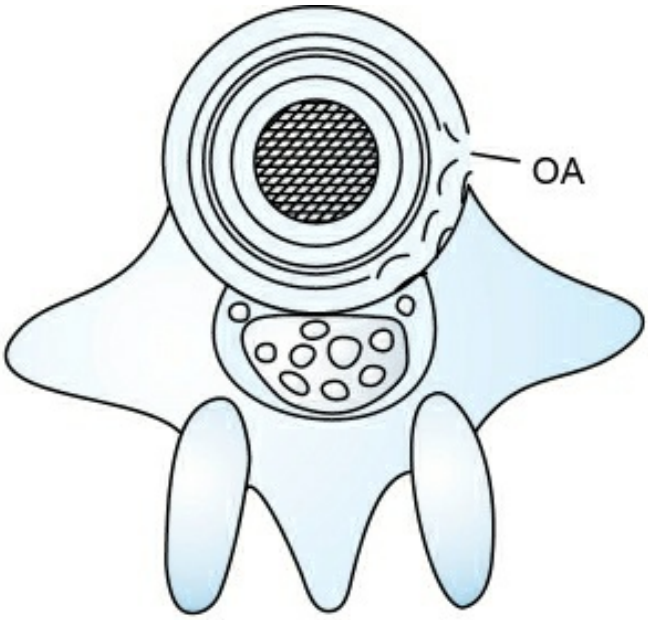

FIG. 32-69Self-contained disc lesion with tear of the outer annulus (OA) with intact nucleus.

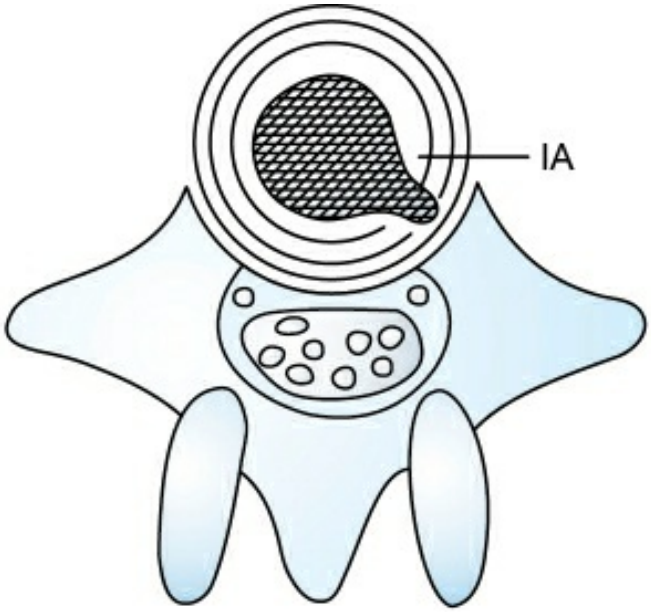

FIG. 32-70Self-contained disc lesion with tear of the inner annulus (IA) causing some extrusion of the nucleus, but outer annulus is intact.

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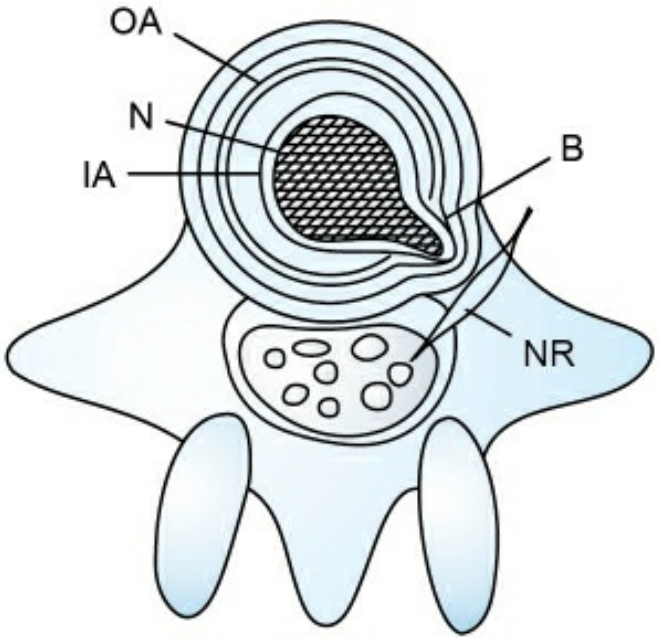

FIG. 32-71Central nuclear extrusion causing protrusion of the outer annulus (annular bulge B).

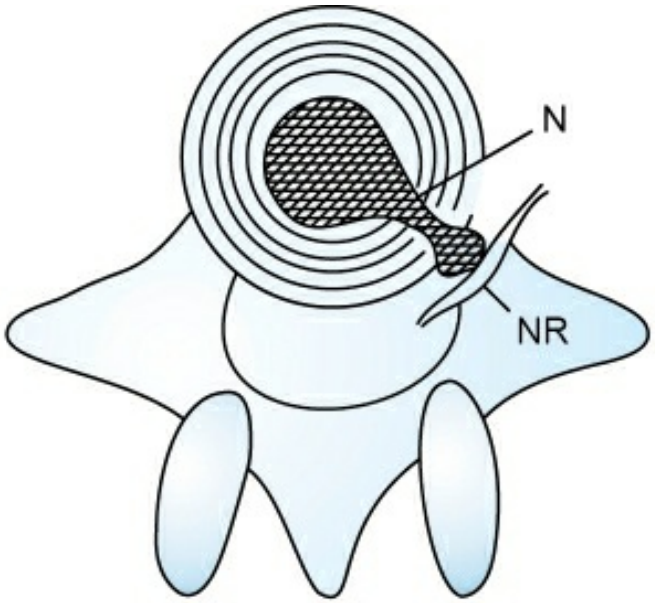

FIG. 32-72True herniation: extrusion of the nucleus through the ruptured outer and inner annulus into the foramen against the nerve root.

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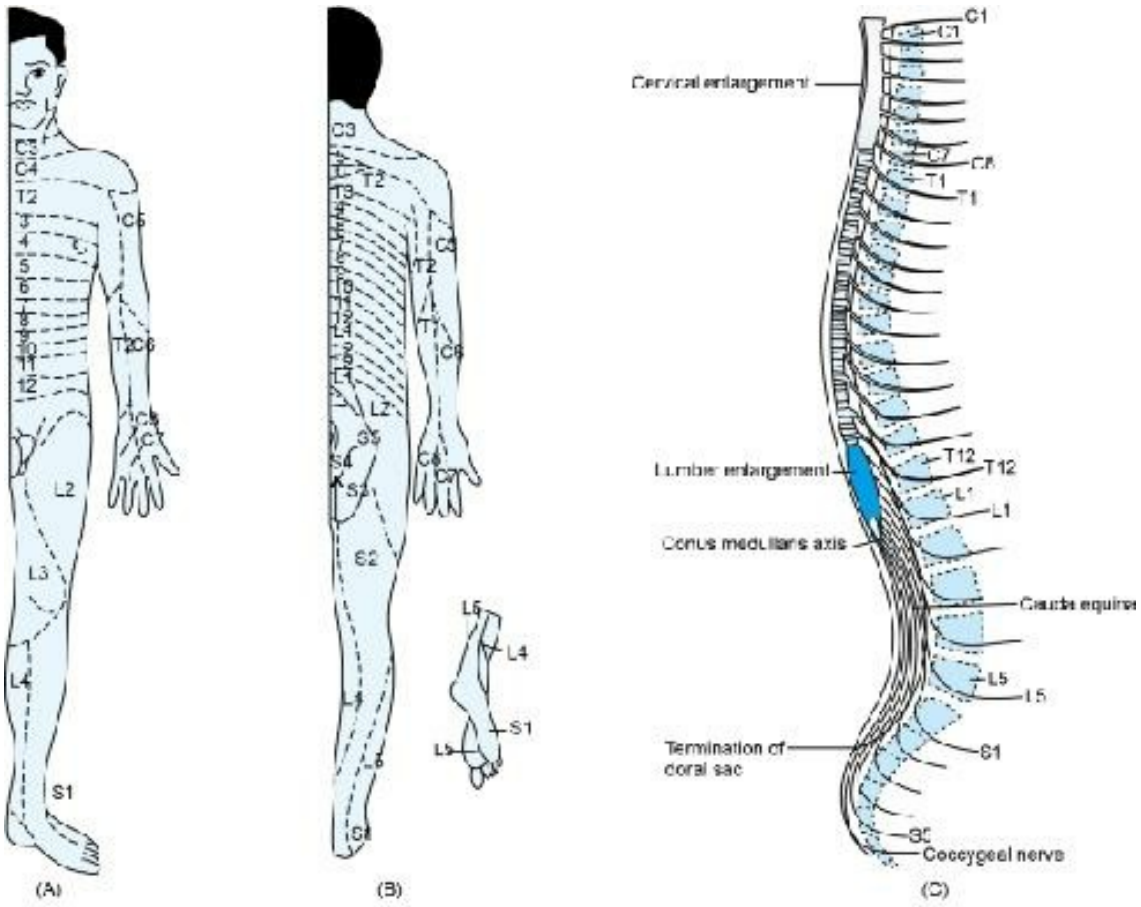

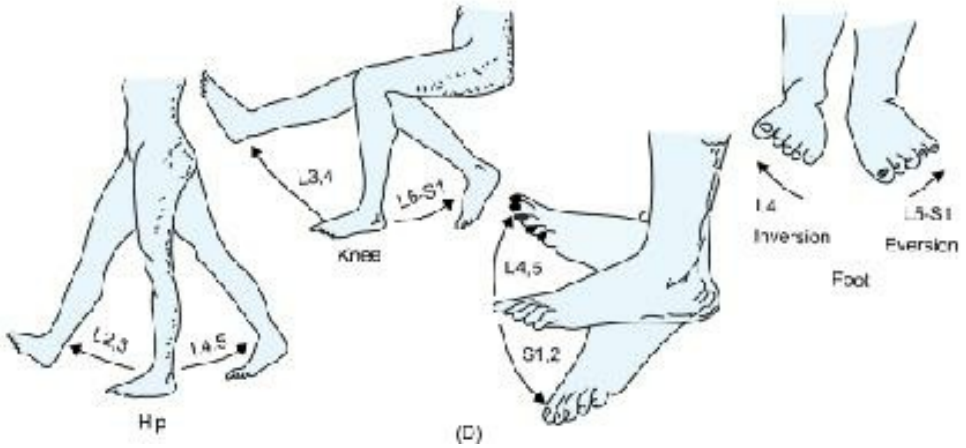

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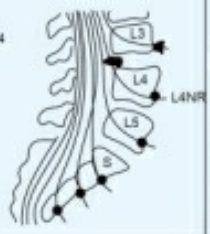
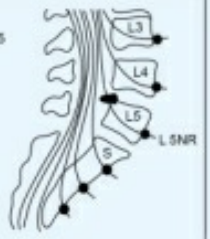
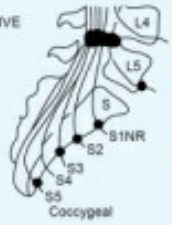
	Pain	Numbness	Weakness	Atrophy	Reflexes
L3–4 			Weakness of quadriceps	Quadriceps	Knee jerk diminished
L4–5 			Foot drop Weakness of extensor hallucis longus and dorsiflexion	Minor	Uncommon
MASSIVE L4–5 DISC 	Lower back, thighs, legs, and/or perineum, may be bilateral	Variable; thighs, legs, feet, bilateral	Variable paralysis of paresis of legs, bowel, bladder	May be extensive	Ankle jerk diminished or absent
L5–S1			Weakness of gastrocnemius		Ankle jerk diminished or absent

(E)

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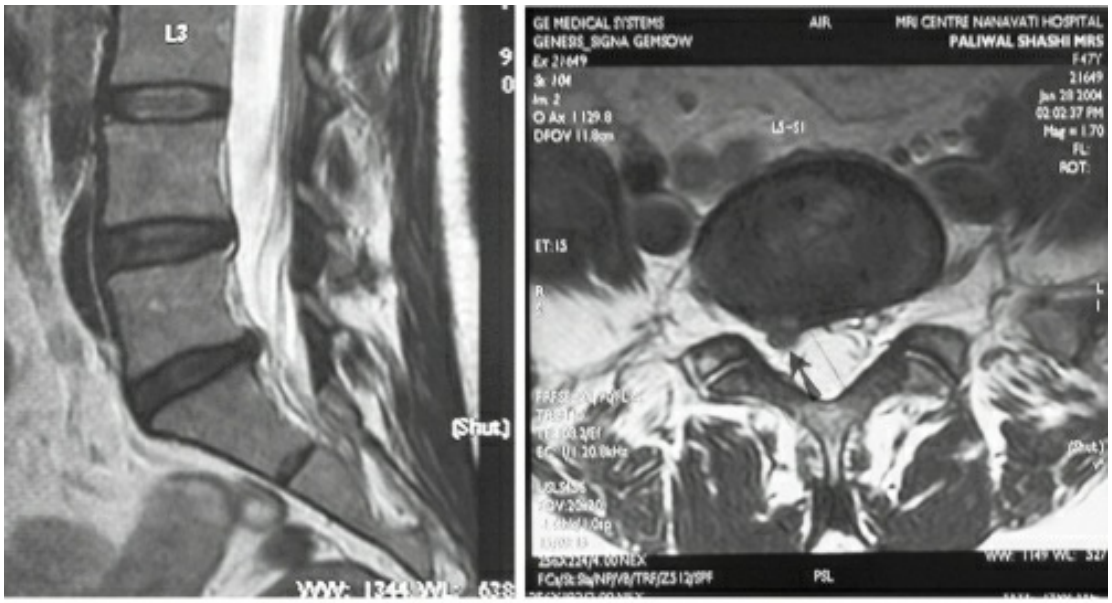

(F)

FIG. 32-73**(A–D)** Segmental sensory (dermatomal) innervation. **(A)** Anterior aspect of the body. **(B)** Posterior aspect of the body. **(C)** Course and the relationship of the spinal nerve roots to the vertebral levels. **(D)** Segmental myotomal distribution of the movements of the lower limb. **(E)** Clinical features to herniated disc at various intervertebral levels. **(F)** MRI views showing posterolateral disc protrusion at L5–S1 levels.

Various diagnostic tests may be necessary to assess the extent of nerve entrapment.

Anterior or anterolateral disc lesion: Anterior or anterolateral disc lesion, although rare, may also occur. Protective accentuation of the lumbar lordosis is a definite sign. Symmetrical or asymmetrical pain may be felt across the L4–L5 region or may radiate to buttock or thigh.

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The attitudes of extension or hyperextension are strictly avoided.

Treatment of disc lesion

Conservative management.

Acute phase: During the acute phase, the aim of the treatment is as follows:

1. Prevention of progression of the prolapse

2. Control of pain and inflammation

3. Gradual mobilization

1. Prevention of progression of prolapse and reduction of the suspected disc prolapse is attempted by the following:

(a) Bed rest in optimal posture, minimizing intradiscal pressure, e.g., maintaining normal lumbar curve.

(b) Any flexion attitude of the lumbosacral complex, even isometrics to the abdominals is deferred.

(c) In a bulging or herniated disc, gentle pelvic traction can be given only for brief periods, provided it does not aggravate the symptoms. Static traction for a longer duration may result in absorption of additional fluid by the nucleus during the period of traction and may lead to high discal pressure on its release, thus aggravating the symptoms.

2. Pain and inflammation are controlled by a suitable

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modality, such as cryotherapy, hydrocollator packs, pulsed diathermy, diapulse, TENS or ultrasound and drugs.

3. Intermittent brief periods of protected mobilization using lumbosacral spinal support may be attempted when safe. Sound ergonomic principles should be used and the mobilization should be gradual. Brief periods of lying with adequate assistance should be encouraged, gradually increasing its duration. Relaxed continuous passive mobilization of the lumbar spine, pelvis and lower limbs has been reported to be effective in the healing of tissues and also in improving nutrition to the disc. Whenever feasible it should be initiated in a very small range and with great caution (Choler et al., 1985).

Caution

It should be remembered that subjective improvement is not a definite indication of the reduction of a disc prolapse. Apparent relief may be experienced by the patient when the lesion is actually progressing. Once the nuclear material escapes the confines of the outer annulus and posterior longitudinal ligament, it may not exert significant compression on nerve roots. Therefore, other parameters of objective assessment should be relied upon.

Subacute phase: When the acute symptoms recede and definite improvement is objectively seen, the programme of mobilization is made intensive in steps.

Gentle extension exercises are started initially on forearm supports, and advanced to full extension on hands if there is

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no increase in symptoms.

Intermittent traction can provide gentle compression and elongation of collagen fibres, thus augmenting disc healing.

Flexion should be initiated gradually in the form of isometrics to the abdominals. Combination of flexion and rotation should be deferred to avoid stress on the healing disc. Trunk flexion should be progressed initially, using spinal corset.

Stretching of low back muscles to avoid their shortening is initiated with single leg hip and knee flexion (knee–chest position) and progressed to bilateral knee–chest position in a graduated manner (see Fig. 32-55D and E).

Extension and flexion exercises, which have been passive so far, are made active and progressed to resistive exercises along with stretching procedures. However, intensive flexion exercises, such as bilateral straight leg raising, which puts tremendous stress on the back (Fig. 32-74), is contraindicated.

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FIG. 32-74Exercise for lower abdominals.

Aerobics – such as fast walking, jogging, running and sports – could be gradually resumed.

Ergonomic advice and home exercise programme to be emphasized to avoid recurrence.

Lesions with self-contained discs or annular protrusion need to be treated with emphasis on gradual extension from the initial phase, avoiding flexion and rotation.

Basic differences between the exercise prescriptions for disc lesions:

1. When the disc lesion is self-contained, the emphasis is on initiating gentle extension, first passive, then active. Movements of trunk flexion and rotation are contraindicated. The condition is self-limited and responds very well to conservative treatment. However, greater emphasis is laid on avoiding recurrence.

2. The treatment of an inner annulus tear with external annulus protrusion follows the same pattern as mentioned in (1) but it is necessary to observe any increase in the symptoms.

3. When there is true herniation of the nucleus pulposus, extension positioning or extension exercises are strictly avoided, as it may lead to the entrapment or further protrusion. Flexion exercises are also avoided to prevent further herniation. Therefore, no exercises are initiated at

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least for a week. If any movement is attempted, it has to be done strictly with the lumbar spinal corset.

Graded pelvic traction with careful monitoring is useful in reducing lordosis, elongating the spinal canal and reducing erector spinae spasm.

If there is neurological deficit, abnormal bladder function and impaired perianal sensation, surgical intervention is the only alternative.

Surgical management.

The indications of surgery (discectomy, i.e., disc excision) in a case of PIVD are as follows:

1. Backache with or without radicular pain, associated with neurological deficit.

2. Cauda equina syndrome.

3. Persistent severe backache with a CT scan or MRI scan proves disc herniation even without neurological deficit.

1. **Disc excision**: The following operative techniques are used for disc excision:

(a) *Interlaminar or fenestration technique:* The prolapsed disc is excised through a space created between the laminae of two adjacent vertebrae after removing the ligamentum flavum (Fig. 32-75). In this technique, the posterior ligament complex and thereby the stability of the spine is not disturbed.

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(b) *Laminectomy*: A wide and adequate exposure can be obtained by laminectomy. The spinous processes and laminae are excised from one or two vertebrae and the disc is excised through the opening thus created (Fig. 32-76). A wide laminectomy can jeopardize the stability of the spine. This procedure is also useful in cases where there is an associated lumbar canal stenosis.

(c) *Hemilaminectomy*: The lamina of only one side is removed to take out the disc material. The damage to the stability of the spine is much less as compared to laminectomy.

(d) *Microdiscectomy*: The disc is excised through a small incision using an operating microscope.

(e) *Percutaneous discectomy*: It is a minimally invasive technique where the disc excision is performed using an endoscope.

(f) *Disc arthroplasty*: Disc arthroplasty involves either replacement of the disc nucleus alone (*nucleus replacements*) or the whole of the disc with end plates (*total disc replacements*). Total disc replacement consists of placing an artificial end plate as well as a simulated nuclear core through an anterior approach.

2. **Spinal fusion**: Some surgeons prefer to do spinal fusion in addition to disc excision. It helps to stabilize the spine for the instability caused by the degenerative changes in the intervertebral (apophyseal) joints. However, in our opinion, spinal fusion is rarely indicated.

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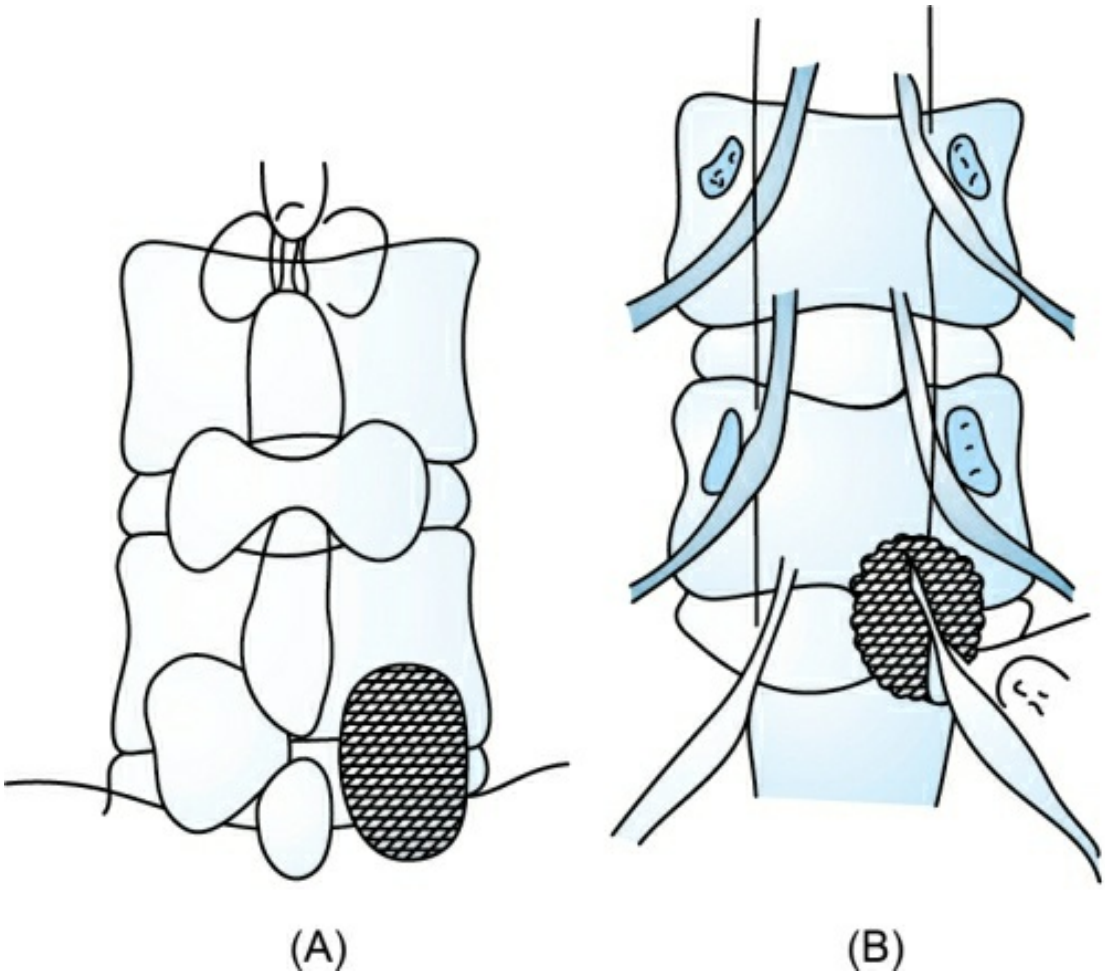

FIG. 32-75Interlaminar or fenestration procedure for unilateral single protrusion: extruded disc is excised through the space created between the laminae of the two adjacent vertebrae after removal of ligamentum flavum. **(A)** Extent of removal of bone. **(B)** Exposure available as related to spinal theca and extrathecal roots.

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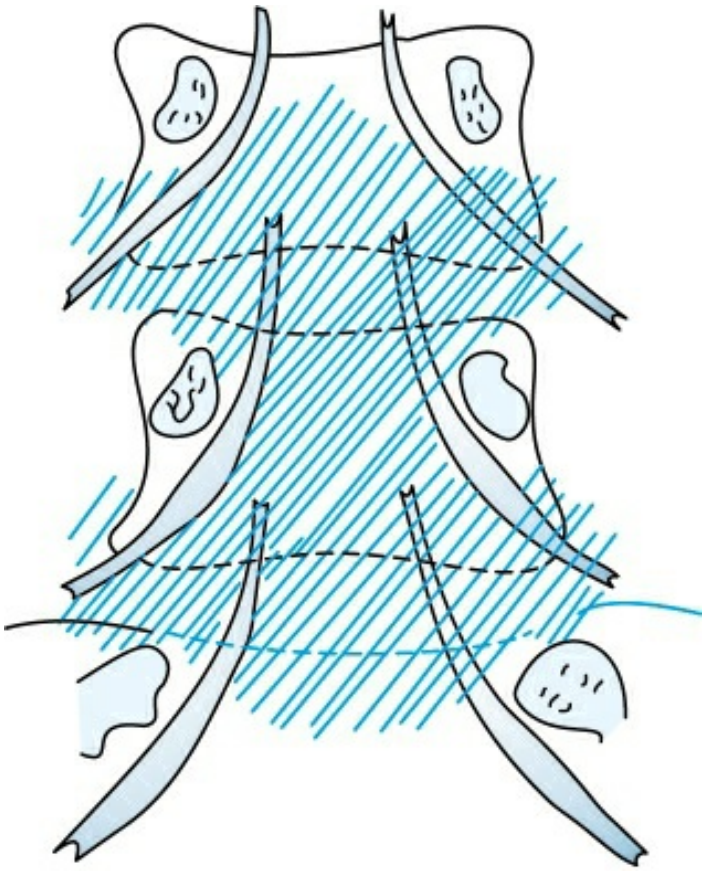

FIG. 32-76Complete laminectomy: extruded disc is excised through the opening created by removal of spinous processes and laminae from one or two adjacent vertebrae.

Postoperative management: The patient should be kept in bed for at least 10–12 days after operation. No useful purpose is served by endeavouring to get the patient up and walking in a few days as advised by many surgeons.

Patients of disc excision by the 'fenestration' method are allowed to take turns in bed on the second or third postoperative day. Spinal extension exercises are started at the end of the first week. The patient is made ambulatory in the second week.

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In the case of patients who have undergone laminectomy, mobilization is deferred until the end of the third week.

Patients with spinal fusion are given a POP jacket or a lumbosacral corset for 3 months.

Principles of physiotherapy

The patient is mobilized as early as possible to prevent the complications of prolonged bed rest (e.g., thrombophlebitis, gastrointestinal disturbances, muscular weakness and atrophy and urinary tract infections).

Therefore, safe methods of early mobilization in graduated steps should be concentrated on.

Strenuous exercises such as trunk flexion which put extra strain on the operated area should not be included during the first week following surgery.

The normal physiological lumbar curve must be maintained during all static and dynamic postures.

Ergonomic advice, depending upon the patient's daily routine postures, should be initiated with the mobilization.

Patients with lumbar fusion should not be mobilized in haste, giving due consideration to the complexities of the surgical procedure.

Physical therapy management following surgery

1. **Following interlaminar or fenestration technique**

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Week 1 and 2: Excision of the prolapsed disc by this technique allows early mobilization, as the stability of spine is not disturbed. In the immediate postoperative phase, the following are advised:

(a) Vigorous ankle and toe movements.

(b) Chest physiotherapy.

(c) Upper extremity movements.

(d) Static gluteal and quadriceps exercises.

(e) Graded hip and knee flexion by heel drag in supine.

On the 2nd and 3rd postoperative day:

(f) Turning in bed from supine to side lying to be initiated with assistance. This is done by bending the hips and knees with foot resting on the bed. The whole body is turned as one unit.

By the end of 1st week:

(g) Assisted spinal extension exercises are initiated by forearm supports in prone position (see Fig. 32-62).

(h) Isometrics for the abdominals are started and progressed to the limit of pain and discomfort.

(i) Supported sitting is begun, maintaining the lumbar lordosis.

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(j) Guided ambulation and graduated flexion with trunk rotation can be initiated.

By 3rd week:

(k) Ambulation with correct posture and gait: Spinal extension exercises are made progressive in stages, from forearm support to hand support and finally with hands on the back.

(l) Graduated spinal rotation, forward flexion and side flexion are introduced and progressed.

(m) Proper ergonomic advice is emphasized with retention of lumbar lordosis during activities.

The patient should be back to normal activities by 6–8 weeks.

2. **Following laminectomy**: The basic approach of physiotherapy during the initial stage remains the same as mentioned earlier in (1) except for the initiation of spinal mobilization and ambulation. Spinal movements are progressed gradually as follows:

(a) Back arching in supine (bridging) is initiated by the second week with assisted turning in bed.

(b) Strong isometrics to the abdominals are carefully controlled without producing spinal flexion.

(c) Prone lying and forearm-supported hyperextension to be initiated by 2nd–3rd week. Sitting up from side lying is initiated by 3rd week.

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(d) Ambulation and other spinal movements can be begun by the end of 4th week.

Caution

(i) The normal lumbar lordosis should be maintained during all activities and rest. The flexion exercises should be deferred to 6–8 weeks, or until they are painful.

(ii) Hyperextension exercises are made vigorous and without arm support. Ergonomic advice and avoidance of forward bending and weight lifting to be ensured. Guarded sport activities are safe only after 12 weeks.

3. **Following hemilaminectomy**: The physiotherapeutic management following this procedure proceeds on the same lines as described for laminectomy. As the surgical procedure is less extensive, mobility procedures can be initiated earlier. The patient should be back to his preoperative activities in 4–6 weeks.

4. **Following spinal fusion**: The extensive surgical procedure and the subsequent prolonged immobilization lead to muscular weakness and limitation of spinal movements. Physiotherapy, therefore, needs to be concentrated on two aspects.

Initially, immobilization is given in a plaster jacket. Besides the other procedures described for laminectomy, special attention is needed for the following:

(a) To improve the tone and strength of the spinal extensors

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and flexors. Regular and repeated isometrics are given while in plaster jacket.

(b) Gradual turning in bed to side and prone can be initiated by the 3rd week.

(c) Assisted sitting from side lying to be initiated by the 4th week with lumbosacral corset.

(d) Graduated walking and other ambulatory procedures can be introduced by the 6th week.

(e) Spinal movement in smaller range can be initiated by the 8th week. Flexion should be initiated carefully with rotation.

(f) Spinal corset can be gradually weaned off from 10 weeks and discarded by the 12th week.

(g) Spinal mobilization and strengthening to be made vigorous. All the movements should be made vigorous. The patient should resume his daily activities and light sports by 8–12 weeks and continue to follow the principles of back ergonomics.

Treatment of disc herniation by chemonucleolysis: Chemopapain, an enzyme derived from the leaves of papaya plant, breaks down the protein polysaccharide complexes of cartilage. When this enzyme is injected into the degenerated disc, it digests the nucleus pulposus. This offers an alternative to laminectomy in selected cases (Smith & Brown, 1967).

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Degenerative disc diseases

Spondylosis or degenerative osteoarthritis

The lumbar complex has always been a seat of degenerative changes due to excessive mobility over this area of spine. The annulus fibres undergo fibrillation, which predisposes annulus tears. The area of maximum mobility and stress, L4–L5 and L5–S1 interspaces are common sites of such annulus tears. Dehydration sets in at the intervertebral disc, resulting in the reduction of disc space. The reduced disc space brings about approximation of the zygapophyseal and facet joints, resulting in slackening of posterior longitudinal ligament. The slackening of the posterior longitudinal ligament detaches it from the periosteum due to increased intradiscal pressure, resulting in disc extrusion. The extruded disc material becomes fibrous and eventually gets calcified into a spur (Fig. 32-77). This gives rise to the following symptoms:

■ Tenderness over the lower facet joints.

■ Restriction of movements in all directions.

■ Early morning stiffness.

■ Generalized backache.

■ Intermittent acute attacks of pain with periods of total relief.

■ Radiographic evidence of segmental scoliosis at L4–L5 or L5–S1 level with facet degeneration. Asymmetrical disc

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degeneration may also occur.

(A)

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(B)

FIG. 32-77**(A** and **B)** Lumbar spondylosis. There is diminution of disc space with osteophyte formation.

Treatment

■ Nonsteroidal anti-inflammatory medication.

■ Local injection of anaesthetic agent or steroid preparation may be indicated in severe pain.

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■ Cryotherapy for acute pain.

■ Diapulse, ultrasound therapy and TENS may be useful.

■ Gentle spinal mobility exercises are initiated at the earliest.

■ Gentle flexion rotatory manipulation is beneficial.

■ As the problem is mechanical in origin, prevention of its recurrence is difficult. Therefore, ergonomic advice for back care is extremely important.

■ Relaxed mobilization of spine after recumbency is a must.

■ Long periods of recumbency as well as standing or walking is to be discouraged.

Sciatica

The disc degeneration may result in the degeneration of cartilage with capsular thickening. Osteophytic impingement and posterior articular closure may lead to narrowing of the intervertebral foramen, causing root entrapment. The root entrapment results in a typical radicular pain of *sciatica*. The radicular pain is felt over the buttocks, posterior thigh, radiating down to the calf. The entrapment may result in further closure of the foramen by activities such as sudden trunk forward bending and straightening with twisting. The radicular pain is reduced on trunk flexion with contralateral/lateral flexion. With this manoeuvre, pressure on the entrapped nerve root is relieved. Therefore, a patient usually develops pelvic tilt as a compensatory mechanism to

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avoid compression.

Treatment

It follows the same pattern as described for spondylosis. Emphasis is laid on posture and exercises that relieve symptoms.

Strengthening of the abdominals and minimizing lumbar lordosis by encouraging flexion are initiated in stages.

Patients with persistent symptoms and neurological deficit may need surgery in the form of foraminectomy.

Lumbar canal stenosis

The further narrowing of the anatomically narrower spinal canal in the lower lumbar region due to a structural abnormality is termed as *spinal stenosis*. Since this occurs most commonly in the lumbar spine, it is known as *lumbar canal stenosis*. It presents as backache with radicular pain in the legs, brought on by exercise or walking for a particular distance.

Classification

1. ***Congenital or developmental stenosis***

The lower lumbar canal becomes narrow due to laminar thickening of developmental origin or congenital as seen in achondroplastic dwarfs.

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2. ***Acquired stenosis***

The canal becomes narrow over a period of time due to various causes:

(i) *Degenerative disease*: Osteophytes encroach upon the space of the lumbar canal and cause compression (Fig. 32-78). Ligamentous laxity due to degenerative disease of lumbar vertebral joints leads to subluxation of these vertebrae, thereby narrowing the canal.

(ii) *Degenerative spondylolisthesis*: The canal becomes narrow due to slip of the vertebrae, particularly at L4–L5 level.

(iii) *Miscellaneous*: Conditions such as fluorosis and Paget's disease are associated with a narrow lumbar canal. Spinal stenosis may also develop following laminectomy or spinal fusion and following trauma.

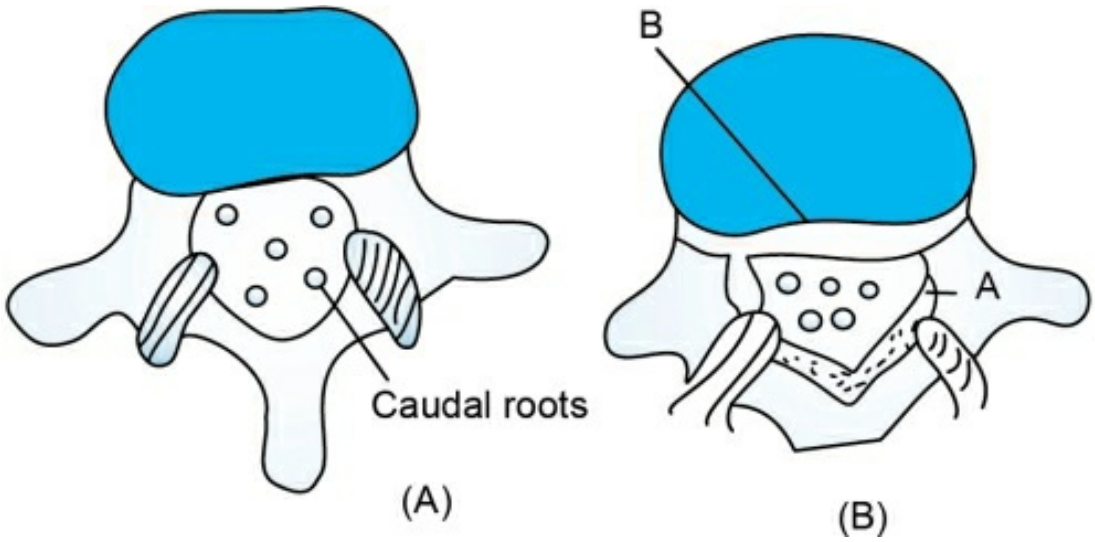

FIG. 32-78Lumbar canal stenosis. **(A)** Normal canal with adequate space for cauda equina. **(B)** Encroachment of the central canal by osteophytes and

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changes in the neural arch (B) and vertebral body (A).

Clinical features

The patient classically presents with symptoms of *intermittent claudication*. He develops pain, heaviness or paraesthesia in the lower limbs after walking for a certain distance. The symptoms become so severe that he has to take rest (sit down) immediately for a few minutes. The symptoms settle down temporarily and allow him to walk further the same distance.

Neurological examination of the lower limbs may be normal or may show a bizarre neurological deficit. In severe cases, there may be signs of cauda equina compression with loss of bladder and bowel control. Thorough examination is necessary to rule out disc herniation (Table 32-19).

Investigations

1. Plain radiograph of spine: Measurements of the lumbar canal will show decreased anteroposterior diameter of the canal or narrowing of the interlaminar space (Fig. 32-79).

2. Myelography is useful in the diagnosis. It shows multiple indentations in the dye column (Fig. 32-80).

3. CT scan and MRI are also helpful in the diagnosis.

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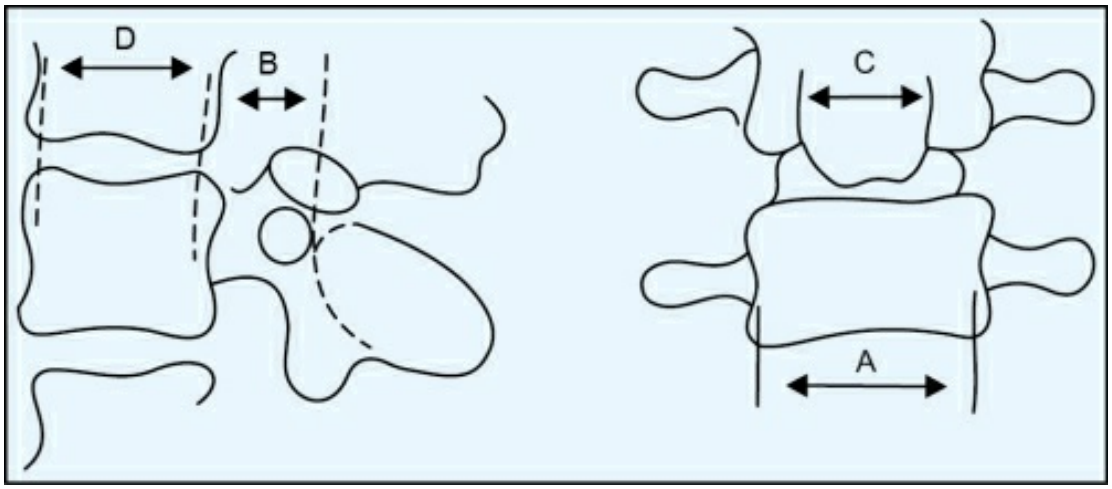

FIG. 32-79Radiographic method of measurement of the spinal canal stenosis by calculating the canal to body ratio (AB:CD). A, interpedicular distance; B, front to back distance of spinal canal; C, vertebral body width; D, front to back measure of vertebral body. Normal ratio is about 1:2 to 1:4.5; values greater than 4.5 suggest stenosis.

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FIG. 32-80Myelography: AP view of the LS spine showing multilevel spinal stenosis (SS).

Treatment

The treatment could be:

1. Conservative

2. Surgical

Conservative treatment

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The conservative approach is basically to emphasize flexion exercises and generalized flexion attitudes, avoiding extension.

1. Drugs to control pain and inflammation.

2. Improve strength, endurance and tone of the abdominal muscles: This greatly helps in the maintenance of flexed posture, which provides comfort to these patients. It should be initiated as an isometric mode so that excessive motion to lumbar spine and tension on the caudal roots is prevented.

3. Back ergonomics, avoiding extension attitudes are taught.

4. Lumbar traction may be beneficial if comfortable.

5. Lumbar corset should be used during strenuous activities.

6. Gentle passive manipulation technique is effective.

Surgical treatment

The aim of surgery is to decompress the cord by performing laminectomy. In cases of spondylolisthesis, the spine becomes unstable after laminectomy, and hence an intertransverse fusion is done.

Physiotherapy, following surgery, is described under respective headings.

Facet joint arthritis

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Degeneration of the cartilage of the facet joints can occur as a result of excessive lordosis, asymmetry of facets, abnormal postural activity and faulty extension from trunk flexion.

Treatment

The treatment will be directed mainly to avoid undue compression of the facet joints which occurs with spinal extension. However, isometric resistive exercise to the spinal extensor group of muscles is necessary. Strengthening of the abdominals (rectus abdominis and obliques) is also included to achieve strength and improve the balance between trunk flexors and extensors, thereby exerting lesser strain on the facet joints.

Anti-inflammatory and pain controlling medication is useful. Hydrocortisone may be injected at the localized facet joints when there is severe pain.

Spondylolysis

Spondylolysis is the defect in the neural arches of L5–S1 or L4–L5 vertebrae, where the bone is replaced by fibrous tissue with loss of continuity between the superior and inferior articular processes. It could be congenital or acquired following vertebral fracture. The common site of spondylolysis is L5–S1 interspace. The chief causative factor is the comparatively unstable anatomical configuration at L5–S1 junction. The body of the 5th lumbar vertebra, which is exposed to the major portion of body weight from head downwards to trunk, rests on unstable L5–S1 disc space.

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Instead of being horizontal similar to other disc spaces, the body of L5 slopes anteriorly downwards, causing excessive tension and making it susceptible to slip forward on the corresponding surface of the sacrum. When there is no slipping of L5 vertebra, in spite of the defect in neural arch, it is termed as spondylolysis. A loss of bony continuity between the superior and inferior articular processes bridged by fibrous tissue gives the typical *Scottish dog* appearance with neck belt (Fig. 32-81).

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(A)

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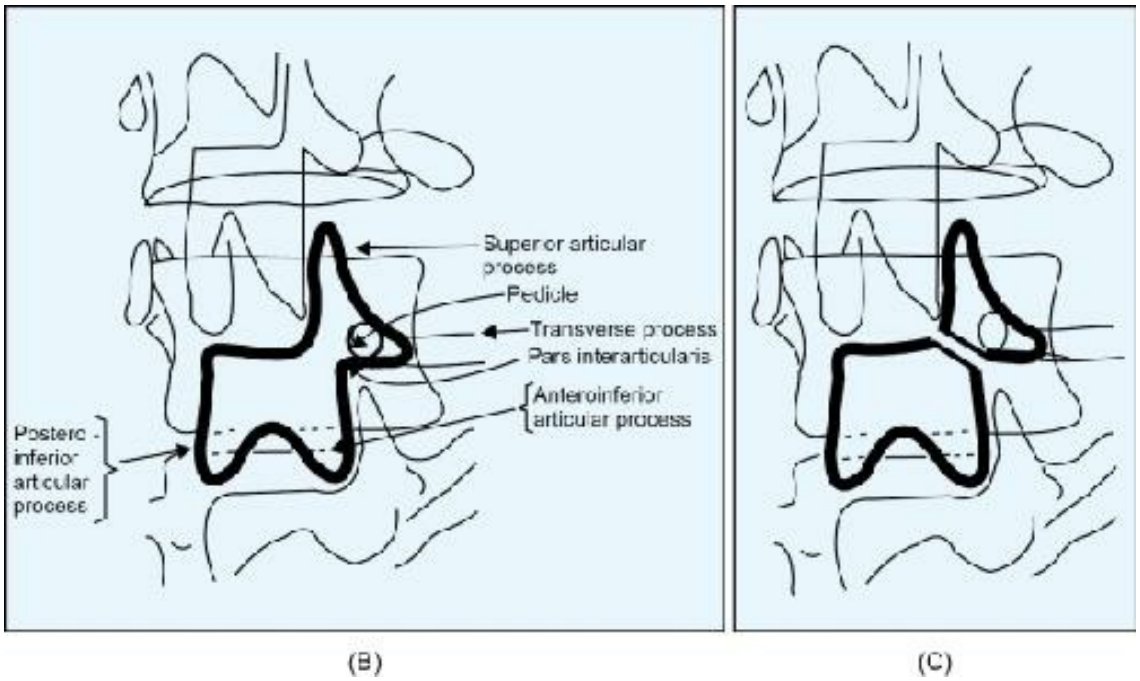

FIG. 32-81**(A)** Oblique radiograph view of the lumbosacral spine showing 'Scottish dog' appearance. **(B)** Line diagram to show the 'dog' better. The neck of the 'dog' is formed by the pars interarticularis. **(C)** Spondylolysis; note the break in the pars interarticularis.

Spondylolysis may remain quiescent or may give rise to LBP radiating to buttocks.

Treatment

When symptomatic, the management follows on the same lines as described for grade I spondylolisthesis.

Lumbar spondylolisthesis

Anterior slipping of one vertebra over another is termed as

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spondylolisthesis (Fig. 32-82). It commonly occurs between L5 and S1 vertebrae. However, a slip between L4 and L5 vertebrae is also seen. It could be congenital or acquired.

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FIG. 32-82Lateral radiograph indicating slipping of the

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fifth lumbar vertebra over sacrum.

Congenital spondylolisthesis

The incidence of congenital spondylolisthesis, also called *dysplastic*, is reported to be 6% in a survey of 500 school children of adolescent age group (Fredrickson, Baker, McHollick, Yuan, & Lubicky, 1984). The body of the 5th lumbar vertebra slips forward on the 1st sacral vertebral body. Congenital maldevelopment of the neural arch of the 5th lumbar vertebra may be present, resulting in the displacement of L5 on S1 vertebrae with kyphosis at L5–S1 junction. Pain and symptoms of compression of lumbosacral nerve roots may occur along with lumbosacral segmental instability.

Acquired spondylolisthesis

The acquired type of spondylolisthesis can be of the following types:

1. *Isthmic*: This is the most common type seen in younger people. There is a break in the *pars interarticularis*, i.e.. the part between the superior and inferior articular processes.

2. *Traumatic*

3. *Degenerative*: Seen in the old age, the displacement is mainly due to ligamentous instability and degeneration at the facet joints.

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Clinical presentation

The slipping of the vertebral body may result in low backache due to the following reasons:

1. Lumbosacral segmental instability

2. Compression of the dura mater and lumbosacral nerve roots

3. Reduction of the spinal canal

4. PIVD: The pathophysiology of low backache.

(a) During early stage of the disease, particularly in adolescent patients, acute low backache may be present.

(b) Increased stress on the pars may lead to marked paraspinal muscle spasm and localized lumbar back pain (Gramse, Sinaki, & Illstrup, 1980). There may be tightness in the hamstrings, producing positive SLR test.

(c) Majority of patients present with recurrent episodes of low backache after exertion. This is due to the ligamentous strain as a result of instability at the level of slip. The segmental instability may cause reduction in the diameter of spinal canal with symptoms of compression.

(d) Fibrous tissue due to pseudo-arthrosis of spondylolisthesis may cause irritation of the nerve roots resulting in radicular pain.

(e) Local lesions in the muscle, ligament or joint may give

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rise to referred pain.

(f) Osteophytes at the posterior joints may also cause pressure on the nerve roots (Fitzgerald & Newman, 1976).

5. *Cauda equina syndrome*: In rare instances, a severe rapid slip may present with symptoms of cauda equina syndrome, i.e., bilateral pain, neurological deficit and even urinary retention. The physical and radiographic examinations reveal exaggeration of lumbar lordosis. History is typical of increased symptoms of back exertion. Palpation reveals step at the level of slipping of vertebra with marked segmental instability.

Diagnosis

Radiographic examination (lateral view) of lumbosacral complex reveals various aspects of listhesis, which are as follows:

1. *Percentage of slip*: It can be calculated by measuring the anterior slip of the vertebral body. Myerding (1931, 1932) classified slip in the following four grades:

Grade I:	Slip from 0 to 25% up to one-fourth length
Grade II:	Slip from 25% to 50% up to half length
Grade	Slip from 50% to 75% up to three-fourth

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III:	length
Grade IV:	Slip more than 75% up to three-fourth length

Tillard (1954) formulated a simple equation to calculate the percentage of slip:

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$$\text{Percentage of slip} = \frac{\text{Displacement of L5 on S1}}{\text{Width of S1}}$$

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2. *Sacral inclination*: This is measured as an angle formed by the posterior sacral border with the vertical border (Fig. 32-83).

3. *Overall degree of lumbar lordosis*: This is measured from the top of T12 to the top of both L5 and S1. These can be accurately determined from the lateral radiograph.

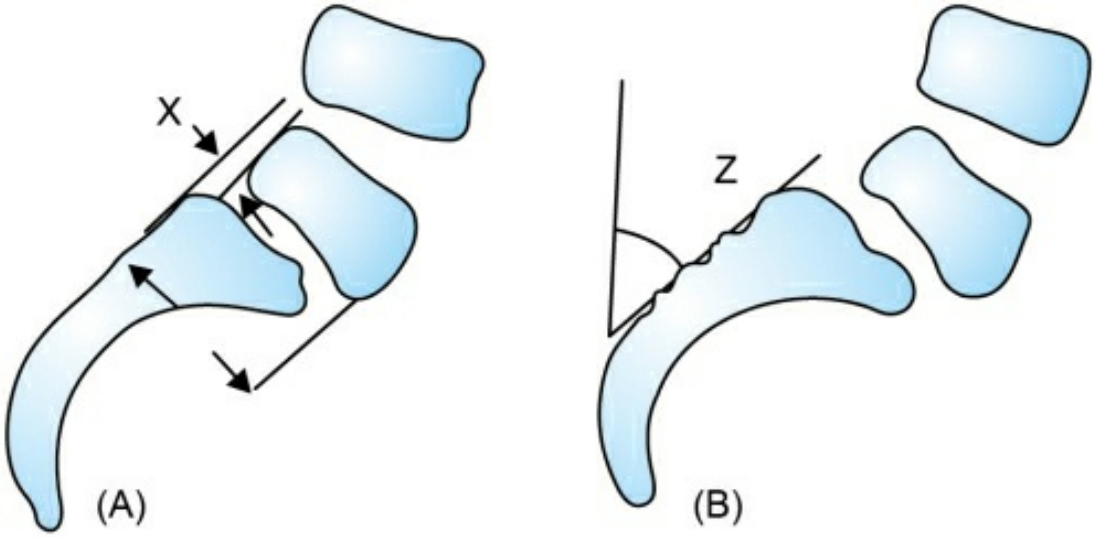

FIG. 32-83**(A)** Formula for calculating the percentage of slip: Percentage slip = X/Y × 100. **(B)** Calculating the degree of sacral inclination by measuring the angle between the posterior sacral border and the vertical line perpendicular to the floor (Z).

MRI scan may be necessary to detect cord compression or disc prolapse.

Treatment

The aim of treatment is to achieve maximum correction of

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the exaggerated lordotic curve and maintenance of the correction.

The grade of slipping of the vertebral body determines the approach of treatment. Grade I and II can be managed successfully by conservative treatment (Bell, Ehrlich, & Zaleske, 1988). However, Grade III and IV with unremitting symptoms need surgical intervention.

Conservative management

1. *Bracing*: Bracing forms an important part of conservative management. Antilordotic total contact, thoracolumbosacral-moulded brace (orthosis), is fabricated in the corrected position of lordosis (Fig. 32-84). The measurement of the slip percentage, sacral inclination and the degree of lumbar lordosis are taken into consideration while fabricating the brace. The brace has to be worn continuously. Bell et al. (1988) has reported successful results of conservative treatment but it needed brace for an average period of 25 months.

2. *Deep heat modality*: It is effective in providing relief of pain.

3. *Correct posture*: Correction of posture at rest as well as during work plays a key role. Maintenance of flexion attitude is important.

4. *Correction of deformity by corrective exercises*

(a) Exercises to improve relaxation and general mobility of the spine are initiated first.

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(b) Obliteration of the exaggerated lumbar lordosis in supine lying is taught by active posterior pelvic tilt and its maintenance (Fig. 32-85).

(c) Strong abdominal exercises are taught, maximal effort being placed over the lumbar spine.

(d) Arm chair sitting with lower back resting against the back of the chair. Gradual forward bending of the trunk at the lumbar region with strong abdominal contractions, and holding the breath (Fig. 32-86).

5. *Regular periods of prone lying and hamstrings stretching*: These are necessary to control the advancement of the lordotic tendency.

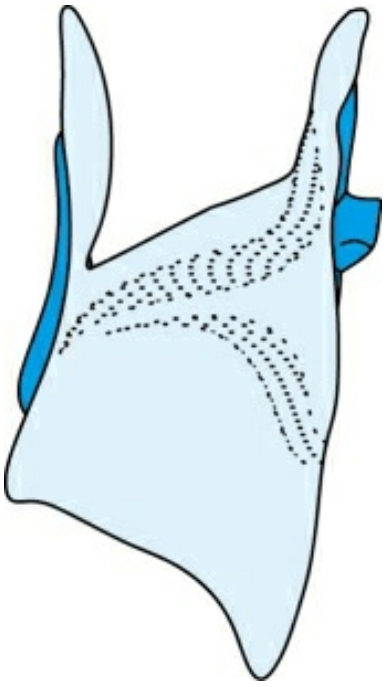

FIG. 32-84Antilordotic total contact-moulded thoracolumbosacral brace.

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(A)

(B)

FIG. 32-85Exercise to achieve active correction of the exaggerated lumbar lordosis. **(A)** Exaggerated lumbar lordosis. **(B)** Actively correcting the anterior pelvic tilt to the posterior pelvic tilt using lower abdominal muscles.

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FIG. 32-86Forward bending of trunk at the lumbar spine in chair-sitting with strong abdominal contractions.

Periodic radiographic checkup should be done, and periods of wearing brace to be waned gradually till the correction is maintained voluntarily.

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Caution

(a) Spinal extension exercises, which increase the lordosis further, are contraindicated.

(b) Wrong body mechanics or excessive standing and ambulation may give rise to fracture of the pars interarticularis. Therefore, it needs to be restricted.

Surgical management

Surgery is indicated if there is neurological deficit or the pain is disabling or the slip progresses rapidly. The various surgical procedures performed are as follows:

1. **Spinal fusion**: The spine is fused in situ, i.e., without correcting the slip. Posterior, posterolateral or anterior spinal fusion may be performed. However, posterolateral fusion is common. The loose posterior element of the vertebra may be removed to decompress the nerve roots (Fig. 32-87).

Postoperatively, the patient is nursed in bed for 4–6 weeks, after which a lumbosacral corset is given and the patient is mobilized. Some surgeons prefer a plaster jacket for 3 months after surgery.

The corset is discarded after the fusion consolidates, i.e., after 6–9 months.

Spinal fusion prevents further progression of slip.

2. **Reduction of the listhesis (slip) and spinal fusion**: Some

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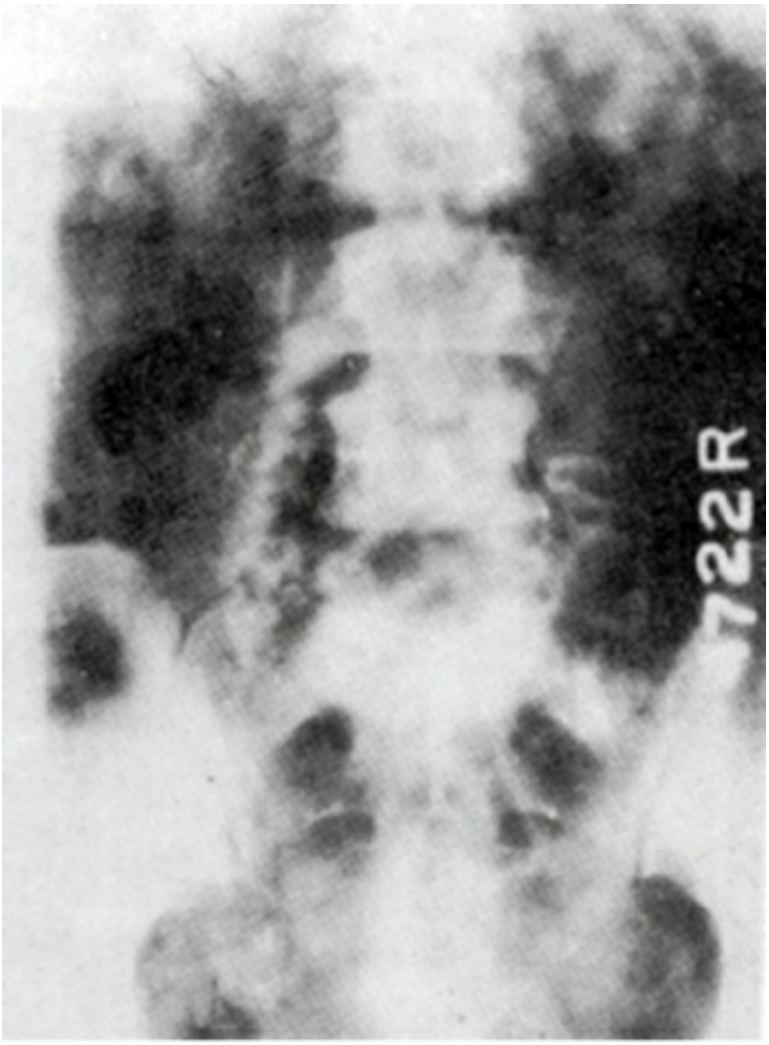
surgeons reduce the slip of vertebrae and fuse the spine posteriorly. The spine is stabilized internally with the help of rods or plates (Fig. 32-88) or some instrumentation. It requires extensive surgery and great expertise.



(A)

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(B)

FIG. 32-87Posterolateral fusion. **(A)** Anteroposterior view, bone formed along the transverse processes and the ala of sacrum. **(B)** Lateral view.

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FIG. 32-88Internal stabilization after reduction of the slip.

Physiotherapeutic management

During immobilization

1. Deep breathing and arm movements encouraged with ankle and foot movements.

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2. Assisted knee movements.

3. Hip flexion, when given, should not be taken beyond 60 degrees.

4. Isometrics to the glutei.

Mobilization: A POP jacket is applied by the 2nd week of operation. The jacket continues for a very long time, sometimes even up to 6 months or till the fusion is evident. Therefore, total mobilization with the jacket should be instituted immediately. Educating and guiding the patient to perform functional activities forms an important part of the management so that he does his activities of daily life and goes back to work.

When the jacket is removed, gradual mobilization of the spine is initiated as described in the conservative management section and progressed till total functional independence is achieved. It may take 7–8 months to regain full function.

Miscellaneous: LBP may occur as a result of conditions such as diskitis, Paget's disease, metabolic bone disease and multiple myeloma. The pain is usually severe and does not respond to any therapy, including medications. It needs appropriate investigations and therapy to control the disease as the first priority.

The following conditions, although rare, need to be identified:

1. Piriformis syndrome

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2. LBP of thoracic origin.

Piriformis syndrome

Many a times, typical symptoms such as classical sciatica may appear due to entrapment of sciatic nerve in the piriformis muscle.

Tests to confirm the piriformis syndrome

1. The patient is asked to lie on the unaffected side. The knee of the painful leg is flexed to 90 degrees. Catching the foot behind the calf of the healthy leg, the knee of the affected leg is gradually brought down till it touches the top of the examination table. This results in the combination of adduction–internal rotation and flexion at the hip. As this manoeuvre produces further compression of the entrapped sciatic nerve, there is sudden increase in the symptoms of sciatica.

2. Pressure can be directly exerted over the piriformis muscle by vaginal or rectal examination. If present, it can be treated conservatively with deep heating modality, stretching exercises or local infiltration of hydrocortisone.

Low back pain of thoracic origin

The characteristics of pain of thoracic origin resemble those of LBP. The distinguishing features are as follows:

Palpation of a well-localized point on the iliac crest, 8–10 cm

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from the mid-line produces pain in the low back region. Palpation in the region of the posterior intervertebral joints T12–L1 on the same side is particularly painful. Subcutaneous tenderness is felt over the buttock by pinch roll manoeuvre. Infiltration of this spot with local anaesthetic provides immediate relief.

Arachnoiditis

It is an inflammation of the pia-arachnoid of spine and cauda equina. Arachnoid is a nonvascular membrane which envelops the spinal cord and dural sheaths of caudal nerves. Pia-arachnoid inflammation results in the formation of fibrous strands around the nerve roots. The fibroblastic activity and collagen deposition further thicken the pia-arachnoid tissues (Fig. 32-89). This results in compression and atrophy of the concerned nerve roots and even spinal cord.

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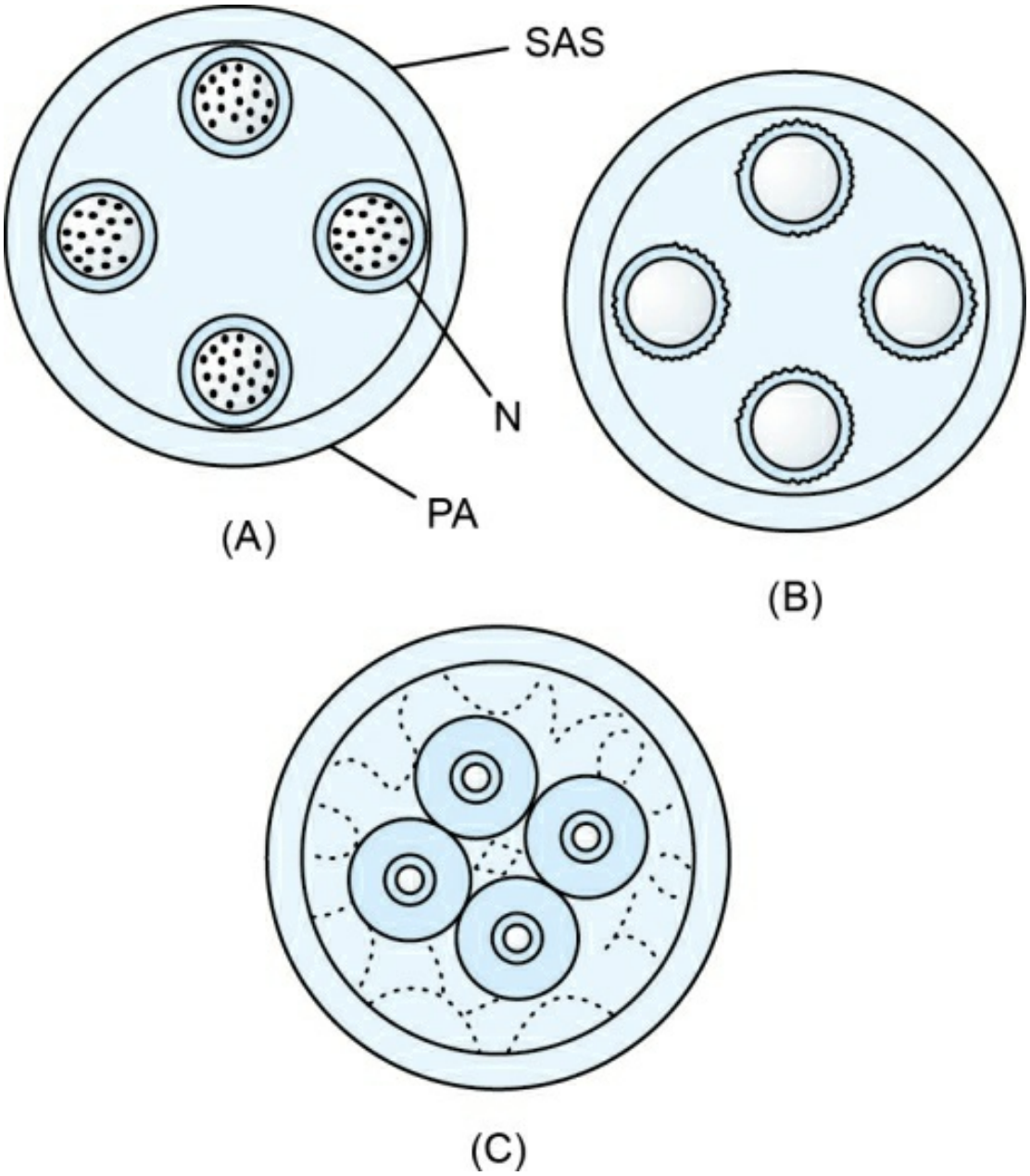

FIG. 32-89Arachnoiditis natural evolution. **(A)** PA: Pia-arachnoid, SAS: Subarachnoid space, N: Normal nerve roots. **(B)** Thickening of pia-arachnoid with swelling of nerve roots. **(C)** Pia-arachnoid becomes adherent with fibrous strands, and atrophy sets in the nerve roots.

Infection, trauma, allergic tissue reaction, autoimmune reaction, chemical irritation by contrast dyes of myelography

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and spinal surgery may precipitate this condition.

Symptoms and signs

■ Continuous LBP unrelated to postures

■ Radiating pain

■ Pain aggravated by trunk flexion and relieved by extension

■ SLR may be positive

■ Symptoms of cord compression depending on the size and extent of the lesion

Treatment

The treatment of arachnoiditis offers some relief but complete relief is difficult.

Conservative treatment

Local deep heat procedures, and postural training and education on the guided activities may provide some relief. The therapeutic approach depends upon the degree of involvement of the spinal cord and its related neuromuscular involvement. Intrathecal steroid injections and surgical lysis of adhesions may rarely be indicated.

Scheuermann's disease

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Scheuermann's disease, also called adolescent kyphosis, usually affects the thoracic spine in adolescents, particularly boys. There occurs rounded kyphosis of more than 40 degrees due to anterior vertebral wedging of three or more vertebrae (Fig. 32-90).

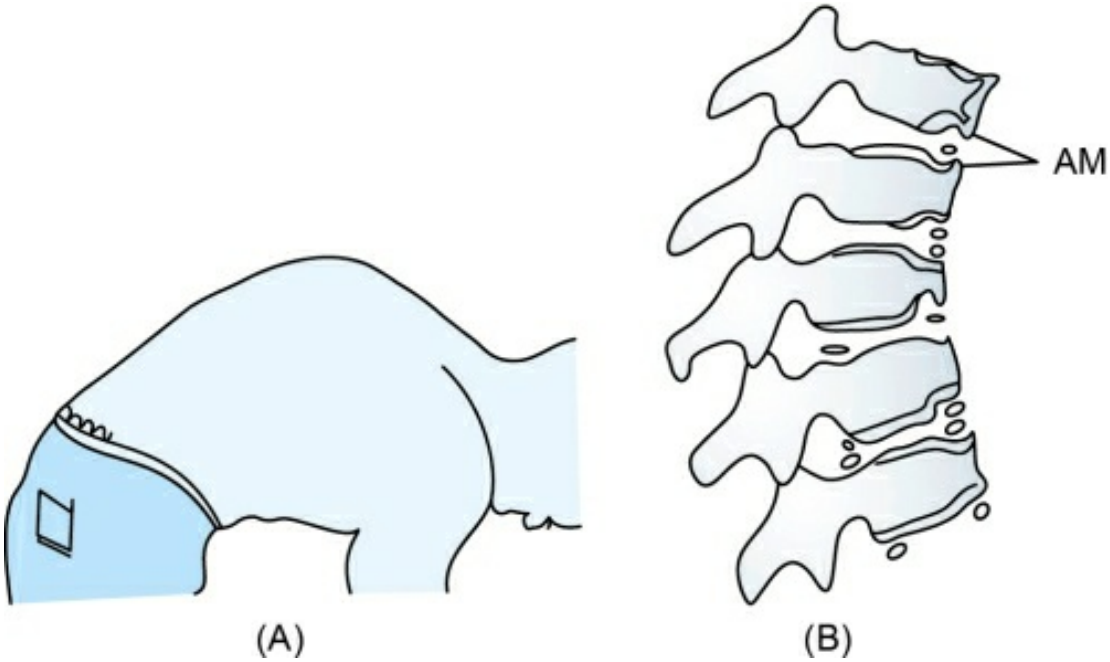

FIG. 32-90**(A)** Scheuermann's disease with round dorsal kyphosis. **(B)** The anterior margins (AM) of vertebral bodies are irregularly indented.

Aetiology

The aetiology of Scheuermann's disease is not known. The child presents with a thoracic kyphosis, which is relatively rigid. Pain is an occasional feature. Hamstring tightness is a consistent finding. Mild scoliosis may be present. There is usually a compensatory hyperlordosis at the lumbar spine.

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Treatment

The aim of treatment is to maintain the extended position of spine.

Conservative treatment

Localized extension exercises to the spine may be advised. However, these are not effective. A spinal brace or a plaster jacket is given with pressure over the apex of the kyphosis. It is maintained till the kyphotic deformity is decreased to 20 degrees.

Surgical treatment

Surgical treatment is rarely indicated in Scheuermann's disease. However, in severe cases, Harrington instrumentation or segmental spinal instrumentation may be undertaken. In some cases, combined anterior and posterior spinal fusion may be indicated.

Physiotherapeutic management

Cases treated conservatively:

Positioning: The patient should be taught to assume prone lying position as frequently as possible and to remain in this posture for longer durations. This reduces strain on the inflamed epiphyses of the involved vertebrae besides minimizing the expected flexion deformity.

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Exercises: Deep breathing exercises are taught to maintain and improve the respiratory capacity. Spinal extensors should be exercised isometrically if active extension is painful. However, isotonic hyperextension in prone position should be initiated as soon as it is pain free.

Exercises to the posterior muscles of the neck, dorsal spine with shoulder girdle retraction are useful to minimize the deformity of round back. With increased thoracic kyphosis, the possibility of developing lumbar lordosis should be considered and exercises of posterior pelvic tilting should be initiated early.

Postural guidance: Guidance for correct technique of wearing spinal brace with padding over the gibbus or apex of the kyphosis is provided. Correct posture of lying, sitting, standing and walking with brace and later without brace is important.

Exercises for mobilization and strengthening are made vigorous as the acute symptoms subside. However, flexion exercises to the spine should be initiated with caution to keep a watch on the symptoms of pain and fatigue.

Cases treated with surgery: They are treated on the same lines as described for scoliosis since the surgical procedures are the same, namely Harrington instrumentation, segmental spinal instrumentation or combined anterior and posterior spinal fusion.

Prevention of low back pain

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Preventive aspect of LBP has not received enough attention except for a few reports in the recent years (Kirkaldey-Willis, 1983). With the established knowledge of the aetiology and advanced methods of examination and investigation, management and prevention of LBP has become more precise. The observation that higher incidences of LBP are due to faulty postural mechanisms emphasizes the importance of correct body mechanics in the prevention of LBP in majority of the population (White, 1983).

Prevention through controlling the predisposing factors seems to be an ideal approach.

Prevention broadly falls into three categories:

1. *Primary prevention*: To prevent the disorder before it occurs.

2. *Secondary prevention*: To limit the development of disorder before it becomes symptomatic.

3. *Tertiary prevention*: To limit the complications of the established disorder (Anderson, 1984).

Measures of prevention can be as follows:

(a) ***General preventive measures***

Mass education of the public at an early age on the principles of ergonomics at rest and work is important.

Identification of the subjects who are prone to develop LBP due to wrong postural attitudes and muscular imbalances is

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important. Simple programmes to correct these attitudes will help its prevention.

Guidance and education on the measures to prevent direct or indirect trauma by avoiding accident-prone attitudes.

(b) ***Specific preventive measures***

Physical fitness: Physical fitness is one of the major contributory factors in the prevention of LBP (McQuade, Rurner, & Buchner, 1988). Therefore, proper fitness programme should be initiated at an early age. The physical fitness programme should be planned to include the whole body and not just the trunk and lower extremities.

Occupational hazards: Frequent change in the posture should be advised to a person engaged in an occupation which demands heavy lifting, repeated trunk twisting and static stooping and/or forward bending. Specific conditioning exercises should be planned to suit an individual's professional demands.

(c) ***Preventive measures in other situations***

Early detection of conditions such as scoliosis, ankylosing spondylitis, spinal canal stenosis, spondylolisthesis, fractures and other infective and inflammatory conditions.

Psychological conditions such as depression, anxiety should be detected and treated adequately.

Role of physiotherapy

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Physiotherapy has a predominant role to play in all the three types of preventive measures. It can be instrumental in mass education on the basis of back care and ergonomics (Fig. 32-91).

1. *Retention of natural spinal curvatures*: The natural physiological curvatures of spine should be retained as they protect the spine by absorbing shocks and preventing it from undue compressive and shearing forces. Emphasis on the *maintenance of lumbarlordosis* is of primary importance in all static and dynamic positions (McKenzie, 1981).

2. *Sustained wrong postures*: When work involves periods of long sitting position, frequent changes of posture is necessary. Sitting with hips at a lower level than the knee should be emphasized in patients with exaggerated lumbar lordosis. However, this position does not hold true for patients with normal lumbar lordosis or those with flat backs, as it produces lumbar kyphosis.

3. *Standing from sitting*: Preferably use arm chair as it reduces weight on the lumbar region by 30% (Nachemson, 1985). While getting up from sitting position, first move to the front of the seat. Stand up by straightening the knees, maintaining lumbar lordosis without bending forward.

4. *Lying*: Use firm bed with wood base, keeping a roll under the lumbar area and knees in flexion (Fig. 32-57A). However, the best sleeping posture is side lying with hip and knee in flexion.

5. *Sitting up*: While getting up from the lying position, turn to

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the side and draw bent knees forward over the edge of the bed. Gradually, lift trunk to sitting by supporting on both hands and simultaneously bringing the legs down keeping knees and feet together. The head and feet remain in a straight line throughout (Fig. 32-91B), and trunk forward bending should be strictly avoided.

6. *Sneezing/coughing*: To avoid sudden jerky forward flexion of spine during sneezing and coughing, stand up, keep the back straight or bend it backwards, preferably holding with hands to prevent excessive jerk.

7. *Forward bending*: As far as possible, bending forward should be avoided. When it is a must, initiate the bending at the hip and knee joints, keeping the back straight. First 60 degrees of forward bending puts maximum strain on the lumbar spine. Therefore, initiate bending at the hip and knee joints with arms supporting over the thighs or with some other stable support.

8. *Pushing*: Do not push heavy objects by bending the trunk; rather it should be done from the buttocks by turning around.

9. *Lifting*: Lifting weights should be avoided totally. If it is a must, it has to be done with more of flexion and extension at the hip and knee. After lifting, stand upright and bend backwards a few times. Take a deep breath just before lifting; then as the trunk moves upwards hold the breath, keeping the abdominals contracted. The rise in intra-abdominal pressure against the contracted diaphragm lifts the thoracic spine upwards, relieving the lumbar spine of some weight

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and providing cushioning effect anteriorly on the dorsolumbar spine (Fig. 32-91C-1).

10. *Carrying weight*: Do not carry weight in one hand only, carry it in both hands. While carrying heavy objects, balance the weight of the object on the hip. It helps the stress pass directly through the hip, rather than through lumbar spine. Always carry object close to the body (Fig. 32-91C-2).

11. *Crouching*: Crouching or relaxed sitting should not be adopted even after strenuous work or fatigue. In crouching, as the muscles relax, the body weight is borne by joints and ligaments. The latter are over stretched and the vertebrae and discs are compressed.

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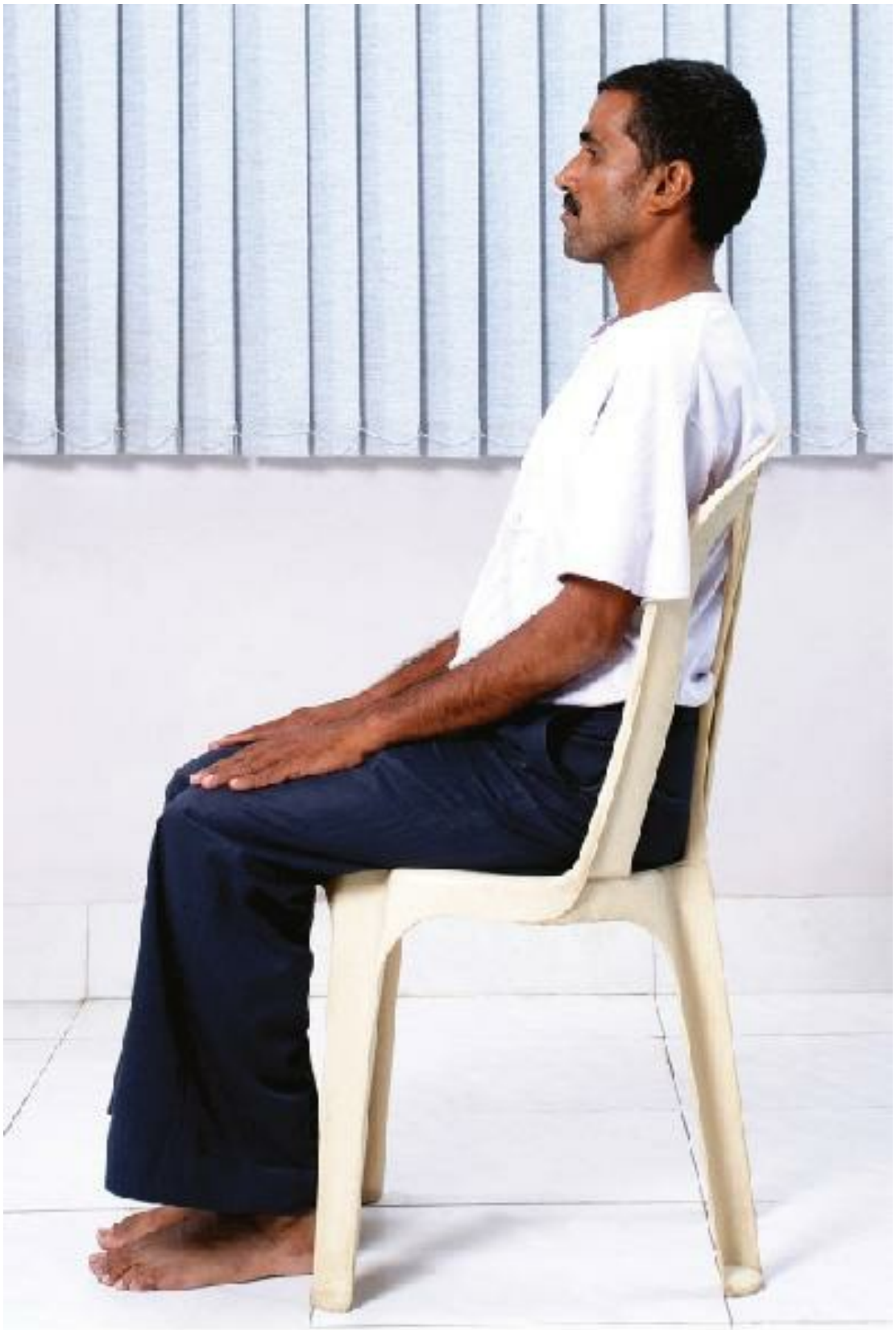

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FIG. 32-91**(A)** Back ergonomics in fundamental postures: (i) in supine, (ii) inside lying, (iii) sitting, (iv) standing. **(B)** Sitting from supine lying B1 to B6. **(C)** (i) Lifting, (ii) carrying.

Other precautionary measures

To increase physical fitness, conditioning and strengthening of the extensor group of muscles, rotators and flexors, in that order, should be done regularly (Cady, Bischoff, O'Connel,

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Thomas, & Allan, 1979). Strong erector spinae, obliques, gluteus maximus and hamstrings are of special importance for persons engaged in heavy lifting and bending activities.

The back care programme should be planned on an individual basis, since the back care techniques vary with individual problems and postural attitudes during work and other activities of daily routine.

A quick look at postural deviations from the normal, and brief examination of soft tissue imbalances should be useful to prevent LBP due to these causes.

Frequent checks on the back care programme are extremely important.

Prevention of recurrence of low back pain

Once LBP is controlled, it is most important to prevent its recurrence. This is achieved by the following:

■ Continuing the exercise programmes and ergonomic advice.

■ Maintenance of correct posture during rest and work.

■ Avoiding the postural attitudes that are likely to induce excessive stress.

■ Regaining the maximum flexibility of soft tissues of the lumbosacral region and pelvis.

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■ Further improving the strength and endurance of flexor, extensor and trunk rotators, and gradually progressing to the maximum.

What to do when there is recurrence of pain:

■ Pain reducing modalities such as hydrocollator packs, ice massage, relaxation techniques and rest with proper posture.

■ Specific exercise programme, which gave relief at the earlier episode, should be gently introduced.

■ Any posture or exercise causing excessive pain should be totally eliminated.

■ Avoid one constant posture for long periods even if it gives relief.

■ Analgesics and anti-inflammatory drugs can be started.

■ If the pain is not relieved within a day or two, immediate consultation is necessary.

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Chapter 33

Regional orthopaedic soft tissue lesions of the shoulder, elbow, forearm, wrist and hand

Outline

- Functional anatomy of shoulder
- Soft tissue lesions at neck and shoulder
- Frozen shoulder (syn: adhesive capsulitis, periarthritis)
- Painful arc syndrome
- Lesions of the rotator cuff
- Infraspinatus tendinitis
- Soft-tissue injuries at the elbow
- Tennis elbow (lateral epicondylitis)
- Golfer elbow or medial epicondylitis
- Olecranon bursitis (minor elbow)
- Wrist sprain
- Ganglion
- De Quervain disease

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■ Trigger finger

Functional anatomy of the shoulder joint

Factors like proximal positioning, free all-round mobility, overuse and comparatively unstable joint surrounded by crowded soft tissues make the joint susceptible to fractures and a great variety of soft-tissue lesions.

Movements

Perfectly synchronized action of the shoulder complex, consisting of four different articulations, is necessary for the optimal function of this joint. The components of the shoulder complex are as follows (Fig. 33-1):

1. Glenohumeral joint

2. Acromioclavicular joint

3. Sternoclavicular joint

4. Scapulothoracic joint

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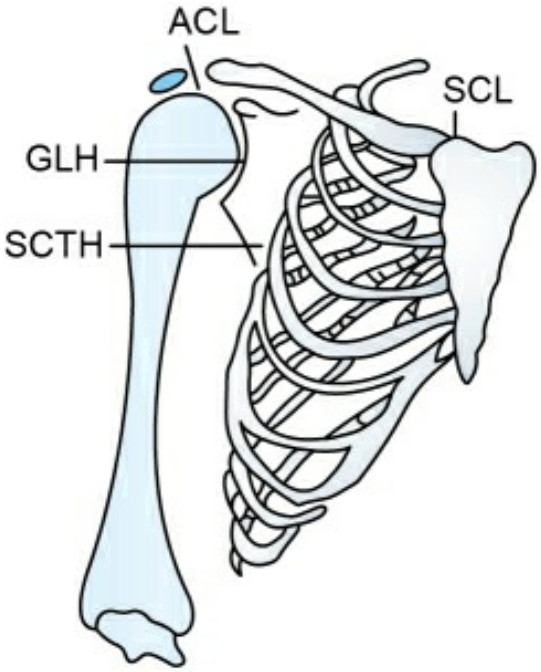

FIG. 33-1Shoulder joint complex. ACL, acromioclavicular joint; GLH, glenohumeral joint; SCL, sternoclavicular joint; SCTH, scapulothoracic joint.

Multidirectional wide arcs of movements are the results of the immaculate structural design of the shoulder complex. The dynamic force and stability to this complex are provided by precisely controlled muscular actions. The structure and disposition of these muscles provide a base for a wide range of controlled activities from strong and powerful actions in sports and heavy work to the fine coordinated prehensile finger movements of a musician.

The normal process of raising the arm to a vertical position above the head is carried out with smooth, uninterrupted motion at all the afore-mentioned four joints of the shoulder complex. The intricate interplay of all the four joints was termed as scapulohumeral rhythm by Codman (1934), which was later modified by McMillan (1966) to

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scapulohumeroclavicular rhythm, as the clavicle also participates along with the scapula and humerus. However, the appropriate terminology to describe the movement of the whole complex would be scapulohumeroclaviculothoracic rhythm since scapulothoracic articulation is also actively involved apart from the other three joints.

In the total arc of 180 degrees of elevation, contribution from the glenohumeral joint is 120 degrees while the remaining 60 degrees is contributed through the outward rotation of the scapula, i.e., in the ratio of 2:1. For every 15 degree of arm abduction, 10 degrees of abduction takes place at the glenohumeral joint, the remaining 5 degrees being contributed by rotation of the scapula upon the thorax. Out of the total 60 degrees of scapular rotation, 30 degrees occur due to elevation of the clavicle at sternoclavicular joint and the remaining 30 degrees at the acromioclavicular joint. At the same time, axial rotation of the clavicle by as much as 50 degrees is also an important contributory factor in this mechanism (Singleton, 1966) (Fig. 33-2).

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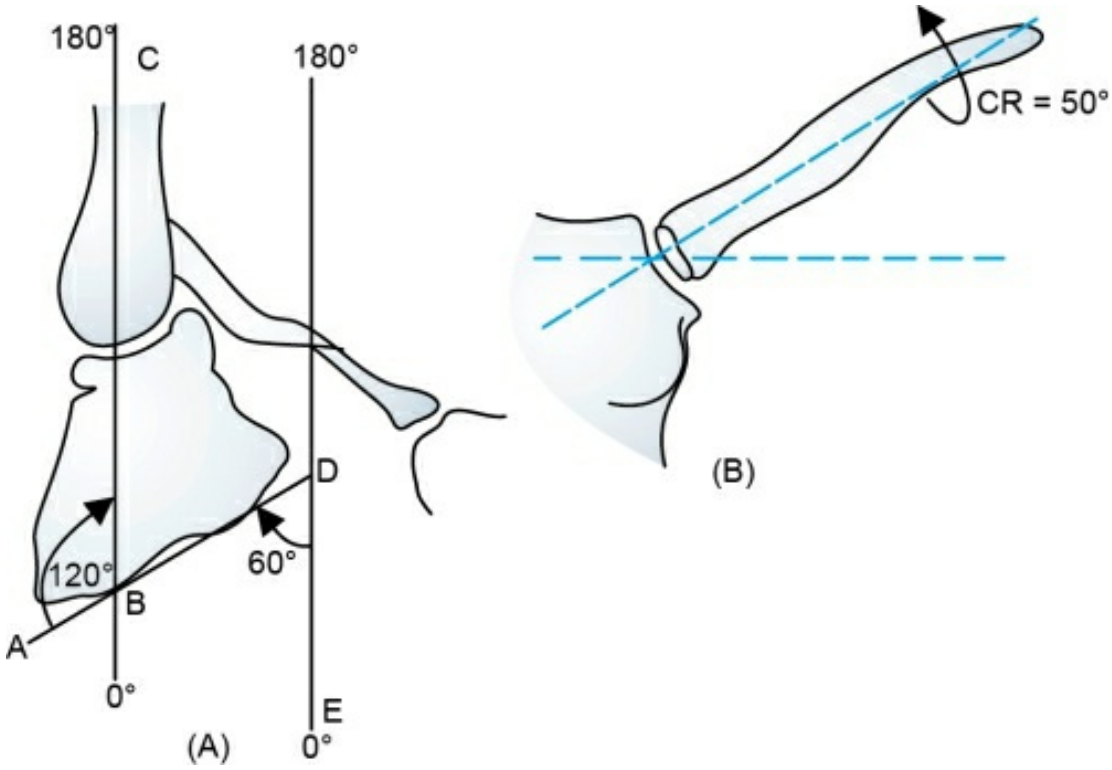

FIG. 33-2Components of the total arc of shoulder abduction elevation. Total range = 0–180 degrees. (A) Glenohumeral joint ABC = 120 degrees, outward rotation of (ADE) = 60 degrees (acromioclavicular 30 degrees = sternoclavicular 30 degrees). **(B)** Besides these, the clavicle rotates around its axis by 50 degrees (CR).

Kent (1971) noted that elevation at the sternoclavicular joint occurs during the first 90 degrees of arm elevation. For every 10 degrees of elevation of arm, 4 degrees of elevation occurs at the sternoclavicular joint, thus at 90 degree, the clavicle has elevated to 36 degrees, whereas motion at the acromioclavicular joint occurs during the first 30 degrees and thereafter, after 135 degrees of abduction.

Muscle action

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The complex mechanism of arm elevation to 180 degrees is made possible by the coordinated actions of different muscle groups that act through two mechanical force couples. A force couple is defined as two equal forces acting in opposite directions to turn the part about its axis of rotation.

Glenohumeral force couple (fig. 33-3)

The first mechanical force couple acts on the glenohumeral joint in the following sequence:

1. The supraspinatus fixes the head of the humerus to the glenoid.

2. The humeral head is maintained and stabilized in the glenoid cavity by the downward pull of short rotators, i.e., the infraspinatus, subscapularis and teres minor.

3. The secured head of the humerus can be efficiently pulled into abduction by the strong action of the deltoid.

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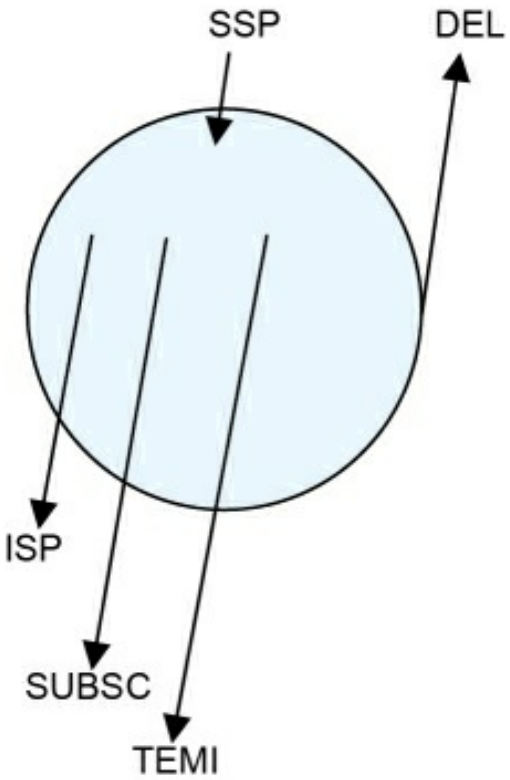

FIG. 33-3Events at the glenohumeral force couple which facilitates abduction elevation. DEL, deltoid; ISP, infraspinatus; SSP, supraspinatus; SUBSC, subscapularis; TEMI; teres minor.

Thus, the supraspinatus (SSP) fixes the head of the humerus to the glenoid; the infraspinatus (ISP), subscapularis (SUBSC) and teres minor (TEMI) exert a downward pull and stabilize the humeral head in the glenoid, facilitating the strong action of the deltoid (DEL) to pull the arm in abduction elevation.

Scapulohumeral force couple (fig. 33-4)

The second mechanical force couple acts on the scapula. It is the main force behind the 60 degrees of outward rotation of the scapula.

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1. The upper portion of the trapezius acting on the acromion rotates the scapula outwards.

2. The lower portion of the trapezius pulling on the lower scapular spine carries further the outward rotation of the scapula.

3. At this stage, the serratus anterior provides the strongest force in outward rotation of the scapula.

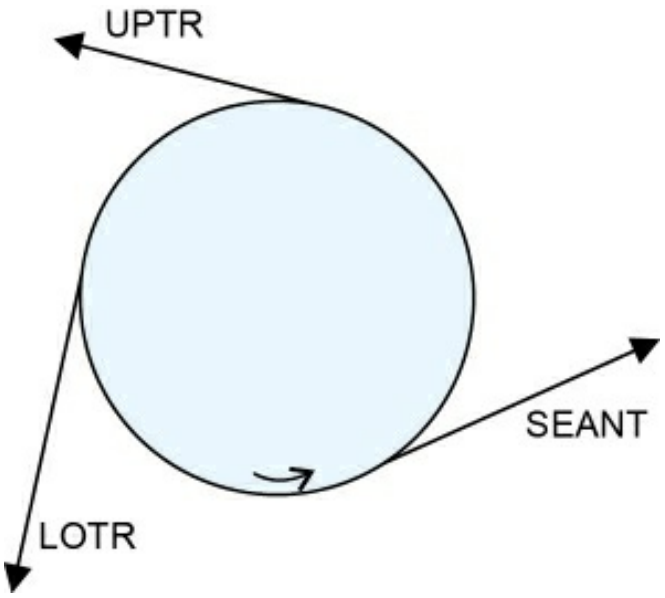

FIG. 33-4Scapulohumeral force couple which facilitates outward rotation of scapula. LOTR, lower trapezius; SEANT, serratus anterior; UPTR; upper trapezius.

The combined effect of both these mechanical force couples provides the arc and strength to the 'scapulohumeroclaviculothoracic rhythm'.

To summarize, the glenohumeral motion is accomplished by (a) fixation of the humeral head to the glenoid by the supraspinatus, (b) the humeral head is maintained in the

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glenoid cavity by the downward pull of the short rotators (infraspinatus, subscapularis and teres minor) and (c) abduction of the arm is achieved by the deltoid.

The upper trapezius (UPTR) rotates the scapula outwards from upper scapular region. It is further supplemented by the lower trapezius (LOTR) and the strong action of the serratus anterior (SEANT).

The rotation of the scapula is made possible by the action of the second force couple. The coordinated action of these muscles rotates the scapula outwards and thereby, the glenoid is pulled upwards.

Scapulohumeral group of muscles: Subscapularis, teres minor and infraspinatus function as depressors as well as stabilizers of the head of the humerus against the glenoid during arm elevation. The subscapularis also functions as an internal rotator while the teres minor and infraspinatus act as external rotators of the humerus. The subscapularis also acts as a strong protector of the anterior portion of the joint.

Axioscapular group of muscles: Trapezius, rhomboids, serratus anterior and levator scapulae act as an anchoring force giving support to the scapula on the thoracic cage and at the same time allowing freedom of motion. The upper and lower portions of the trapezius and levator scapulae anchor the scapula vertically. The serratus anterior also gives horizontal stability to the scapula preventing its ‘winging’.

Axiohumeral group of muscles: The pectoralis major and minor and the latissimus dorsi help to move the scapula and

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push the pectoral girdle upwards when the deltoid is weak or paralysed.

Rotator cuff: It consists of four muscles, namely, the supraspinatus, infraspinatus, teres minor and subscapularis. They terminate into short, flat and broad tendons which fuse intimately with the capsule of the shoulder joint to form a musculotendinous cuff. These muscles act as a force couple with the deltoid. The deltoid's pull on the humerus is upwards and outwards. If this muscle acts alone, it will only succeed in jamming the head of the humerus against the acromion instead of producing abduction. On the other hand, if the cuff muscles act alone, only depression of the head of the humerus results. However, if both actions are combined, the motion of abduction is produced. Therefore, the impairment of either of these components of the force couple usually results in impaired shoulder abduction.

Specific muscle actions

Studies conducted by various methodologies including electromyography by Inman et al. (1944), Basmajian (1967), MacConaill and Basmajian (1969) give a clear picture of specific muscle actions and peak of muscle activity during specific arc of a movement.

Trapezius: Upper fibres – scapular elevation; lower and middle fibres – scapular retraction; lower half of trapezius – forward flexion at the glenohumeral joint; middle fibres – abduction at the glenohumeral joint. During scapular adduction – all portions of the muscle are active.

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Serratus anterior: Upper digitations – flexion at the glenohumeral joint; lower fibres – abduction at the glenohumeral joint.

Rhomboids: Similar to middle trapezius.

Deltoid: All elevation movements at the glenohumeral joint; peak activity in 90–180 degrees of abduction. Forward flexion – all the three components, i.e., anterior, middle and posterior fibres act together but with less amplitude.

Pectoralis: Both clavicular and sternal portions together – forward flexion against resistance. Only clavicular portion – forward flexion without resistance.

Latissimus dorsi: Forward flexion – peak activity at 57 degrees and again at 115 degrees. Internal rotation and adduction of humerus. Less activity in the backward extension.

Rotator cuff: All the four components of the rotator cuff act continuously during both abduction and flexion. Infraspinatus demonstrates peak activity at 180 degrees of abduction. In forward flexion, it has two peaks of activities: one at 60 and the other at 120 degrees. The greatest activity of this muscle is seen during forward flexion rather than during abduction.

Teres minor: The activity of this muscle demonstrates a pattern similar to that of the infraspinatus.

Supraspinatus shows peak activity at 80 degrees during the movement of forward flexion and at 100 degrees of

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abduction.

Subscapularis demonstrates peak activity during 90–130 degrees of abduction and between 110 and 130 degrees of forward flexion.

Biceps: Both heads are active during forward flexion at the glenohumeral joint. The long head produces abduction of the humerus when the arm is externally rotated.

Teres major: It is not active during the motion of the shoulder. It is however active if static contraction is required during abduction of the humerus. It shows maximum activity during maintenance of a static arm posture at 90 degrees of abduction.

Soft-tissue lesions at neck and shoulder

Neck

Acquired torticollis

This is a rotational deformity of the neck where the head is tilted to the affected side and chin is deviated to the opposite side.

In the majority of patients, it occurs as a result of malpositioning of the neck–head component during sleep.

The neck is held in malposition due to spasm in the sternomastoid muscle. Attempted active or passive movements are limited and painful with localized

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tenderness.

It is easily controllable by thermotherapy, nonsteroidal anti-inflammatory drugs (NSAIDs), relaxed movements, using a conventional collar and correct well-protected posture (see Fig. 32-20).

In rare instances, it could be infective following acute cervical lymphadenitis or could develop due to the contracture of sternomastoid muscle of psychogenic origin.

Shoulder

It happens to be a common site of both direct and indirect injuries to the bones and the soft tissues. The possible causes can be (i) its proximal position as a joint of the upper extremity, which (ii) bears maximum stresses of functional activities. (iii) It is also a relatively unstable joint.

Each condition can be diagnosed from its typical characteristics (Table 33-1).

Table 33-1

Characteristics of Identifying Soft-Tissue Injuries at the Shoulder

Injury	Identifying Characteristics
Subacromial bursitis	Pain during resistive abduction and internal rotation
Frozen shoulder, adhesive	Painful limitation of elevation in flexion and abduction and external rotation

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capsulitis or periarthritis shoulder	
Rotator cuff syndrome	Passive pain-free normal to near normal joint excursion Marked weakness with inability to perform shoulder overhead elevation through flexion or abduction of a shoulder joint (arm cannot be abducted beyond 45 degrees)
Painful arc syndrome, superficial lesion in the supraspinatus	Pain experienced only in a particular arc of shoulder joint, overhead elevation through abduction between 45 degrees and 160 degrees
Deep and distal lesion	Full passive elevation is painful
Complete rupture	Pain-free total loss of active abduction
Infraspinatus tendinitis: Strain Superficial rupture Distal deep rupture Complete	Pain only during resistive external rotationPainful arc Full passive elevation is painful Pain-free weakness, with pain-free arc, loss of 30° of external rotation

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rupture	
Subscapularis tendinitis	Pain in the terminal stage of resistive internal rotation, passive movement is pain-free
Bicipital tendinitis	Pain tenderness in the intertubercular groove during lifting or pulling Resistive elbow flexion and supination elicits pain

Note: A combination of a painful arc syndrome and adhesive capsulitis may be present in some patients.

Frozen shoulder (syn: Adhesive capsulitis, periarthritis)

Frozen shoulder is a clinical syndrome with painful restriction of both active and passive shoulder movements. The condition is aggravated by systemic problems like diabetes mellitus, cardiovascular disease and reflex sympathetic dystrophy.

The term 'frozen shoulder' is often used injudiciously for any painful condition of the shoulder joint. However, there are two known entities which must be differentiated and a proper diagnosis should be arrived at, since the treatment of each is different. These conditions are as follows:

1. Painful shoulder: Any condition, around the shoulder, that

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causes pain and limitation of the movements of the shoulder may be included in this group. In this, there is no true contracture of the capsule of the shoulder joint. The various conditions include tendinitis of the rotator cuff, sprain and tears of the rotator cuff, bicipital tenosynovitis and synovitis of the shoulder.

The patient has limitation of movements which is more due to pain rather than due to intra-articular or capsular contractures. Radiograph may show areas of calcification around the shoulder indicating calcific tendinitis. Arthrograph will rule out a capsular contracture.

Magnetic resonance imaging (MRI) of the shoulder would help rule out tears in the rotator cuff. Treatment depends upon the primary lesion. Manipulation should not be undertaken.

2. Adhesive capsulitis or *frozen* shoulder: Capsular adhesions form as a result of inflammation in the capsule and synovium. The adhesions are more marked in the axillary fold. Neviaser and Neviaser (1987) have classified this condition into four stages: (1) preadhesive stage, (2) acute adhesive stage, (3) stage of maturation and (4) chronic stage.

The exact cause of the capsular contracture is not known. However, relative immobility of the shoulder due to coronary artery disease, mastectomy or other operations over the chest and cervical spondylosis may precipitate frozen shoulder. Even not performing full shoulder stretches in our daily activities may lead to capsular contracture and thereby a stiff shoulder in majority of individuals.

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Diagnostic tests

1. Active test of range of motion (ROM) with slight overpressure at the terminal point of each movement: This test will reveal definite capsular restriction of the glenohumeral joint. The movements principally involved will be abduction and external rotation; the movements of flexion and internal rotation are involved to a lesser extent. No apparent muscular weakness will be present in the available ROM, but overpressure at the end of the range will elicit pain.

2. Active resisted test of ROM: At the initial range, usually there is no pain; however, considerable resistance may be painful.

3. Passive test of ROM: With the patient in supine position, this test confirms the capsular pattern of restriction of the joint and the diagnosis of adhesive capsulitis (Kessler & Hertling, 1983).

Treatment

It is treated mainly by analgesics and physiotherapy with shoulder mobilization exercises. Occasionally, a periarticular injection of hydrocortisone is given to reduce pain and inflammation. These days, arthroscopic capsular release is done which improves the range of movements.

Physiotherapeutic management

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Physiotherapy plays an important role in the prevention as well as resolution of this condition.

Preventive programme

1. Prevention of primary capsulitis: The natural history of the disease is still undecided as regard to the aetiology of this condition. It is very difficult to know the onset of the disease in its early phase as the symptoms of pain and stiffness are not acute. However, from our observations, we have noticed that the initial pain and stiffness were elicited when the shoulder was passively taken to its terminal range of overhead adduction in elevation (Fig. 33-5). Secondly, the early symptom is pain in lying on the side of the affected shoulder.

Therefore, the regular practice of this particular movement could be instrumental in prevention, early detection and lessening the impact of this condition.

2. Prevention of secondary capsulitis: Careful early mobilization to the extreme ROM needs to be emphasized for the other benefits of exercise in addition to the prevention of secondary adhesive capsulitis in the following situations:

(a) All the procedures around the chest and shoulder requiring prolonged immobilization.

(b) All situations requiring prolonged bed rest, e.g., coronary artery disease; fractures in the upper limb.

(c) Paralysed arm following stroke.

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(d) Unconscious patient following head injury.

(e) Mastectomy.

3. Prevention of further damage: Further damage to the joint can be done by avoiding the following actions: (i) Suddenly applied jerky stretching and (ii) crude self-styled manipulations by a quack. These result in high tensile resistance and give rise to further constriction of the already constricted capsule (Kottke et al., 1966). Thus, there is an increase in pain due to muscle spasm leading to further stiffness.

Adhesive capsulitis can be avoided through proper measures and by education to the masses to seek proper advice on simple terminal stretching of the shoulder.

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FIG. 33-5Test for early diagnosis of adhesive capsulitis: extreme range of passive overhead adduction of the shoulder in full range of motion (ROM) of elevation in supine position elicits pain – tightness.

Restorative programme

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The basic aim of the restorative programme is

1. To reduce pain,

2. To increase extensibility of the thickened and contracted capsule of the joint at the anteroinferior border and at the attachment of the capsule to the anatomic neck of the humerus,

3. To improve mobility of the shoulder and

4. To improve strength of the muscles. However, it may be remembered that strengthening of muscles is secondary to mobilization.

Mobilization is attained through three basic approaches:

1. Relaxation

2. Specific exercise to offer graduated stretching

3. Passive mobilization technique

To have better results, strengthening done within available range helps in further movement as because of strength in the available range, the person is now able to use the hand to the available range; this encourages him or her to use it to try doing movement more than available.

1. Relaxation:

Through prior heating: Prior heating of the joint has been found to facilitate relaxation and mobilization (Gersten, 1955;

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Lehmann et al., 1954). One may use any heat modality suitable to the patient's response. However, ultrasound therapy, besides deep heating, has the added advantage of increasing extensibility of the contracted soft tissues and is therefore preferred. Stanley (1972) advocated the use of ultrasound via axilla over the anteroinferior border of the capsule to be closer to the seat of actual defect.

Relaxed passive mobilization: The patient is placed in supine position with the affected shoulder in maximum possible abduction, neutral rotation and elbow in 90 degrees of flexion.

The physiotherapist grasping the arm below the shoulder joint carries out relaxed passive gliding movements of the head of the humerus on the glenoid (Fig. 33-6). Axial traction and approximation is carried out along with anteroposterior glide and abduction–adduction glide. To induce relaxation, always begin with slow rhythmic movements.

Slow and rhythmic circumduction at the glenohumeral joint, in forward stoop position, effectively induces relaxation and promotes mobility. It should be done by stabilizing the shoulder girdle with one hand and grasping just above the wrist joint with the other hand (Fig. 33-7). Gentle relaxed passive movements short of pain and pathologic limits of motion reduce pain (Maitland, 1983). The reduction in pain occurs because of the neuromodulation effect on the mechanoreceptors within the joint (Barak et al., 1985).

Mobilization by passive accessory movements of the acromioclavicular (AC), sternoclavicular (SC) and/or

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scapulothoracic joint articulations are also extremely helpful.

2. Exercise Programme: Exercise plays an important role in the management of adhesive capsulitis (Lee et al., 1973; Rizk et al., 1983).

While planning the exercise programme, one must give due importance to the observations of Bohanan et al. (1985), Kottke et al. (1966, 1983), Rizk et al. (1983), Sapega et al. (1981) who proved that contracted soft tissues when subjected to repeated prolonged mild tension show extensibility and plastic elongation.

Secondly, Lee et al. (1973) and Rizk et al. (1983) also noted that an increase in the movement following the sessions of prolonged stretching was usually associated with a corresponding increase in other movements too. However, Maitland (1983), although in general agreement with these findings, cautioned that improvement in the range of other movements is not always at the same rate. Our clinical experience agrees with the statement of Maitland.

Giving due weightage to these clinical observations, ideally, the specific exercise programme should include the maximum number of combinations of various movements by minimizing the number of exercises.

We advocate graduated relaxed sustained stretching based on the PNF patterns. We have designed two movement combinations of

(a) Shoulder elevation with flexion, abduction and external

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rotation (Fig. 33-8A).

(b) Shoulder internal rotation with extension, adduction and elbow flexion, i.e., attaining 'hand to lumbar' position (Fig. 33-8B).

FIG. 33-6Rhythmic relaxed passive gliding of the humerus on the glenoid with axial traction.

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FIG. 33-7Rhythmic relaxed passive mobilization with the patient in supported stoop standing while the physio therapist moves the glenohumeral joint with

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one hand and stabilizes the shoulder girdle with the other.

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(A)

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(B)

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FIG. 33-8Self-assisted relaxed mobilization followed by gentle but sustained passive stretching. **(A)** Shoulder elevation with flexion abduction and external rotation. **(B)** Extension with adduction and internal rotation.

Following the preparatory programme of inducing relaxation, the afore-mentioned regime of exercise can be done in two ways:

(i) By pulley and tolerable weight in supine or sitting position.

(ii) By self-assisted stretching: The patient uses normal or better contralateral arm to gradually stretch the affected shoulder, maintaining the specific groove of these two exercises after self-induced relaxed passive mobilization.

While applying weights, one must be careful not to overstretch the contracted capsule which induces pain. Ideally, it is better to start with minimal weight and increase it gradually, without causing any discomfort to the patient.

Remember

Stretching with pain should never be given or advised but can be given within the limitation of pain.

3. Passive *mobilization technique***:** Methods described by Codman, manipulation and mobilization techniques by Maitland (1983) and specialized techniques of PNF by Voss and Knott (1968) could be used with great advantage. Middleditch and Jarman (1984) reported objective response

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in 78% patients treated with ultrasonics, ice pads and ice massage over the hot spots detected by thermography.

However, in spite of the various reports on the doubtful periods of resolution of the stiffness, we have observed that majority of patients respond favourably within a period of 6 months with a properly guided simple and specific exercise programme which ensures relaxed graduated stretching of the contracted capsule. However, it must be remembered that the ultimate results depend upon the efficacy of home treatment regime.

Irregular or nonresponding patients are benefited by the special mobilization techniques of Maitland (1983).

Caution

1. The importance of regular stretching has to be emphasized to the patient even after he is relieved of stiffness and pain to avoid recurrence.

2. Patients with diabetes respond slowly to treatment and feel much more pain and discomfort as compared to nondiabetics. Therefore, explain the prognosis, achieve maximum relaxation and go slow in patients with diabetes. Varying periods of total resolution from 1 to 3 years have been recorded in a number of studies (Reeves, 1975; Grey, 1978).

3. Nocturnal pain: Patients complaining of nocturnal pain should not be treated by thermotherapy. This type of pain has a low threshold for pain; therefore, the pain increases on

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warming up of the body at night. Thermotherapy is likely to increase pain in such patients (Lewis, 1942); if given, it should be monitored at regular intervals.

4. The contralateral normal shoulder should always be examined in the extreme ROM as a precautionary measure.

Painful arc syndrome

In this syndrome, the arc of shoulder abduction elevation is painful from about 45–160 degrees, but this is painless up to the initial 45 degrees as well as in the terminal range from about 160 degrees to full elevation. The passive ROM is pain free.

The cause is mechanical – the tender structure get nipped in between the tuberosity of the humerus and the acromion process or coracoacromial ligament.

Five types of lesions can give rise to this syndrome (Fig. 33-9).

1. Minor tear of the supraspinatus tendon

2. Supraspinatus tendinitis

3. Calcified deposit in the supraspinatus tendon

4. Subacromial bursitis

5. Crack fracture of greater tuberosity of humerus

6. Bicipital tenosynovitis

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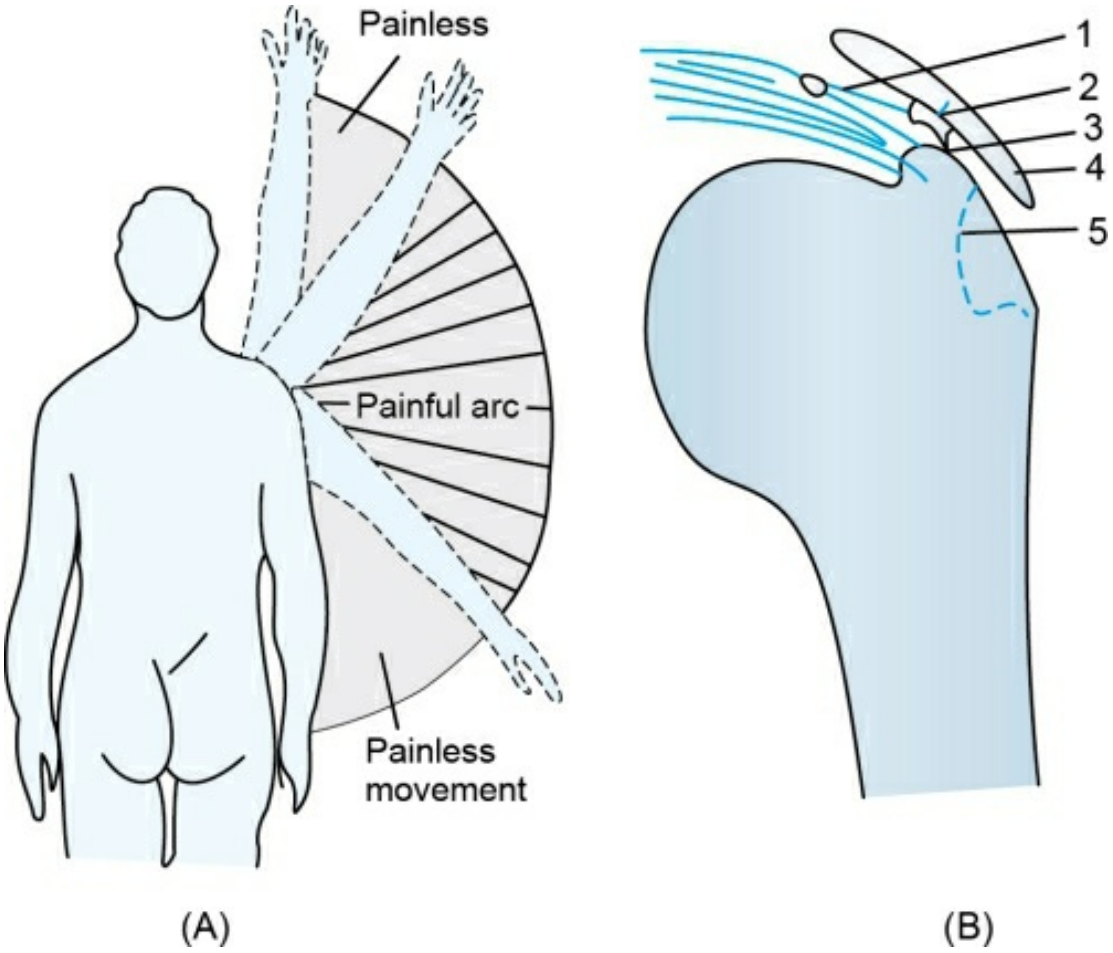

FIG. 33-9**(A)** Painful arc syndrome (PAS). **(B)** Five possible causes of painful arc: 1. Incomplete supraspinatus tear, 2. Supraspinatus tendinitis, 3. Calcified deposit in supraspinatus, 4. Subacromial bursitis, 5. Crack fracture of greater tuberosity.

Investigations

X-rays: Plain X-ray of the shoulder joint may show calcification in the region of the supraspinatus tendon. In a longstanding tear of the supraspinatus, the space between the acromion and the head of the humerus may be reduced due to upward migration of the humeral head (Fig. 33-10).

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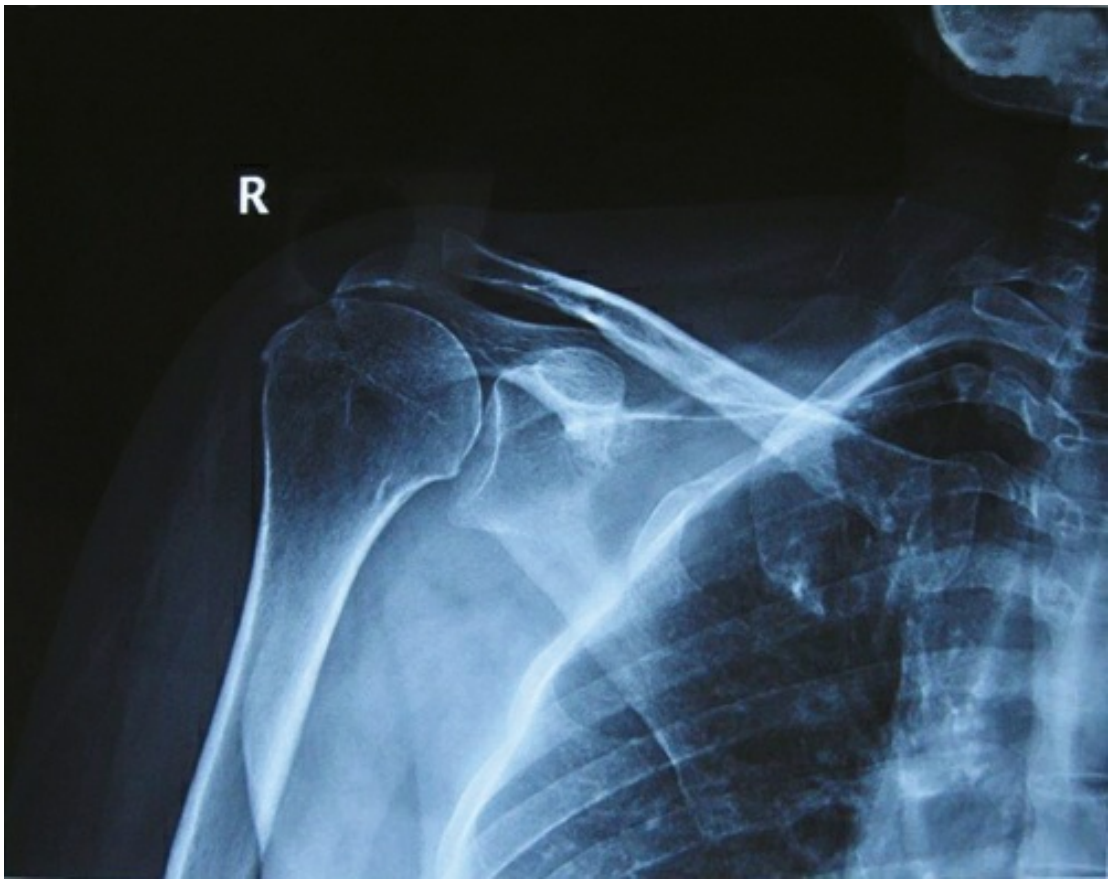

FIG. 33-10X-ray of the shoulder showing upward migration of the head of the humerus due to rotator cuff arthropathy.

MRI: An MRI may show collection of fluid or altered signals in and around the supraspinatus tendon (Fig. 33-11).

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FIG. 33-11MRI of the shoulder showing collection of fluid and altered signals around the supraspinous tendon.

The acromion process may show downward displacement of its tip causing impingement of the underlying rotator cuff (Fig. 33-12).

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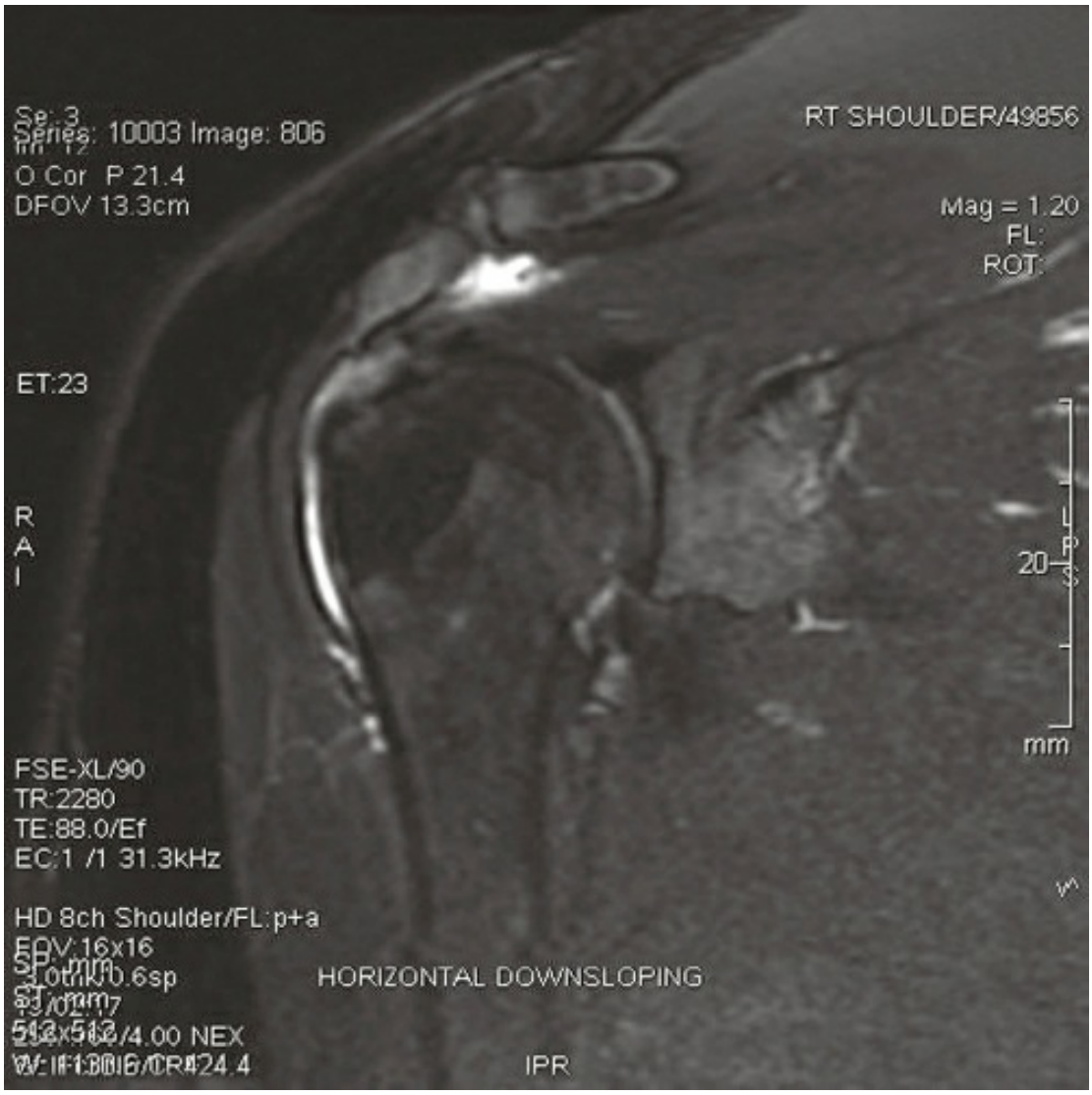

FIG. 33-12MRI of the shoulder shows downward slope of the tip of the acromion causing subacromial impingement.

Differential diagnosis

■ History of injury is suggestive of supraspinatus strain or fracture of greater tuberosity.

■ Spontaneous onset suggests tendinitis or subacromial

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bursitis.

■ Acromioclavicular joint arthritis may also cause painful arc, but the pain appears later in the range and it also increases when nearing to the extreme range of abduction.

Calcified deposit can be confirmed by radiography.

Treatment

1. Initial rest in a sling.

2. Short-wave diathermy is very effective.

3. Relaxed passive pain-free full range elevation in supine position.

4. Gradual progression in abduction; begin with active assisted movement in a gravity-eliminated position progressing to antigravity exercises and then to graduated progressive resistive exercises (PREs).

The cases which do not respond to the conservative treatment may require surgery as follows:

1. (a) Open anterior acromioplasty: In this operation, a part of the anteroinferior undersurface of the acromion is removed. The aim of this operation is to remove the anterior acromial overhang and to produce a flat undersurface to the acromion and thereby create more room.

(b) Arthroscopic acromioplasty*:* Anterior acromioplasty can

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also be performed by arthroscopic surgery. It is a minimally invasive surgery and therefore carries lesser morbidity.

2. The space between the humeral head and the acromion is widened. The neck of the scapula is divided, and the glenoid fragment with the glenohumeral joint is displaced downwards.

The calcific deposits in the region of the supraspinatus tendon may require removal/excision to improve the ROM.

3. Repair of the rupture. The repair may be achieved by open or arthroscopic methods.

Physiotherapeutic management

Immobilization (2–3 weeks): Vigorous exercises for the joints free from immobilization.

Mobilization:

1. Relaxed passive pendular flexion–extension with sling.

2. Gravity-eliminated assisted abduction.

3. Strong isometrics to abduction with self-generated internal tension.

4. Gradual progress to active-resisted abduction.

Lesions of the rotator cuff

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Aetiology

The tendinous fibres of the rotator cuff muscles at or near their insertion into the tuberosity undergo degenerative changes with advancing age. Disintegration of the tendon predisposes to rupture. Neer (1972) emphasized subacromial impingement as an important aetiological factor in rotator cuff tears. Intrinsic tendon degeneration is also, undoubtedly, a substantial contributory factor to most rotator cuff defects (Keyes, 1933, 1935). All rotator cuff tears are the result of some combination of age-related degeneration, trauma and subacromial impingement.

Mode of injury

A fall on the shoulder or an attempt at lifting a heavy object or throwing a heavy object with overhead action may cause tear of the rotator cuff. A severe acute pain and snap in the shoulder is felt immediately, and the patient is unable to actively abduct the arm. In a senile person in whom the tendon is quite degenerated, rupture may occur with trivial trauma and minimum pain. Often, the pain is referred to the deltoid insertion.

Clinical picture

The arm can be raised actively to about 45 degrees by the deltoid, after which elevation from flexion as well as abduction of the arm is accomplished by elevating the shoulder girdle. The pain is most severe in the arc from 45 to 90 degrees when the traumatized tendon is compressed

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between the tuberosity and the coracoacromial arch.

If the arm is elevated passively above the horizontal, further abduction is possible with very little discomfort. The pain is most pronounced when the painful tear is exposed to compression. The following signs can be elicited for diagnosis:

Neer's (1972) Impingement Sign: This sign is elicited by passively fully abducting the arm overhead which causes pain by compressing the inflamed subacromial bursa and rotator cuff against a prominent anterior acromion (Fig. 33-13).

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FIG. 33-13Neer's impingement test.

Hawkins Sign (Hawkins & Hobeika, 1983): Hawkins sign, also called impingement reinforcement sign, is performed with the arm in 90 degrees of elevation in the scapular plane. The humerus is internally rotated so that the greater tuberosity passes under the coracoacromial arch. This causes pain in cases of impingement syndrome (Fig. 33-14).

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FIG. 33-14Hawkin's sign.

The pain reduces gradually and the active range of abduction improves. Eventually, a full range of painless motion results. However, the arm is weak for more than ordinary use and sustained work above the horizontal is difficult.

Treatment

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Ideally, the tendon should be repaired immediately in a case of fresh rupture. After which active exercises are instituted.

A chronic tear can be treated either by conservative methods or by surgical repair. Anterior acromioplasty (open or arthroscopic) is performed as an adjunctive procedure to rotator cuff repair.

A neglected case will develop stiffness and weakness of the shoulder. Physiotherapy including application of heat and exercises will mobilize the joint for better evaluation. When full passive abduction and flexion to elevation are possible, active abduction and flexion by the shoulder girdle defines a tear of the cuff.

Physiotherapeutic management

Injury to the rotator cuff, though commonly observed, is quite often wrongly diagnosed and treated as adhesive capsulitis.

Therefore, proper examination, evaluation and clinical diagnosis are necessary for correct management as the methodology of treatment differs widely.

The basic aims and objectives of physiotherapy are as follows

1. **Preventive measures:** To avoid its occurrence:

(a) Avoid sudden lifting of heavy weight. When the weight exceeds the tensile strength of the tendon, it invariably

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ruptures the tendon.

(b) Avoid repeated compression and nipping of the tendon, e.g., professions involving repeated movement of strenuous abduction and flexion.

(c) People in age group prone for degenerative changes need to take extra cautions while attempting these movements with weights.

(d) Strengthening of the rotator cuff muscles by PRE. It should be planned on an individual basis specifically to strengthen all the three components of the rotator cuff, namely, abductor, internal rotator and external rotator muscle groups.

(e) Avoid sports involving repetitive movements of elevation without specific conditioning and strengthening programme. Rotator cuff injury has been reported by McLeod and Andrews (1986) in 68% of throwing athletes as a result of summation of microtrauma due to several repetitive sessions of practice.

2. **Prevention of further damage**

(a) *Positioning during standing*: Even hanging the arm by the side of the body for a longer period puts constant strain on the rotator cuff. Therefore, guidance to use support of good arm should be taught or an arm sling with proper and secured support to the shoulder and elbow may even be considered.

(b) *Positioning during exercise*: In the presence of a rupture,

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the patient should be taught the correct positions and actions so that the ruptured tendon is not exposed to any further stretch and damage. Shoulder movements, especially flexion and abduction against gravity or resistance, should be discontinued. They should be initiated in a gravity-eliminated position.

(c) Passive full ROM to avoid adhesive capsulitis is to be kept in mind and taught to the patient as self-assisted movements in supine lying position and not in standing or sitting positions.

3. **Restoration of function:** During the early phase of an acute episode:

(a) Rest with proper support in a sling,

(b) Movements of elbow, forearm, wrist and hand,

(c) Cryotherapy, transcutaneous electrical nerve stimulation (TENS), ultrasonics.

After acute symptoms are abated, isometric contractions should be given to all the three muscle groups with special emphasis on abductors and flexors with self-built-up pain-free controlled contractions.

Transverse friction massage just below the acromion is useful (Cyriax, 1978). Friction massage is contraindicated in older patients, where shredding of the tendon could have occurred.

Deep heating modality like short-wave diathermy could be

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given provided the patient does not complain of increased pain during the exposure.

Exercise programme

1. *Relaxed passive movements*: Relaxed passive full range movements with the patient in supine lying position for abductors and side lying for flexors should be started at the earliest. Care should be taken to secure total relaxation and proper stabilization, especially during abduction. The aim is to achieve full range movements without further injury to the rotator cuff.

2. *Active or active-assisted exercises:* This programme is of vital importance in the return of function. Optimal strength of the cuff muscles is the guiding principle to plan exercise. However, initiation of abduction, rotation and flexion has to be started with gravity-eliminated positions.

With the patient in supine position, the arm is held in neutral position of rotation with the elbow in flexion. Stabilization is given just above the glenohumeral joint over the shoulder girdle. The patient is then asked to the abduct the arm. If the patient can perform this, the lever arm is lengthened by extending the elbow joint. The patient should be taught to perform movements without elevating the shoulder girdle. If both these movements are not possible, assisted abduction should be initiated with the physiotherapist totally supporting the weight of the arm. During this manoeuvre, the elbow is held in flexion, and the shoulder girdle is stabilized with the other arm (Fig. 33-15). Rotation should be

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initiated in sitting and flexion in side-lying position. This regime should be gradually progressed to abduction and flexion against gravity.

3. Resisted exercises: Finally, manual resistance or resistance with dumbbells starting with minimal weight could be added. The shoulder needs to be compared with the normal side to assess the progress. Properly controlled resisted exercise programme for rotator cuff muscles and self-generated tension are important because the scapular muscles are the ‘power house’ of the shoulder movements, whereas the muscles of the humerus are primarily oriented to provide greater range of movement.

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FIG. 33-15Active assisted shoulder abduction in gravity-eliminated supine position.

Supraspinatus tendinitis/tear

A complete tear of the supraspinatus results in total loss of active abduction at the glenohumeral joint. Many tears of the supraspinatus may be asymptomatic; however, some patients may have stiffness of the shoulder, in addition to the loss of voluntary abduction.

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The partial tear or tendinitis results in classical 'painful arc syndrome'. Pain is felt around 90 degrees of abduction.

Diagnostic test

1. Active test of the ROM of shoulder abduction with slight over pressure at the terminal point of movement: The ROM for all the movements will be near normal (except in chronic lesions). Weakness and/or pain during the selected range of the arc of abduction are a major finding, indicating a strain.

2. Active resisted test of the ROM of shoulder abduction: The muscular resistance to the movement will be affected; it will be weaker as compared to the contralateral shoulder and may be painful.

3. Passive test of ROM of abduction: It will not reveal marked limitation or pain, if done gradually with the patient fully relaxed.

4. In moderate to complete tear of supraspinatus, the active abduction will indicate total loss of true abduction. Patient's attempt to actively abduct the shoulder will result only in elevation and retraction of the shoulder girdle. The passive ROM test will not indicate the capsular pattern of the restriction.

Treatment

Asymptomatic cases usually do not require any treatment.

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Surgical treatment

Symptomatic cases with weakness and limitation of abduction may require surgical treatment. The surgical procedures may be repair of the torn tendon and/or subacromial decompression.

Physiotherapy

Strain or partial rupture: In scarring or strain of the supraspinatus, pain is present only on resisted abduction. In partial rupture, the painful arc is present in the ROM of 60–120 degrees of abduction.

In both the situations, a carefully guided exercise programme (as described for the rotator cuff tear) is to be planned following cryotherapy, wet heat or ultrasound as an adjunct.

Relaxed full range passive movements in supine lying position are done to avoid secondary adhesive capsulitis.

In a complete tear, there is disruption of abduction and restoration of the function depends upon the method of treatment. After surgical repair, the arm is immobilized for 3 weeks.

First 3 weeks: Only elbow, forearm, wrist and hand movements are given. Static contractions for the abductors can be initiated gradually by 8–10 days if they are not painful.

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After 3 weeks: Exercise measures could be made intensive to strengthen and re-educate the abductor mechanism. Van Linge and Mulder (1963) observed that full abduction was possible without the supraspinatus but abduction against resistance was diminished. Therefore, proper strengthening methods using resistance by graduated dumbbells are necessary till a fairly acceptable result is obtained. In case surgery is not performed, compensatory mechanism to abduct the shoulder by using the long head of the biceps or by bringing the arm forward in flexion and to perform abduction with flexion should be taught.

Infraspinatus tendinitis

A complete rupture, strain or tendinitis may occur in this muscle, though it is rare. Painless weakness and painful arc with loss of 30 degrees of lateral rotation at the shoulder are the salient features of a complete rupture. In tendinitis and strain, pain is elicited during resisted lateral rotation, whereas other resisted movements at the shoulder are painless. If neither of these movements produces pain, then the lesions exist in the middle part of the tendon. A painful arc denotes a superficial lesion of the tendon.

If the lesion is deep and distal, full passive elevation will be painful because the tendon is caught between the tubercle of the humerus and the acromion.

Diagnostic test

1. Active test of the ROM of the shoulder external rotation

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with slight over pressure at the terminal point of range: Pain appearing at the end of the range of external rotation is indicative of tendinitis of infraspinatus.

2. Active resistive test of the external rotation of shoulder: Degree of resistance will be good but considerable pain will limit the force of muscular contractions.

3. Passive test of ROM of external rotation will not reveal much limitation or pain.

In rupture of the infraspinatus, both active and active resistive tests will indicate definite muscular weakness without the capsular pattern of restriction of joint movements.

Treatment

Treatment consists of (i) physical therapy and (ii) injection therapy.

Physical therapy

Besides various modalities used as an adjunct, deep friction massage over the area of tendon has a definite place.

The treatment of other symptoms directly depends upon the site and type of the lesion.

The only affected movement is the loss or weakness of external rotation at the glenohumeral joint. Pain on resistive movement, without weakness, indicates that the lesion is

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probably in the tendon or at its insertion.

Strengthening of external rotation without any resistance should be the initial approach. Progressively as the pain becomes less self-resistive, exercise is the best mode of exercise (Fig. 33-16).

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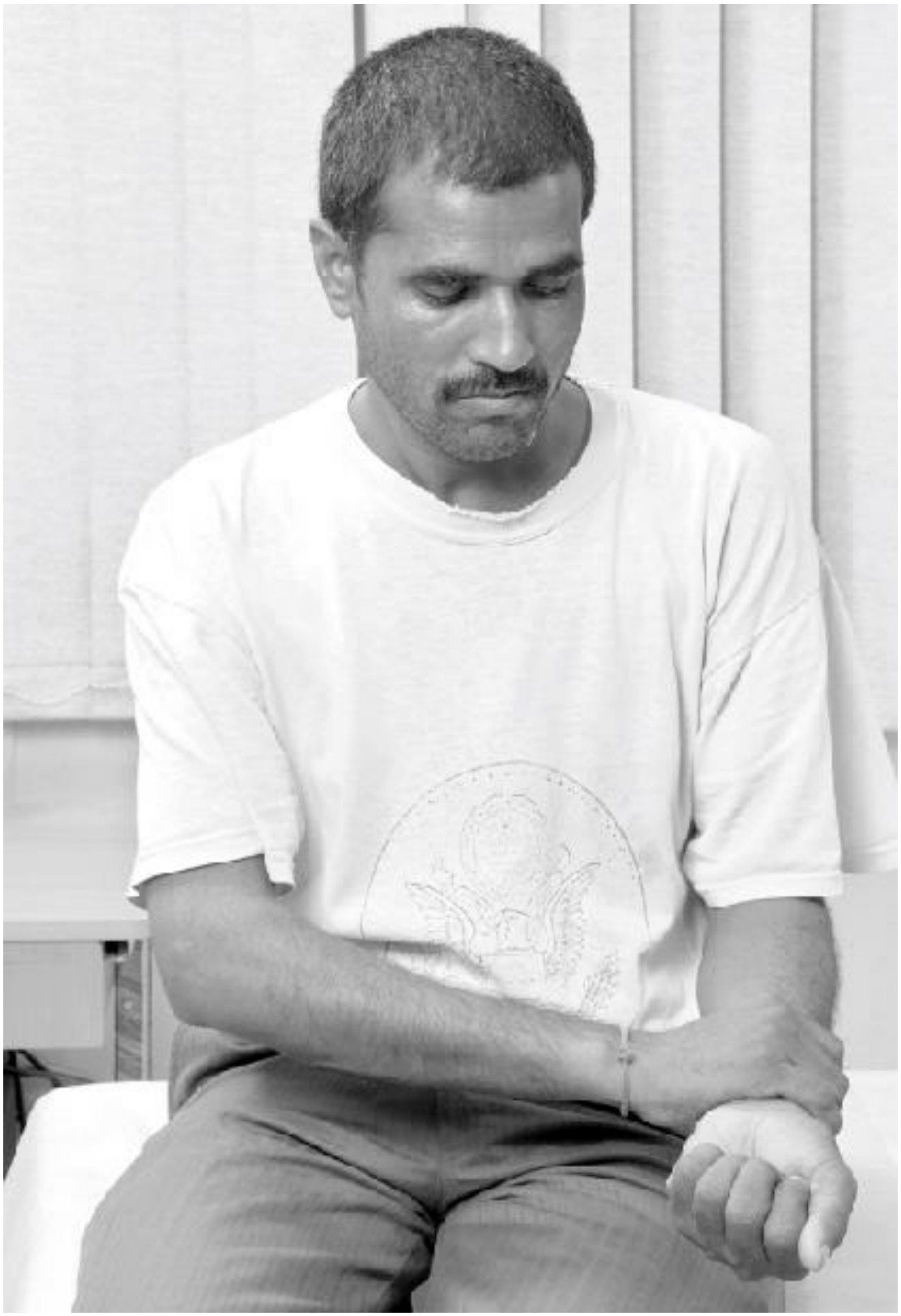

FIG. 33-16Self-resisted external rotation exercise for

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infraspinatus tendinitis.

In deep lesion, full passive elevation is painful. Full passive elevation could be effectively obtained with elbow relaxed in 90 degrees of flexion with the patient in supine position.

Superficial lesion gives rise to painful arc which should be treated as described earlier. Complete rupture of the tendon gives rise to painless weakness and eventually may result in limitation of external rotation.

Full range relaxed passive arc of external rotation and gravity-assisted external rotation should be instituted as early as possible. It should be gradually progressed to increase resistance till strong and painless maximum arc is attained.

Injection therapy

Injection hydrocortisone may be given at the site of the lesion.

Subscapularis tendinitis

Stress injury because of overstrain or continued overuse could be responsible for damage to the subscapularis. Passive range of shoulder internal rotation is usually full and painless. Only the movement of resisted medial rotation is painful. Adduction is usually pain-free unless there is an associated involvement of the pectoralis major, latissimus dorsi or teres major.

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Diagnostic test

1. Active test of the ROM of shoulder internal rotation is performed with slight overpressure at the end point of the range. Pain will be present at the end of the range of shoulder internal rotation indicating tendinitis of the subscapularis.

2. Active resistive test of shoulder internal rotation: The overall force of resistance will be good, but there will be definite increase in the degree of pain with increase in the force of resistance.

3. Passive test of the ROM of internal rotation will not reveal marked limitation or pain.

In the event of rupture of subscapularis, both active and active resistive tests will reveal definite weakness of the muscular action, but without the capsular pattern of restriction of movements.

Treatment

It consists of (i) physical therapy and (ii) injection therapy.

Physical therapy

The early stage of the syndrome is to be managed by cryotherapy or ultrasound along with rest. Movements to other joints are to be started immediately. The value of friction massage is disputable. However, manipulations like

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gentle circular kneading could be given for relaxation (Cash, 1984; Cyriax, 1978).

Strengthening of the movement of internal rotation: The movement of internal rotation is painful when carried out against resistance. Therefore, self-assisted movement or movement against self-resistance, not strong enough to cause pain, should be initiated (Fig. 33-17). It could be progressed further as the pain reduces.

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FIG. 33-17Self-resisted internal rotation exercise for subscapularis tendinitis.

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If the patient feels pain during the movement of resisted adduction due to the involvement of the pectoralis, latissimus dorsi and teres major, bilateral resisted adduction as well as abduction could be useful. This, of course, should be done with well-controlled resistance (may be negligible) to the painful side. Relaxed pain-free full-range passive movements, at least once a day, should not be overlooked to avoid secondary stiff shoulder.

Injection therapy

Hydrocortisone may be injected at the site of the lesion.

Rupture of long head of the biceps brachii (tendon)

A complete rupture of the long head of the biceps brachii is rare and usually occurs in a degenerated tendon which is subjected to repeated strains in the elderly male. The presenting symptoms in the initial stage are pain with a feeling of giving way while lifting or pulling. There is localized tenderness in the intertubercular sulcus. Resisted elbow flexion causes pain, while the strength of flexion as well as supination is not significantly affected. At a later stage, a bulge may be noticed in the arm (Fig. 33-18).

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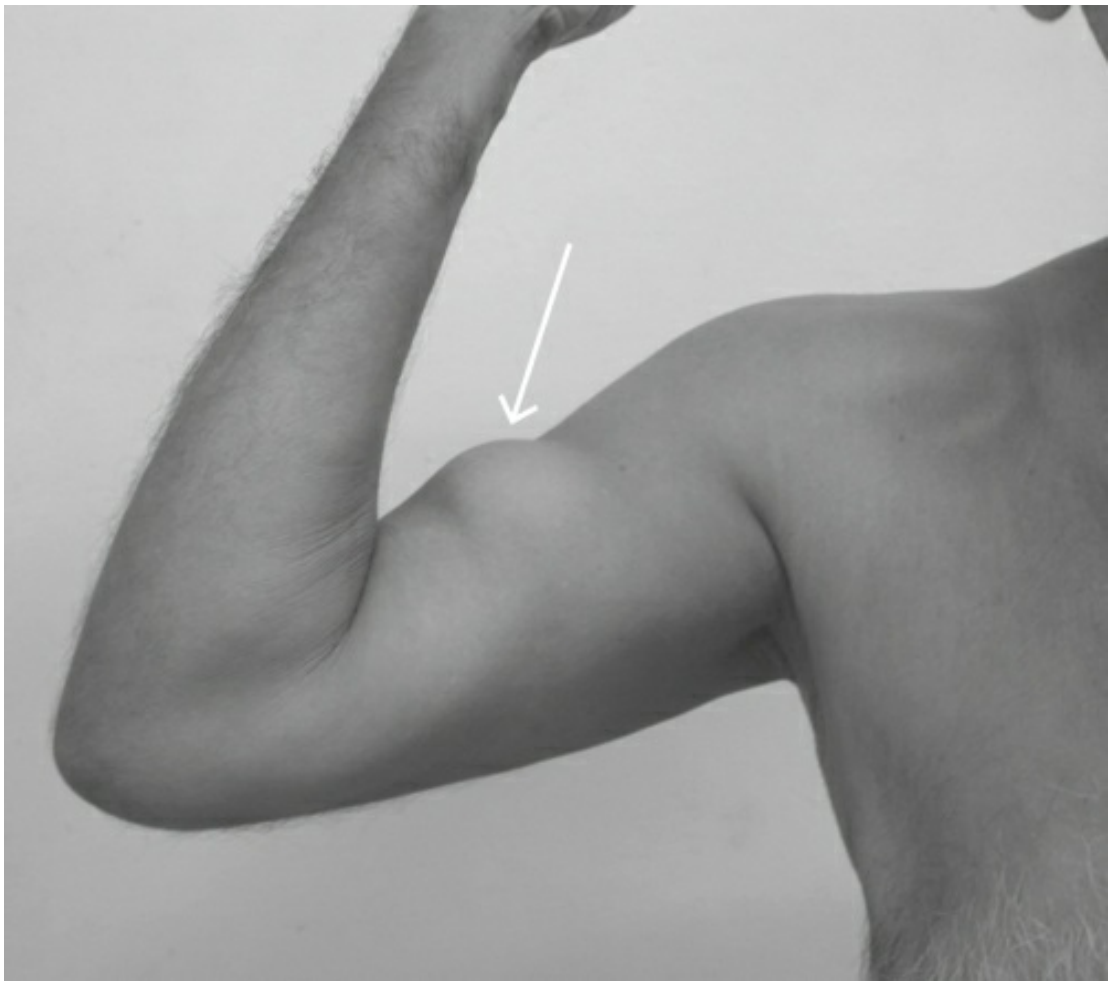

FIG. 33-18Rupture of the long head of the biceps brachii muscle (arrow).

Tendinitis occurs due to overuse or severe strain. Resisted supination and/or flexion of the elbow produces pain. The other movements are pain free.

Diagnostic test

1. Active and active resistive movements to the shoulder alone are not limited or painful.

2. Passive ROM to the shoulder will not indicate any

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limitation of ROM.

3. Only the initiation of pain during the terminal range of elbow flexion or forearm supination, especially against resistance, confirms the diagnosis of tendinitis of the long head of the biceps.

When the tendon of the long head of the biceps is ruptured, there is a definite weakness of the movements of elbow flexion or forearm supination.

Treatment

No treatment is necessary. The patient is given reassurance and symptomatic treatment which may consist of the following:

1. Analgesics: These are given at any stage if the pain is severe.

2. Rest and sling: For the first 2–3 days. The sling may be discarded after 3 days. However, if rest is still indicated, the patient may be advised to put his hand in the pocket.

3. Physical therapy: Whether it is tendinitis or rupture of the long head of the biceps brachii, the basic problem is not the strength, but pain, tenderness and the feeling of insecurity while lifting or pulling.

Pain and tenderness can be adequately controlled with thermotherapy or cryotherapy along with analgesics and rest.

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Initially, wrist and finger movements should be encouraged and isometrics to the triceps and pronators could be tried for the reciprocal relaxation of the biceps brachii.

Cyriax (1978) advocated the use of transverse friction massage.

Relaxed passive full range movements in supine position with or without sling should be started to avoid a stiff shoulder.

Graduated strengthening of elbow flexion and forearm supination

Begin with relaxed passive movements of elbow flexion and forearm supination. When active painless range is achieved, carefully graduated assistive and then resistive movements can be given. By 3–4 weeks, functionally useful movements should be attained.

Surgical treatment: End-to-end suture of the ruptured muscle belly gives satisfactory results. Postoperatively, the arm is immobilized with the elbow in acute flexion for a period of 3–4 weeks.

Postsurgical management by physiotherapy follows the same routine as described for rotator cuff syndrome with emphasis on graduated re-education of elbow flexion and forearm supination.

Subacromial or subdeltoid bursitis

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The subacromial bursa is situated under the upper part of the deltoid muscle and the acromion process (see Fig. 33-19). It reduces friction and thereby permits internal rotation of the greater tuberosity of the humerus under the acromion in movements of abduction and internal rotation of the shoulder.

Subacromial bursitis always occurs following a lesion of the neighbouring structures. The patient complains of pain in the shoulder on abduction and internal rotation of the humerus. The tenderness is over the greater tuberosity which disappears on abduction.

Treatment

Most of the cases respond to conservative treatment. Analgesics and rest may be sufficient to relieve pain. Injection therapy may be undertaken in moderately severe cases. Hydrocortisone is infiltrated into the area of the bursa.

In patients with intense pain, surgical excision of the inflammed bursa may be done.

Physical therapy management

The acute stage is associated with severe disabling pain for 2–3 days. Measures like cryotherapy, TENS could be used along with sling immobilization to combat pain.

Relaxed passive movements should be started at the earliest after ensuring that they are painless.

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Gentle mobility exercises carried out judiciously not only induce relaxation but also bring about improvement in muscle capillary filling.

Ultrasonography during the subacute phase of bursitis induces hyperaemia and facilitates absorption of the calcium deposits when present (Kessler & Hertling, 1983).

Re-education of abduction

When the pain subsides, careful re-education could be started with the patient in supine lying position and progressed gradually in phases as movements become strong (as described for adhesive capsulitis).

Subdeltoid bursitis (fig. 33-19)

A bursa situated between the deltoid and the capsule of the shoulder joint may get inflamed due to rheumatism, infection, direct trauma or inflammatory changes secondary to local deposition of calcium salts.

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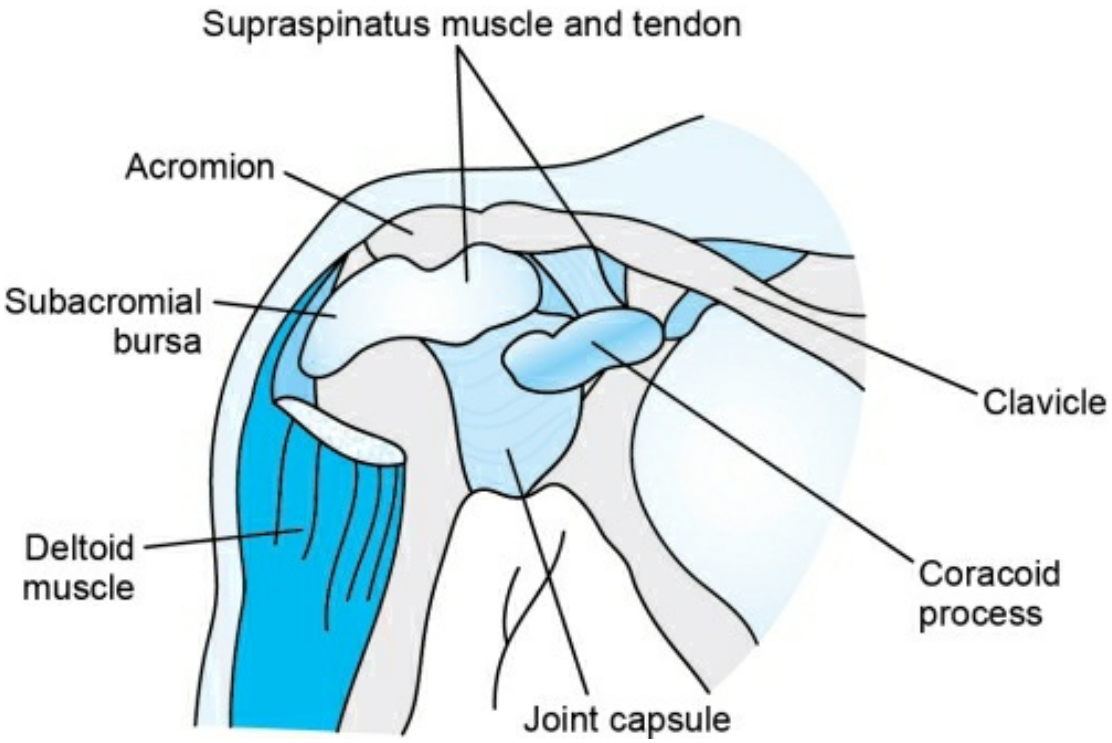

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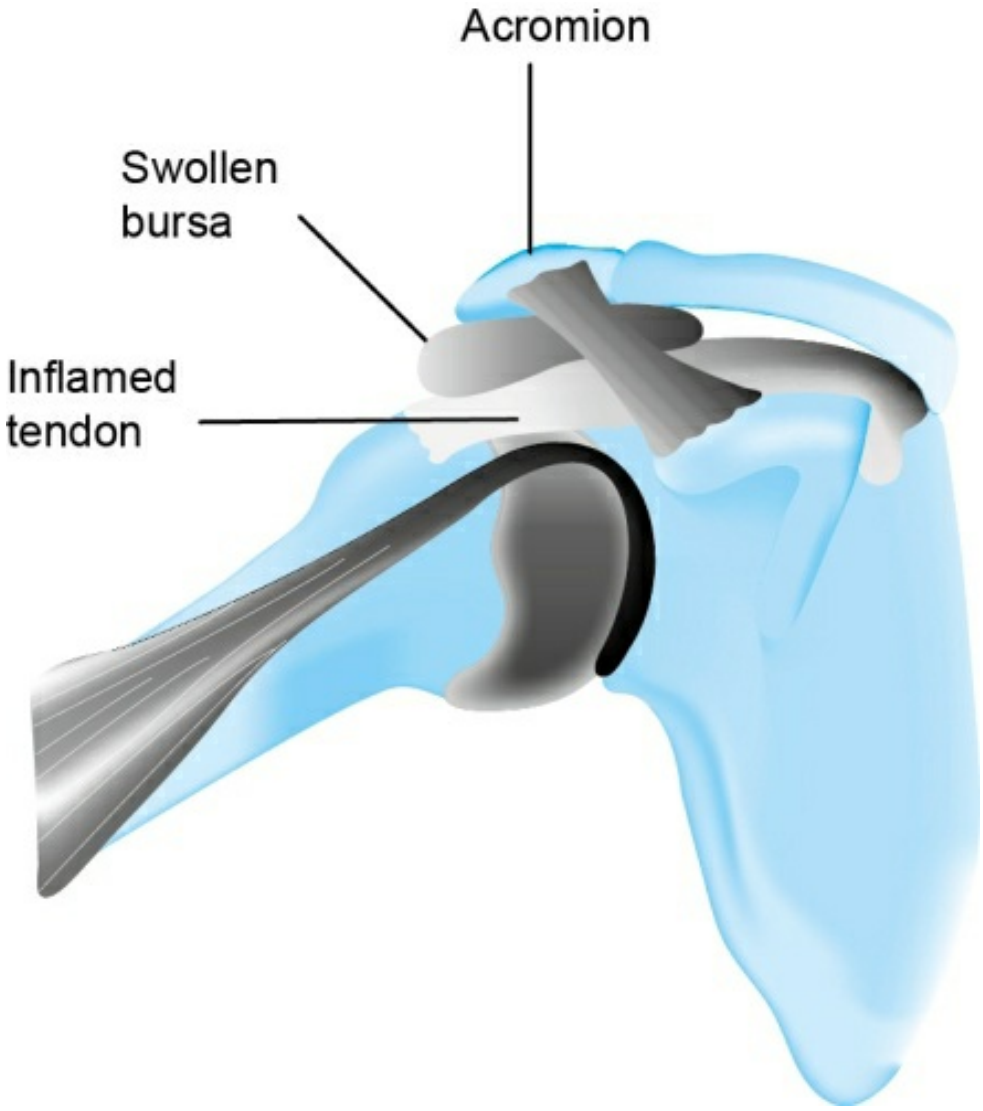

FIG. 33-19Subdeltoid (subacromial) bursitis.

In the acute stage, local inflammatory symptoms like tenderness, severe pain on shoulder movements, especially abduction, and warmth may be present. The onset may be gradual or sudden.

Treatment

Initially, rest in a triangular sling. Appropriate pain relieving

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heat modality should be applied.

When the pain subsides, gradual mobilization should be begun with adequate support and stabilization. Relaxed passive movements to the available pain-free range should be encouraged to avoid a stiff shoulder.

Exercises should be progressed to active, resisted movements gradually.

Local infiltration with hydrocortisone can be given to relieve acute symptoms; deep friction massage following infiltration is also effective. Complete relief may take 4–6 weeks.

Soft-tissue lesions at the elbow

Elbow

1. Tennis elbow

2. Golfer elbow

3. Olecranon bursitis

Wrist and hand

1. Carpal tunnel syndrome

2. Wrist sprain

3. Ganglion

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4. De Quervain disease

5. Dupuytren contracture

6. Tenosynovitis

7. Tenovaginitis

8. Trigger finger

Functional anatomy of the elbow joint

The elbow joint is a complex hinge joint formed by the articulations of the lower end of the humerus with the upper end of the ulna and the head of the radius.

The strong movement of elbow flexion occurs as a result of the action of the biceps brachii, brachialis, supinator and brachioradialis. Extension is the result of the action of a strong triceps muscle.

The three important peripheral nerves – median, radial and ulnar lie in close relationship with the elbow joint.

The important bony landmarks are the medial epicondyle, lateral epicondyle and the olecranon process. When these lines are joined together by the arbitrary lines, they form the following:

■ An isosceles triangle when the elbow joint is flexed.

■ A straight line when the elbow is fully extended; this relationship gets disturbed in injuries to the elbow.

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Tennis elbow (lateral epicondylitis)

Tennis elbow is a common entity characterized by pain and tenderness at the common origin of the extensor group of muscles of the forearm. It is an extra-articular condition believed to be caused by strain or incomplete rupture of the forearm extensor muscles or aponeurotic fibres at their origin, respectively. It is called tennis elbow because it was thought to be caused by an awkward stroke during the game of tennis. However, it is usually an overuse injury in the day-to-day activities of pulling, lifting, pushing, etc.

On examination, there is tenderness over the lateral epicondyle of the humerus. Pain is aggravated by stretching the extensor muscles, e.g., extension at the wrist against resistance with the forearm pronated. Movements of the elbow are full as it is unaffected.

Treatment

Conservative treatment

The treatment consists of rest and trying to avoid the movements that cause pain.

NSAIDs and a tennis elbow splint are used for pain relief (Fig. 33-20).

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FIG. 33-20Tennis elbow splint.

Local injection of hydrocortisone with local anaesthetic solution relieves pain in majority of cases.

1. *Cryotherapy:* Ice pack for 30 min or ice massage for 7 min over the painful area of entire muscle belly.

2. *Supportive measures:* Initially, rest with a splint holding wrist in mild degree of extension and sling with elbow in flexion and forearm in supination. Posterior slab can also be given for the first 2–3 weeks.

Unfortunately, this is usually not done and the arm is allowed free movements which delay the recovery.

3. *Electrical stimulation:* Sinusoidal stimulation for 20 min

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with arm in elevation relieves muscle spasm, prevents formation of adhesions and reduces oedema.

4. *Iontophoresis:* It can help in reducing pain and inflammation.

5. *Diapulse, ultrasonics, TENS:* These can be effective in controlling pain and inflammation. Ultrasonography with hydrocortisone cream of 0.05% concentration as a coupling agent has been reported as a useful modality (Hayden, 1972). Binder et al. (1985) suggested that ultrasound therapy enhanced recovery in 63% cases. Review by Labelle (1992), Wright and Vicenzeno (1997) however suggested that ultrasound provides little benefit beyond that of a placebo.

6. *Gentle effleurage and kneading* during the first 2 weeks.

7. *Gentle active movements* of elbow, wrist and hand and isometrics at the end of each range, if these are not painful, should be carried out with emphasis on the wrist extensors.

8. *Mild resistive exercises:* Self-controlled resistive exercises by using the good arm to resist the movements of wrist extension, radial deviation, finger flexion and forearm supination should be initiated.

9. Vicenzino and Wright (1995), Brien and Vicenzino (1998) and Kavanagh (1999) demonstrated improvement in both pain and function following treatment with Mulligan's lateral glide treatment.

Operative treatment

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In rare instances, surgery is indicated in resistant cases not responding to conservative treatment. The extensor muscles are stripped from their origin, i.e., lateral epicondyle, and are allowed to fall back. An above-elbow slab with elbow in 90 degrees flexion is given for a period of 10 days postoperatively. The elbow is then mobilized.

Trial of resistive exercises could be given with 1 lb or 0.5 kg dumbbell, and gradually progressed to 2 lbs, 3 lbs or 1.5–2 kg dumbbells. The aim is to achieve 15 repetitions of each movement without pain.

Patients with articular involvement respond with difficulty and usually need prolonged rest. Active movement is begun only after 3–4 weeks, if not painful.

Manipulation could be effective in cases where pain is provoked with active use of extensor muscles by Mills manoeuvre (1937). However, manipulation is contraindicated in case of pain at rest, stiffness after rest and fibrositis.

Physiotherapy following surgery

1. Measures to reduce pain and inflammation.

2. Limb elevation and speedy as well as sustained active movements to the joints free of immobilization.

When mobilization is allowed (1 week)

3. Begin with slow relaxed full ROM passive movements to

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the elbow, forearm and wrist.

4. Shoulder and shoulder girdle should be mobilized to full ROM to avoid adhesive capsulitis.

5. Begin with gradual active-assisted exercises and progress to self-resistive techniques. Ultrasonics, TENS, diapulse can be used as adjuncts to reduce pain.

6. Functional movements, carefully avoiding repeated supination, wrist extension and strong grip.

7. Progress gradually to PRE. By 5–6 weeks, functionally painless elbow, forearm and wrist movements should be regained.

Physiotherapeutic management

Physiotherapy plays an important role in the management of 'tennis elbow'.

Preventive management: Repeated forceful jerky movements to the common origin of extensor group of muscles are the main cause.

Activities like wringing washed clothes, using a wrench, tightening a screw and even a vigorous hand-shake should be avoided. Mechanical professions and sports involving repetition of these movements are more prone to getting tennis elbow. Similarly, repeated supination using heavy rackets or weights should also be discouraged.

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Proper conditioning and specific regime of strengthening exercises to the extensor carpi radials longus and brevis as well as supinator forms the basis of preventive programme. Generalized strengthening of the common extensor group and avoiding improper strain because of wrong attitudes in the game, e.g., top spine back hand, or playing tennis with a small handle racket.

Prevention of further damage: It is important to prevent further damage and thereby develop a chronic tennis elbow.

1. Adequate care during the acute phase, resting the elbow joint with proper support.

2. Instructing and guiding the patient against repetitive stretching or trauma to the affected muscles by avoiding movements of supination, wrist extension, radial deviation and tight grips.

3. Avoiding hasty mobilization: Early active movement causes repeated breakdown in the formation of scar tissue which subsequently prolongs the inflammatory reaction and leads to the formation of adhesions.

Restoration: For the restorative programme to be effective, it is absolutely essential for the physiotherapist to carefully evaluate the exact nature of involvement.

1. Strain and tear of muscle: Tenderness will be present at the musculotendinous junction of the extensor carpi radialis brevis.

2. Epicondylitis: Partial tear of the tendon at their origin,

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with lesion in the subtendinous space. Tenderness is felt exactly over the lateral epicondyle. Granulation tissue formation as well as adhesions may be present.

3. Bursitis: Develops a bursa in the subtendinous space.

4. Articular involvement: Painful joint movement.

Golfer elbow or medial epicondylitis

This condition is not as common as the tennis elbow. The site of tenderness being the medial epicondyle of the humerus and the seat of inflammation is the common origin of the flexor group of muscles. The muscles of the common flexor group are strained or torn from the medial epicondyle of humerus. Pain is produced by extension of the elbow, supination and valgus strain. It is called Golfer elbow because it is thought to be caused when a golfer hits the ground instead of the ball, thus producing a valgus strain to the elbow thereby straining the flexor group of muscles.

Treatment

A steroid injection is given locally into the muscle belly at its origin. The physiotherapeutic management programme proceeds on the same lines as for lateral epicondylitis.

Olecranon bursitis (minor elbow) (fig. 33-21)

Repeated trauma to the posterior aspect of the elbow joint is the precipitating cause for olecranon bursitis, hence the name

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'minor's elbow.' It is occasionally found in patients with rheumatoid arthritis.

(A)

(B)

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FIG. 33-21Olecranon bursitis. (A) Note the prominence/swelling at the point of elbow. (B) Normal elbow for comparison.

It is most often pain free, and it does not need any treatment except avoiding strain and friction.

It could become painful if there is associated bacterial infection. An infected bursa is treated by antibiotics, and drainage of the pus, if required.

Wrist sprain

Sudden thrust results in a sprained wrist. It is usually strained in the acute position of flexion or extension, the latter being more common. The degree of damage to the soft tissues, the muscles and the ligaments depends upon the extent of violence.

Violent force in the direction of extension often inflicts injury to the flexor group of muscles passing over the wrist joint and the anterior radiocarpal ligament. Injury with the wrist in flexion results in damage to the soft-tissue structures on the dorsal aspect. Many a times the medial or lateral radiocarpal ligaments are also injured.

The involvement of a particular ligament can be detected by the presence of localized tenderness. Local pain and swelling may extend to the forearm.

Treatment

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Once a bone injury is ruled out, the treatment is usually conservative.

1. A firm pressure bandage or strapping is given. If the injury is extensive, posterior slab, which provides better immobilization, may be applied. Cuff and collar sling is also advisable in major sprains. It helps in reducing the swelling by keeping the wrist in elevation.

2. Adequate umbrella of analgesic and anti-inflammatory drugs is also advised.

3. Cold compress or ice massage followed by prolonged anodal galvanism reduces swelling by iontophoretic effect.

4. Relaxed passive movements should be carried up to the limit of pain to prevent stiffness.

5. Active movements to the fingers reduce swelling and improve circulation. Full range movements to the shoulder and elbow should be advised at hourly intervals by removing the sling.

6. The plaster slab may be discontinued as soon as the pain and swelling permit, but crepe bandage may be used. Active movements with crepe bandage are encouraged as it provides active resistance to movements. Full range of movement and adequate strength should be regained by 2 weeks after mobilization.

7. Passive stretching, deep transverse friction massage and ultrasonography may be necessary if some limitation of movements or pain persists.

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Caution

Regular watch should be kept to detect the development of tenosynovitis of the flexor tendons early.

Ganglion (fig. 33-22)

Ganglion, a round subcutaneous swelling which initially appears as a very small pouch, is a cyst of the synovial membrane. It is a fibrous sac containing viscid material. The small cyst may either disappear spontaneously or may increase in size when the site of ganglion is exposed to repeated friction or pressure. Such a ganglion may occur over the palm of the hand, on the outer side of the knee, the dorsum of the foot or over the dorsal surface of the wrist. The commonest site is dorsum of the wrist. It may be painful and increase in size as the wrist is frequently subjected to friction and pressures of daily activities.

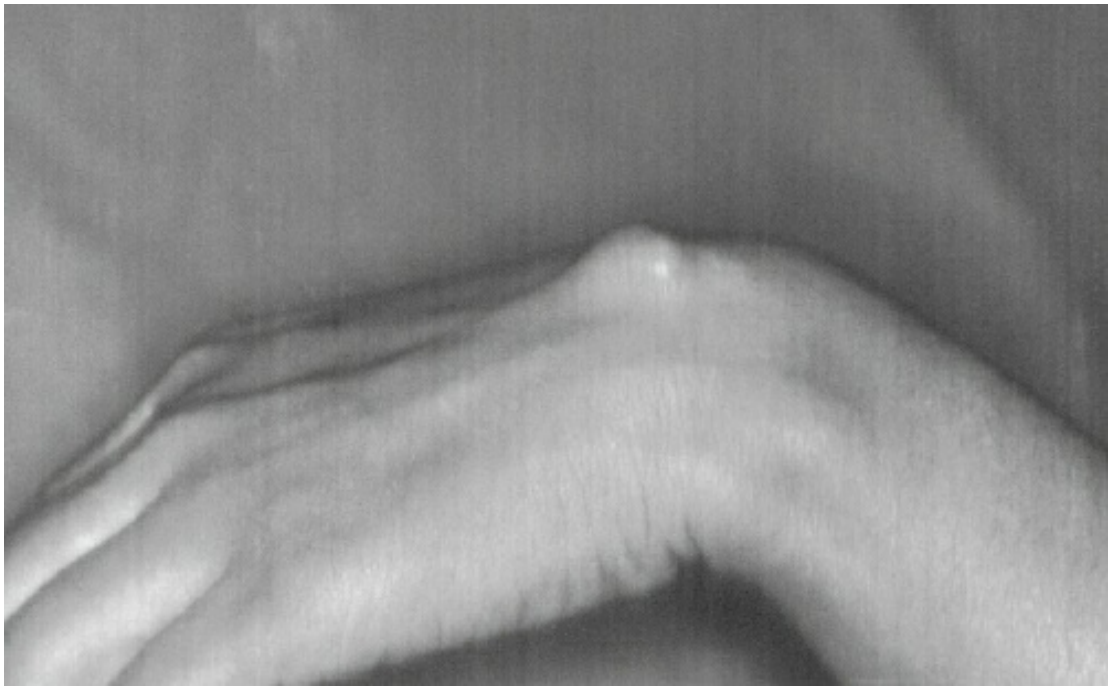

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FIG. 33-22Ganglion.

Treatment

Avoid friction or massage over the ganglion. Local infiltration with hyalase is also one of the methods of treatment.

When recurrence occurs or there is unremitting pain, it may be necessary to excise the ganglion.

Simple active movements following excision are good enough to recover full function.

De quervain disease

This is an inflammation (tenosynovitis) of the tendon sheaths of the abductor pollicis longus and extensor pollicis brevis at the point where they cross the styloid process of the radius (Fig. 33-23). The tendon sheaths get thickened and sometimes crepitus may be present on palpation. Summation of microtrauma due to repeated friction is the common precipitating factor.

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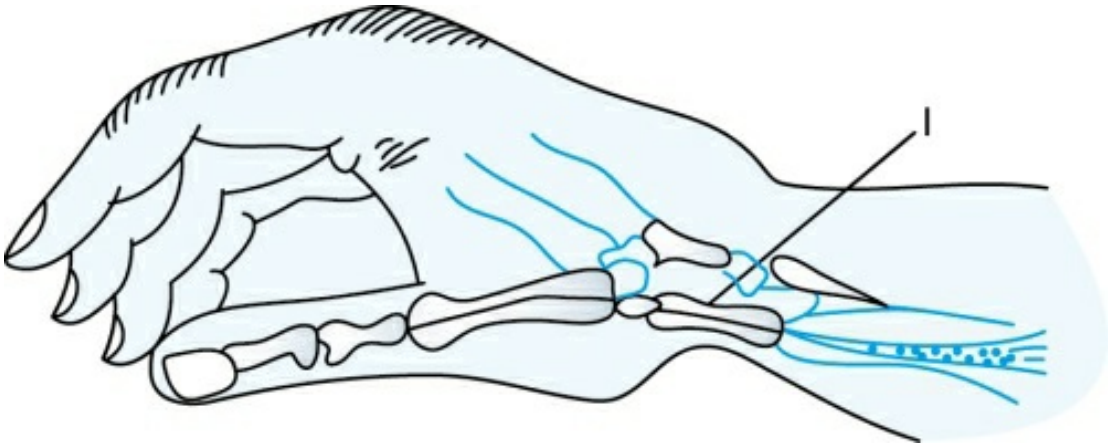

FIG. 33-23De Quervain disease: Inflamed sheaths of the tendons of the abductor pollicis longus and extensor pollicis brevis.

Movements of the thumb are very painful. It may be associated with pain in the wrist with weakness of grip.

Treatment

■ Drug therapy to combat inflammation.

■ Restriction of movements by applying a small hand splint in functional position with immobilization of the thumb.

■ During early stage, ice massage, and at the later stage, ultrasound or any deep heating modality helps in reducing inflammation and pain.

Cyriax (1978) advocated transverse friction massage, as the precipitating factor is repeated exposure to longitudinal friction.

Local corticosteroid infiltration may be effective in some

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cases.

Surgical intervention in the form of splitting the lateral wall of the tendon sheath may be necessary in nonresponding cases. Carefully controlled early initiation of tendon movement in the form of relaxed passive movements is of primary importance. Rapid progression to assisted active then to active and finally to resisted movements is important to restore pain-free hand function.

Tenosynovitis

Following an infection or an injury, the synovial lining of the tendon sheath responds by secreting excessive synovial fluid. This condition is called tenosynovitis.

When it is traumatic, it affects the tendons of the abductor pollicis longus and extensor pollicis brevis, which form the radial boundary of the anatomical snuff box.

Suppurative tenosynovitis

It is a serious form of tenosynovitis where pus formation occurs in the sheaths of the flexor tendons of the thumb and fingers. It is extremely painful and needs early attention. The hydrostatic pressure of the pus may build up to such an extent that it may block the blood supply to the tendons, resulting in stiff and functionally useless fingers. Intramuscular injection of an antibiotic in time can save the hand.

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Tenovaginitis

In tenovaginitis, the difference in the pathology is that instead of secreting abnormal amount of synovial fluid, the tendon gets thickened and fibrosed. This limits the movement of the tendon within its sheath.

Hard tender swelling with pain during the movements of thumb or wrist is the common symptoms. In suppurative tenosynovitis, pain is present even during rest. Excessive use of hand for hard work is a common cause and is one of the most common industrial diseases.

Treatment

1. During the early stage with acute inflammatory symptoms, rest is needed. It may be done by application of a crepe bandage.

2. A rigid thermoplastic splint is ideal to provide rest and avoid overstretching at work.

3. A modality like diapulse, ultrasound, TENS, cryotherapy or iontophoresis is useful in controlling pain and inflammation.

4. Gentle relaxed finger movements with hand in elevation are useful.

5. Isometrics within the limits of the pain should be encouraged.

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6. Relaxed full range passive movements are important to avoid contractures.

7. Cyriax (1978) and Tidy (1968) found deep friction massage across the affected tendon very effective.

By 10 days to 2 weeks, considerable relief should be obtained.

In resistant cases, surgery may be needed. The stenosed or thickened sheath may be incised and decompressed.

Initially, limb elevation, finger movements and diapulse can be given with rest in a splint. After removal of stitches, active mobilization of the wrist, thumb and finger could be progressed till full function without pain is obtained.

Programmes to strengthen the muscles passing over the wrist, thumb and fingers are concentrated on. Splint is continued for some time while using the hand.

Trigger finger

There is a momentary locking of the flexor tendon on attempting to extend it, following flexion, due to the formation of a nodule in the tendon distal to a constriction in the tendon sheath (Fig. 33-24). It gets released with a sudden snap by passively moving the finger in the extension (Fig. 33-24).

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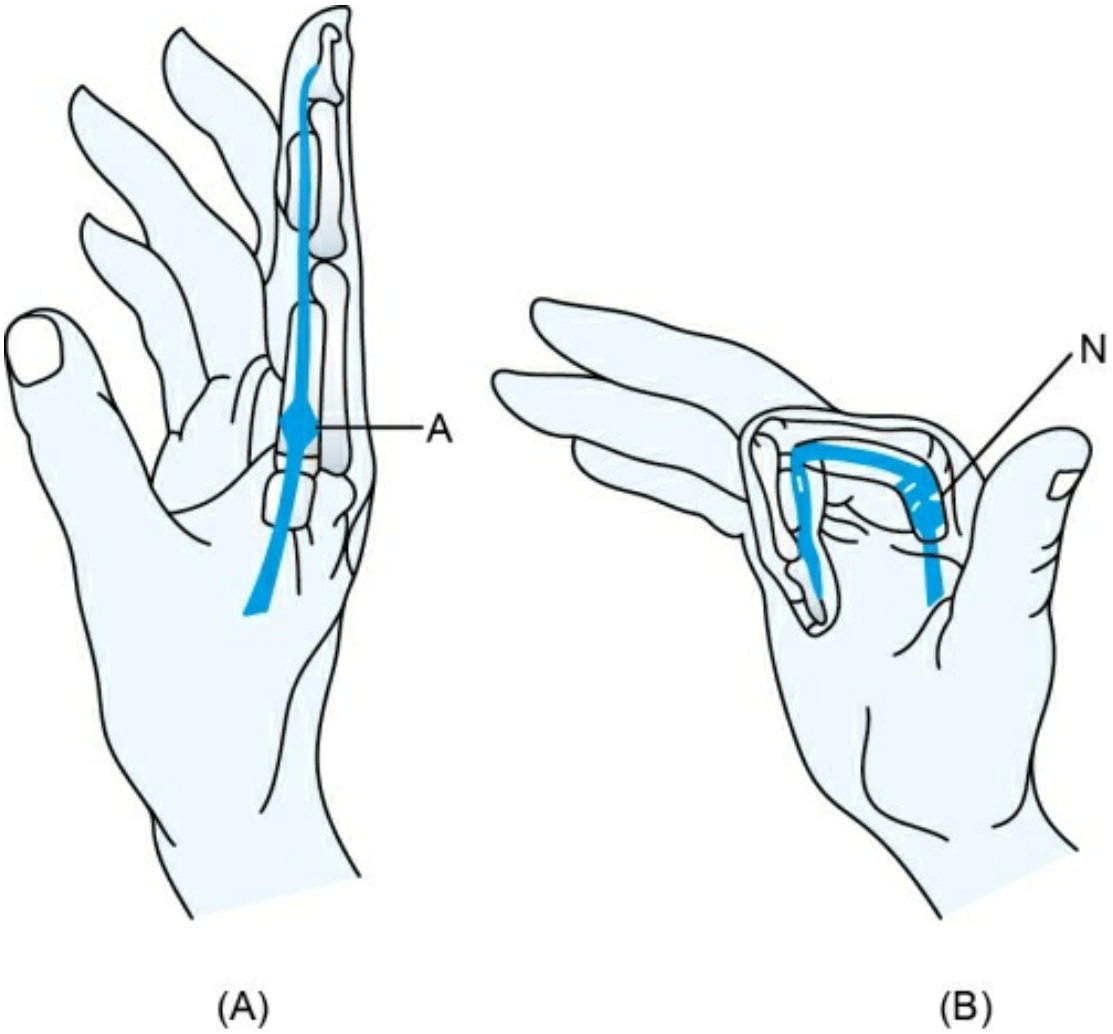

FIG. 33-24Trigger index finger. **(A)** Formation of nodule (N) in the flexor tendon. **(B)** Entrapped nodule (N) in the fibrotic zone at the base of the metacarpophalangeal joint on flexing the index finger.

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CHAPTER 34

Hand

OUTLINE

- Anatomy of the hand
- Functional requirements of the hand
- Methods of evaluation of the hand
- Injuries of the hand
- Splints
- Tendon injuries
- Burns of the hand
- Infections of the hand
- Vasospastic diseases of the hand
- Jersey finger
- Crush injuries and finger amputations

Hand is a major functional component of our body with important functions. It is therefore important that the hand therapist keeps pace with the newer developments which happen every now and then. The advent of microsurgery, replantation and small joint replacements has revolutionized the whole concept of hand management.

However, before proceeding to the techniques of treatment of hand injury, it is necessary to understand the applied anatomy of the hand and the factors which contribute towards the optimal functioning of

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the hand (Backhouse, 1968).

Anatomy of the hand

The hand is an end organ which is designed to obtain information and an organ of execution too. The architecture of the hand is briefly discussed as follows.

Carpometacarpal joints

The carpometacarpal (CMC) joints of the index, middle and ring fingers are plane joints that allow flexion and extension only, for firm gripping. The CMC joint of the little finger, however, is a semisaddle joint capable of rotational movement needed for opposition. The CMC joint of the thumb is a seller joint which allows movements in two planes. The reciprocal concave–convex surfaces allow flexion–extension, whereas the convex–concave surfaces allow abduction and adduction and rotation.

Metacarpophalangeal joints

The metacarpophalangeal (MP) joints of the fingers and the thumb are condylar joints, allowing radial and ulnar deviation, and flexion–extension. The greater slope of the radial shoulder produces ulnar drift or deviation at these joints.

Proximal interphalangeal joints and distal interphalangeal joints

The proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints are bicondylar joints allowing opposition with the thumb, and assist in joint mobilization techniques, without exerting stress on the capsular tissues.

Joint capsule: The capsule is made up of dense and fibrous tissue which can sustain stress and at the same time permit stretch. The joint capsule develops adaptive shortening and stiffness when immobilized.

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Ligaments

The ligaments of the radiocarpal, intercarpal, carpometacarpal and metacarpophalangeal joints provide stability to the hand. The transverse intermetacarpal ligament is the most important extracapsular ligament of the hand. The full extensibility of this ligament is necessary for grasping and prehensile activities. The capsular and extracapsular ligaments are instrumental in providing support and stability to the hand.

Muscle and nerves

The hand activities are brought about by two muscle groups: (i) intrinsic and (ii) extrinsic.

1. Intrinsic muscle groups are the muscles which originate within the hand and act upon the digits. These include the thenar, hypothenar, lumbricals and interossei muscle groups.

2. Extrinsic muscle groups originate in the forearm, proximal to the wrist and act on the hand. The integrated functioning of both these groups is the prerequisite for a variety of hand activities.

The thenar muscle group includes the abductor pollicis brevis, flexor pollicis brevis, opponens pollicis and adductor pollicis. Only adductor pollicis receives innervation from the deep branch of the ulnar nerve; the rest are supplied by the motor branch of the median nerve.

The hypothenar muscle group includes the abductor digiti minimi, flexor and the opponens digiti minimi. Three volar interossei and four dorsal interossei are supplied by the ulnar nerve. The two lateral lumbricals are innervated by the median nerve while the two medial lumbricals are innervated by the ulnar nerve.

Skin

Extensibility as well as sensory perception plays a significant role in the ultimate function of the hand. Efficient tactile gnosis needed on

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the volar aspect of the hand is met with by extensive innervation. The fat pads, eccrine glands and creases on the volar aspect absorb shock and stresses, and allow nonslippery grasps.

Functional requirements of the hand

The hand function is based on the variation of two basic grips: (i) power grip and (ii) precision grip.

Power grip

It is a grip which requires firm control of holding an object during activity (e.g., handling a hammer). This is achieved not only by true anatomical flexion of the fingers but also by the components of rotation and ulnar deviation towards the thenar eminence. The thumb assumes side position and controls the leverage. This is further enhanced by the wrist occupying the position of extension with ulnar deviation (Fig. 34-1A).

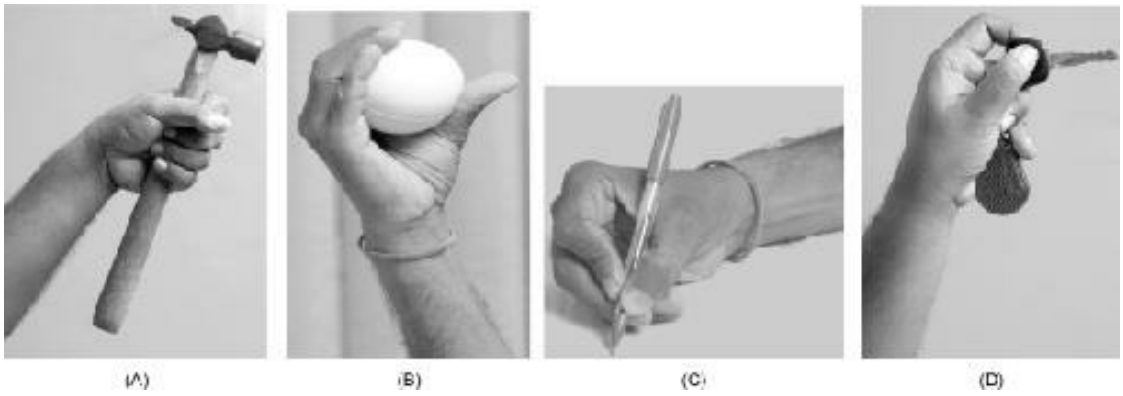

FIG. 34-1 The types of hand grips. **(A)** Power grip. **(B)** Opposition or palmar prehension grip. **(C)** Pinch grip. **(D)** Lateral prehension grip.

However, an activity like carrying a bag requires only true digital flexion, as seen in mass grasp (Fig. 34-2).

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FIG. 34-2 Flexion of fingers in carrying a briefcase.

Precision grip

Precision grip basically needs perfectly coordinated interplay of the small muscles of the hand. They are of four types:

1. ***Flexion–extension at the fingers:*** The main precisive activity of flexion–extension occurs at the MP joints. Interphalangeal joints are held practically immobile in slight flexion (e.g., typing).

2. ***Opposition or palmar prehension:*** It needs an accurate pad-to-pad contact of the thumb with an individual finger. The components are as follows: abduction–rotation at the thumb, slight inward rotation and ulnar deviation at the index and middle fingers, and inward rotation and radial deviation at the ring and little fingers (Fig. 34-1B).

3. ***Pinch:*** This is same as opposition, the only difference being that it is associated with strong flexion at the IP joints of the thumb with the

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concerned finger (Fig. 34-1C).

4. ***Lateral prehension:*** Commonly known as key grip, it constitutes strong adduction, flexion and opposition of the thumb to the radial side of the index finger. This provides useful grip in the absence of true opposition. (Fig. 34-1D).

Muscular activity

Electromyographic (EMG) studies conducted by Long and Brown (1964) and Landmaster and Long (1965) have greatly contributed to the understanding of the muscle function of the hand.

Flexor digitorum profundus (FDP) has been found to be most active in flexion, whereas flexor digitorum sublimis (superficialis) is active only when true power movements and grip are needed in sustained efforts (e.g., holding and carrying baggage).

The two interossei to each finger together produce MP joint flexion along with the necessary rotation and deviation to the side of its insertion. Therefore, they are crucial both in power grip and in precision grip. At the same time, they act as strong extensors at the IP joints acting through the extensor aponeurosis.

Extensor digitorum longus primarily acts during extension at the MP joints. Though lumbricals primarily are flexors at the MP joints, they act mainly in extension of the IP joints. Lumbricals act as flexors only when the interphalangeal joints are held in extension (e.g., holding a newspaper). Lumbricals with their richly innervated sensory end organs appear to be instrumental in the proprioceptive balancing mechanism. Their action controls the coordination between flexion and extension mechanisms. Their function is more precisive rather than acting as muscles of strength or power.

Opposition of the thumb needs strong activity not only in the opponens pollicis but also in abductor and flexor pollicis. They combine to give true and strong opposition.

A lesion of the ulnar nerve greatly handicaps the power grip as there is loss of ulnar deviation of fingers with loss of FDP and lumbricals to the ring and little fingers, and flexor carpi ulnaris.

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A lesion of the median nerve produces loss of opposition of the thumb towards the index and middle fingers along with flexion of the index and middle fingers, thus hampering the precision activity of the hand. The wrist extensors offer significant stability to the grasps and should not be overlooked while assessing the hand.

Sensory control

The precision movements of the hand are greatly dependent on the degree of sensory reception from the skin as well as deeper tissues. The presence of enormous number of Meissner's tactile receptive corpuscles and epicritic sensibility give the hand a status of a specialized organ of touch. In the event of a nerve damage and reduced epicritic sensibility, the efficiency of hand function is greatly diminished. The physiotherapist, under such situations, should concentrate on the techniques of sensory re-education, by several repetitions of accurate movements and the use of audiovisual feedback.

Methods of evaluation of the hand

A careful evaluation of the hand function is done by assessing the following:

Range of motion

Goniometric measurement of both active and passive range of motion (ROM) at each joint should be recorded by using a finger goniometer. This will provide quantitative data on ROM and strength at an individual joint. The total motion at each digit is the sum of the flexion measurements of MP, PIP and DIP joint minus the extension deficit (if present) of the same three joints.

Oedema

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Volumetric measurement of water displacement or tape measure can be used. Change in hand size due to oedema or muscle atrophy can be quantified.

Muscle performance

The technique of manual muscle testing (MMT) as designed by Lovett and Martin (1916) can be used to assess muscle strength, and the subsequent changes in the muscle power. Muscle–tendon continuity, gliding capacity of the tendon, neuromuscular communication and volitional control also need to be assessed.

Sensation

Sensory status has to be evaluated carefully as the hand function depends largely on the sensory integration. Finer sensory evaluation has become important after the advent of microsurgery which has improved the return of sensory status. The skin and nails should be examined for temperature, dryness and denervation, and recorded on a body chart.

Tactile cutaneous sensation can be assessed by using horse hair of various thicknesses or nylon filament of 20 different thicknesses (Werner & Omer, 1970).

Static and moving two-point discrimination (2PD) tests are used to evaluate the functional sensibility (Fig. 34-3). Moving 2PD test is reported to be abnormal in patients with peripheral nerve lesion (Dellon et al., 1987). Blunt tip calibrated calliper can be used to discriminate between

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smoothness and toughness.

Perception of vibratory stimuli should be done by using a tuning fork of 256 Hz which is more sensitive. However, these results are useful but not quantifiable.

Dexterity

Dexterity denotes the skill of using a hand. As the test-tools cannot be generalized, they are selected as per the abilities and daily activity needs of a patient. The time taken to complete the broad range of hand functions of vocational or daily activities (Jebsen et al., 1969), functional efficiency and hand coordination can be objectively recorded. The performance of the following tasks helps in the evaluation:

1. Writing
2. Picking up small and large objects
3. Cord turning
4. Eating
5. Dressing
6. Other ADLs
7. Five speedy coordination

Functional sensibility

Identification and differentiation of the shapes of various

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objects by grasping are also important. Seddon's coin test is a useful measure to assess functional sensibility (Seddon, 1975).

Function and physical capacity

Physical capacity of the patient to perform functional activities like various grips, prehensile movements and their strength can be objectively evaluated by hand dynamometer. This will greatly facilitate the specific areas to be emphasized during treatment.

FIG. 34-3 Two-point discrimination test.

Injuries of the hand

Injuries of the hand are broadly classified into the following two categories (Table 34-1):

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1. Closed injuries

2. Open injuries

Table 34-1
Classification of Hand Injuries

Closed Injuries	Open Injuries
• Fractures, dislocations • Dislocations commonly of the MP joint of index finger or thumb (Bennett fracture dislocation) • Fractures of the metacarpals and phalanges by a direct trauma or twisting, may be displaced or undisplaced • Injury to the collateral ligament of the thumb is common	• Fractures of metacarpals and the phalanges • Cuts by sharp instruments • Lacerations • Crush injuries • Amputations • Tendon injuries

Closed injuries

These are usually fractures, dislocations or ligament injuries.

- Dislocations of the MP joints: Dislocation of the MP joint of the index finger is the commonest injury seen while that of the thumb is the second commonest. On clinical examination, the dislocated head of the metacarpal can be palpated on the volar aspect of the palm.

- Bennett fracture dislocation: It is an intra-articular fracture of the base of the first (thumb) metacarpal, with subluxation or dislocation of the carpometacarpal joint (Fig. 34-4) caused by a direct blow to the thumb.

- Fractures of the metacarpals: A fracture of the metacarpal can occur through its neck, shaft or base. Fracture of the neck of the metacarpal is commonly seen in the little finger.

- Fractures of the phalanges: Fractures of the phalanges are caused by direct trauma or twisting injury and can be displaced or undisplaced.

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- Ligament injuries: Injuries of the collateral ligament of the MP joint are usually seen. The most commonly seen injury is that of the ulnar collateral ligament of the thumb, called gamekeeper's thumb.

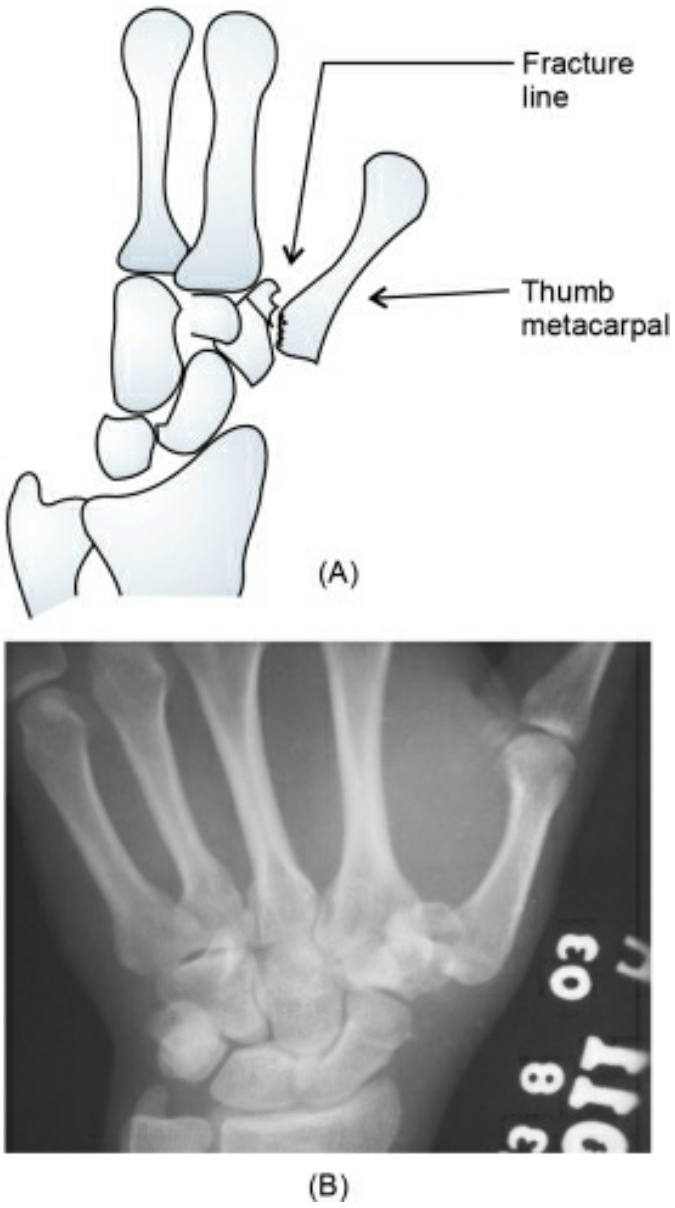

FIG. 34-4 Bennett fracture dislocation. **(A)** Line diagram showing the fracture and the displacement and **(B)** as seen on a radiograph.

Open injuries

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- Fractures of metacarpals and phalanges may be associated with open injuries.
- Cuts and lacerations: Cut wounds are caused by sharp objects/weapons, whereas lacerations are caused by blunt objects.
- Crush injuries are quite common and often serious injuries.
- Amputations of thumb/fingers may also be seen.
- Tendon injuries are common injuries and often missed in the initial examination leading to marked disability.

These injuries are important and are therefore discussed in some detail in the following pages.

During the secondary assessment, a definitive treatment is planned.

Management

Closed injuries management

- Undisplaced fractures are treated conservatively by closed reduction, and immobilization.
- Displaced fractures are treated by manipulation and cast immobilization.
- Displaced fracture is prone to redisplacement (e.g., Bennett fracture dislocation) or grossly displaced fractures are treated by internal fixation by Kirschner wire or mini-screws after open reduction.
- Fractures of the distal phalanx do not require immobilization.

Open injuries management

Open injuries require special aseptic measures to prevent infection – the most common complication of injury to the hand.

Assessment: A thorough assessment of the injury is done in two

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stages:

- Preliminary assessment of the extent of injury is done in the emergency room to plan the tentative line of treatment.
- Secondary assessment is carried out in the OT under anaesthesia when the injury is deep and complicated.

Debridement

Thorough cleaning of the wound is done under GA with irrigation by saline water or sterile water to get rid of foreign bodies, dirt, necrotic tissue, etc. or ligament injuries.

Reduction

In fractures or dislocations, bony stabilization by reduction may be required, preferably done with internal fixation devices.

Nerve repair

It is undertaken earliest in healthy and clean wounds.

Cut tendons: These are already discussed in detail, earlier in this chapter.

Wound closure

Clean wound is closed by primary sutures or else covered by a flap or a skin graft.

Dressing and splinting: A fluffy compressive dressing is applied with cotton wool and gauze pieces. The hand is then immobilized in a POP with MP joints at 90 degrees (*James position*), PIP and IP joints in extension and thumb in abduction and opposition (Fig. 34-5) to reduce the chances of contractures of the ligaments leading to contracture.

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FIG. 34-5 James position of immobilization of the hand.

Treatment of open injuries

The fractures of metacarpals and phalanges are treated by internal fixation and wound repair.

Cuts and lacerations

- Clean wounds: wound suturing is required.
- Contaminated wounds: debridement wound care is required and later on sutures of skin graft if needed.
- Crush injuries: It may be with skin loss – needing wound care or skin grafting.
- Amputations – Amputation of digits is common.
- Fingertip amputation requires full-thickness flap.

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- When good length of stump is available, closure of the stump is done after trimming of the bone ends.

- In the amputation of the thumb, the length of the remaining stump is maximally saved.

- Replantation: It is done only in clean-cut, fresh amputations of less than 6 h duration.

Complications

- Malalignment: Phalangeal fractures may unite with angulation or rotational malalignment.

- Stiffness: It is common at the adjacent interphalangeal joint.

Both complications result in impaired hand function.
Treatment procedures are detailed in Chapter 4.

Basis of physiotherapeutic management

The objective of physiotherapy is to restore both the static and dynamic hand functions to the fullest possible extent with least discomfort.

The anatomical and kinesiological complexities of the hand as well as the pathophysiology and biomechanics of wound healing pose a great challenge in its management. The treatment of hand injuries is based on (i) biology of scar and (ii) anatomical configuration.

Biology of scar: The granulation scar tissue (the body glue) has the ability to imitate and reproduce to the maximum possible extent the characteristics of the damaged tissue. Therefore, the basis of the surgical, pharmacological and therapeutic management depends upon skilful organization of enhancing the potentials of the scar to duplicate the desired outcome (Hardy, 1989).

Anatomical configuration: While treating hand injuries, it must be remembered that even the minimal anatomical changes in the arrangement of bones and soft tissues may have profound effect on

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the function.

Wound healing: The process of wound healing following injury or surgery must be understood clearly to adopt precisive therapy. The wound healing has three phases (Table 34-2):

1. Inflammatory phase (up to 4 days)

2. Fibroplasia phase (5 days to 3 weeks)

3. Remodelling phase (3 weeks to 6 months)

Table 34-2
Wound Healing Stages and Techniques of Management

Healing Phase	Techniques of Management
Phase I: Inflammatory phase (0 to 3–4 days)	• Wound cleaning • Debridement of necrotic tissue • Antibiotics • Good nutrition
Phase II: Fibroplasia phase (day 5 to 3 weeks)	• Elevation • Reduction of inflammation • Slow relaxed passive ROM exercise • Controlled contractions • Gentle active movements for the acceleration of tensile strength
Phase III: Remodelling phase (3–6 weeks)	• Passive mobilization • Dynamic serial splint or casts • Maximum range of active movement (in months or 1 year) with the proper groove • Electrical stimulation to re-educate muscular action, tone and endurance • Controlled functional activities, ROM and (PRE) to regain preinjury status

The techniques of management at each stage of healing are elaborated in Table 34-2.

1. *Inflammatory phase:* The phase of initial inflammation is within the first 4 days after injury. All the injured tissues react with inflammation and cellular proliferation. This results in a single scar, binding all the tissues together. This is known as *one wound one scar concept*. If it is in excess, it leads to excessive joint distension and oedema which results in pain and stiffness. A process of phagocytosis and

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neovascularization occurs during this stage.

Prevention of infection: The basic need of treatment at this stage is prevention of infection. A careful watch has to be kept to detect the signs and symptoms of infection like:

(a) Prolonged swelling

(b) Excessive skin sloughing

(c) Temperature changes

(d) Progressive pain and paraesthesia

The following measures should be taken:

(a) Restrict oedema at the earliest

(b) Reduce pain – TNS, VS

(c) Improve circulation by active movements of the related free joints adjacent to the affected joint

(d) Wound debridement if necessary without delay

(e) Absolute rest and good nutrition

(f) Ensure proper positioning of the affected area to avoid any stress, and to assist circulation

2. *Fibroplasia phase (5 day to 3 weeks):* It begins with the production of primary cells of scar tissue – the fibroblasts. While the wound contraction is progressing, the tropocollagen molecules are synthesized by the excretion of fibroblasts and balanced supplies of

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oxygen, ascorbic acid, zinc, iron and copper (fibroblasts).

$$\frac{Zn, Fe, Cu}{O_2, vite} \text{ torpocollagen} \rightarrow \text{collagen} \rightarrow \text{scar}$$

These tropocollagen molecules have three helical chains. They form collagen fibril with microscopic cross-links which imparts tensile strength to the wound. The collagen mass becomes strong enough to withstand controlled motion by 3 weeks (Fig. 34-6).

Steps followed during this phase:

(a) Graduated progressive steps are initiated in a graduated manner.

(b) Controlled passive movements should be started early as they are important to maintain mobility of the repaired tendon (Merritt, 1984).

(c) Active assisted movements should be encouraged to enhance functional control of the repaired tendon. It stimulates further repair and improves strength (Mason & Allen, 1941).

(d) Gentle assistive active movements with controlled contractions are necessary for acceleration of the tensile strength.

(e) Splint: Depending upon the nature of injury and the

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surgery, a proper splint is applied. The splint should decrease undue tension on the repaired tendon, allowing free movements of the remaining joints. Some commonly used splints are described in the following pages.

3. *Remodelling phase (3 weeks to 6 months):* This is the most important phase of management. Collagen realignment has to be organized to prevent cross-linking of collagen. The collagen fibres between the coapted tendon ends must organize in parallel alignment to provide tensile strength. The fibres along the longitudinal surface of the tendon must disorganize in a random orientation to facilitate tendon gliding, thereby preventing adhesions.

Realignment of collagen: As the collagen fibril matures, it forms cross-linking between its own chains (intramolecular) and with other collagen fibrils (intermolecular) (Fig. 34-7). A favourable cross-linking is done by the following theories.

(a) *Induction theory:* It is based on the fact that the scar tissue attempts to develop the characteristics of the tissue it is healing, e.g., a tissue which is dense will induce dense and highly cross-linked scar tissue. Therefore, if a tendon repair is postponed and immobilization is done following a fracture, bony adhesion and nongliding tendon will result. This occurs due to wrong modelling of the scar into a dense tissue with higher degree of cross-linking. The scar will attempt to imbibe the characteristics of the bone. This highlights the importance of early tendon repair to reduce the incidence of stiff joints following immobilization.

(b) *Tension theory:* During this phase, application of stress

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or tension is successful in achieving lengthening of a scar.

This has revolutionized the whole concept of management. Long-duration stress or tension can be applied by

i. Dynamic serial splinting

ii. Casting

iii. Application of heat with stretch

iv. Relaxed gradual passive mobilization

v. Active mobilization to the maximum range in the correct groove of movement

vi. Electrical stimulation to be used to re-educate muscle actions, and to improve their strength, endurance and tone

vii. Selective hand activities with proper guidance: Besides remodelling, tension has been found useful in the regeneration of nerves (Bora, Richardson, & Black, 1980)

The low-load tension, to be effective, has to be controlled and retained. The beneficial effects of controlled tension and mobilization are as follows:

i. Hastens intrinsic healing

ii. Promotes synovial diffusion

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iii. Augments repair site cellularity

iv. Improves tensile strength

v. Increases peritendinous vessel density and configuration

vi. Improves tendon excursion

vii. Facilitates nerve regeneration

viii. Prevents shortening, obstructions and developing contractures

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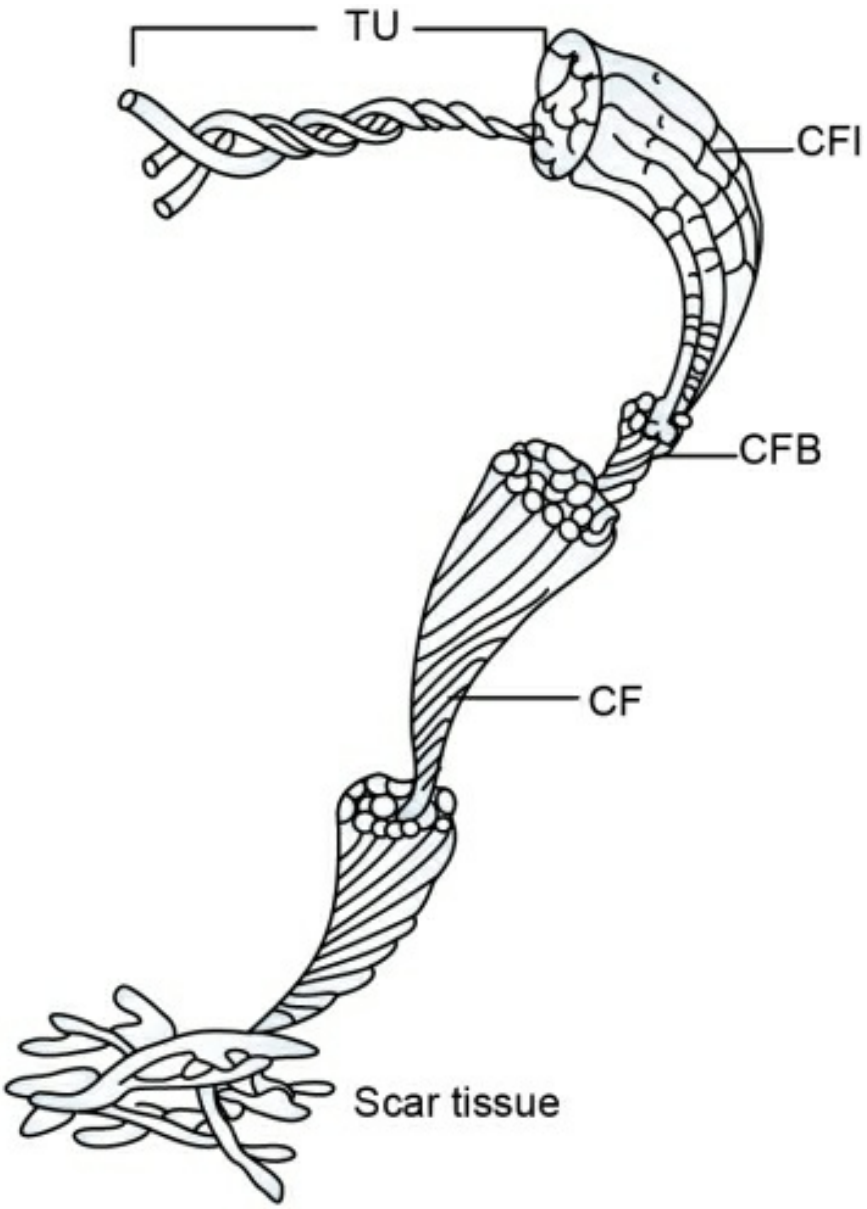

FIG. 34-6 Fibroplasia phase (day 5–3 weeks) synthesis of tropocollagen molecule. CF, collagen fibres; CFB, collagen fibril; CFI, collagen filament; TU, tropocollagen unit.

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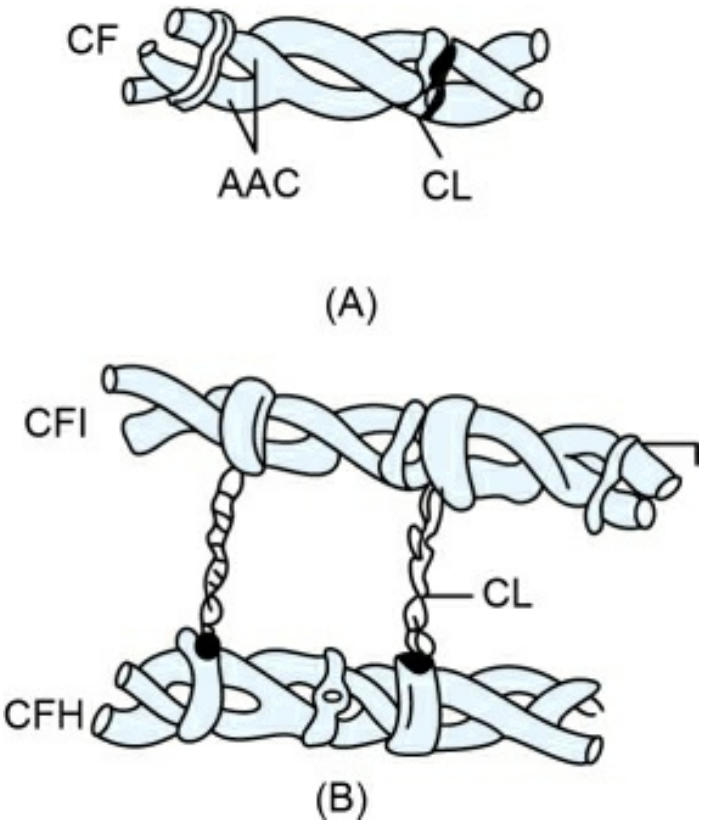

FIG. 34-7 **(A)** Intramolecular cross-linking amino acid chain (AAC) from weak cross-linking (CL) in a single collagen filament (CF). **(B)** Intermolecular strong cross-linking (CL) between one collagen filament (CFI) with an other collagen filament (CFI).

If proper measures are taken to control this stage, optimal restoration of the hand is possible. Methodology varies with the seat of tendon repair and is elaborated under each heading.

Caution

The tension to be applied to the repaired tendon as well as to other scar tissues has to be precise in direction and magnitude. A stronger stress leads to disruption of the tissue repair.

Hand splints

Splints are basically of two types:

1. Static splints

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2. Dynamic splints

Static splints provide rest and stability (e.g., following fracture or acute inflammation).

Dynamic splints assist and guide movement in its proper groove (movement re-education) and even resist and strengthen weak movement.

Splinting materials

1. *High-temperature plastics*: These require mould for fabrication.

2. *Low-temperature plastics*: These are very common, cosmetically acceptable, light material and easy to fabricate; orthoplast, aquaplast and polyform are some of the commonly used materials.

3. *Materials which do not need any heating*, e.g., a material like plaster of Paris: It can be used alone as a static splint or in combination with an outrigger as dynamic digital splint providing traction.

The splint strapping material should be firm, comfortable, pressure controlled and with well-secured strapping. Velcro straps are ideal.

Functions of a static splint

1. It provides protective immobilization to the joint. It is instrumental in supporting and providing rest to the acutely inflamed joints following injury or disease (e.g., soft tissue injury, fracture, rheumatoid arthritis, burns).

2. It aids in the resolution of inflammation, thereby hastening the process of repair.

3. It maintains joints in correct alignment preventing tightness, contractures and deformity.

4. It provides stability and support to lax joints.

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5. It maintains the corrected or improved ROM gained by therapeutic measures.

6. It can provide stability to a proximal joint (when it is unstable) to facilitate the action of the distal joint, e.g., cock-up splint to stabilize the weak wrist extension and to facilitate finger flexion.

7. It corrects the deformity by graduated progressive stretching (e.g., serial splinting).

Functions of a dynamic splint

1. The most important function of a dynamic hand splint is to provide the necessary constant low stretch to facilitate correct remodelling of the scar tissue. The calculated stretch is applied by sling and rubber band. Therefore, it acts as a valuable therapeutic adjunct.

2. It can provide controlled resistance to the tendons for easy gliding, preventing adhesions and stimulating circulation thereby assisting in reducing oedema.

3. It provides mobility to the stiff joints by controlled sustained low load stretching. Constant stretch lengthens the shortened musculotendinous units and the tight articular structures as well.

4. It provides re-education to the weak or paralysed muscles with synchronization of active efforts, e.g., extension deficiency following radial nerve lesion or in silastic implants following MCP joint reconstruction (Fig. 34-8).

5. It protects overstretching of the weak muscles by the strong pull of normal opposing muscle groups.

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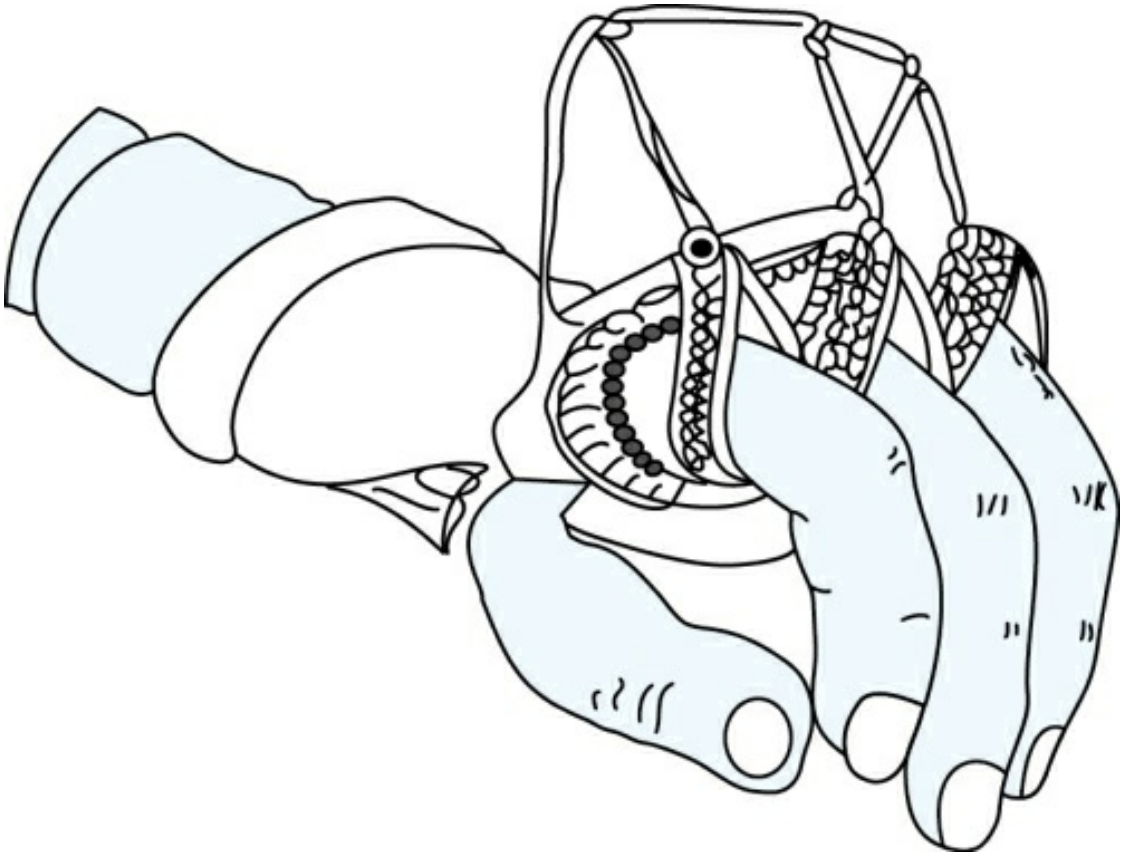

FIG. 34-8 Dorsal dynamic extension assist splint following radial nerve palsy or following MCP silastic implant arthroplasty.

Biomechanical principles (duncan, 1989)

A majority of hand splints work on the principle of three-point pressure and belong to the class I of the lever system. The mechanical advantage (MA) is equal to the ratio of the length of the forearm (FA) and that of the resistance arm (RA), i.e.,

$$MA = FA/RA$$

Therefore, an increase in the length of the forearm or a decrease in the length of the resistance arm will provide maximum mechanical advantage of the lever. The proximal and distal ends of the splint serve as counter forces to the opposing central force. Correct balance

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of the forces is necessary for any splint.

To decrease the compression and distraction of a joint, the rotational force has to be maximum. This is achieved at the position of 90 degrees.

While applying sustained pressure in the dynamic splint, the principle of F = F/A has to be remembered. Thus, the greater the width of the finger sling, the lower will be the pressure at the point of its application.

The dynamic splint can be low profile or high profile. The basic difference between the low-profile splint and the high-profile dynamic splint is the role of the outrigger. In a low-profile splint, the outrigger is not attached to the rubber band. It exerts a steady low load stretching effect, e.g., stiff joint. In a high-profile dynamic splint, the outrigger is attached to a rubber band facilitating weak movement and resisting the strong one. Besides these major hand splints, the upper extremity may need the following splints.

Static splints

1. *Anti–swan neck splint*: It is a simple splint that may be fabricated by using plastic material. It prevents hyperextension at the PIP joint (Fig. 34-9).

2. *Antiboutonniere splint*: It is reverse of the anti–swan neck splint (Fig. 34-10).

3. *Opponens splint*: This splint maintains the web space of the thumb, thus holding the thumb in maximum opposition (Fig. 34-11).

4. *Safe position splint*: It is mainly a resting or positioning splint. The wrist is fixed in slight dorsiflexion (30 degrees), MP joints in 90 degrees of flexion, PIP and DIP joints in neutral extension and thumb is placed in abduction and opposition to allow ROM at the CMC joint (Fig. 34-12). The hand is safe from developing flexion contractures and it promotes functional use at a later stage. This is useful to prevent contractures following burns.

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5. *Factional position splint*: It is very similar to the safe position splint, the only difference being that the flexion at the MP and PIP joints is fixed at 40–50 degrees and the thumb in abduction and opposition to facilitate the functional activity.

6. *Wrist cock-up splint*: A common splint which maintains the wrist in a functional position of 25–30 degrees of extension (Fig. 34-13). In cases of lack of extension control at the MP joints, outriggers may be applied to make it dynamic, e.g., radial nerve palsy.

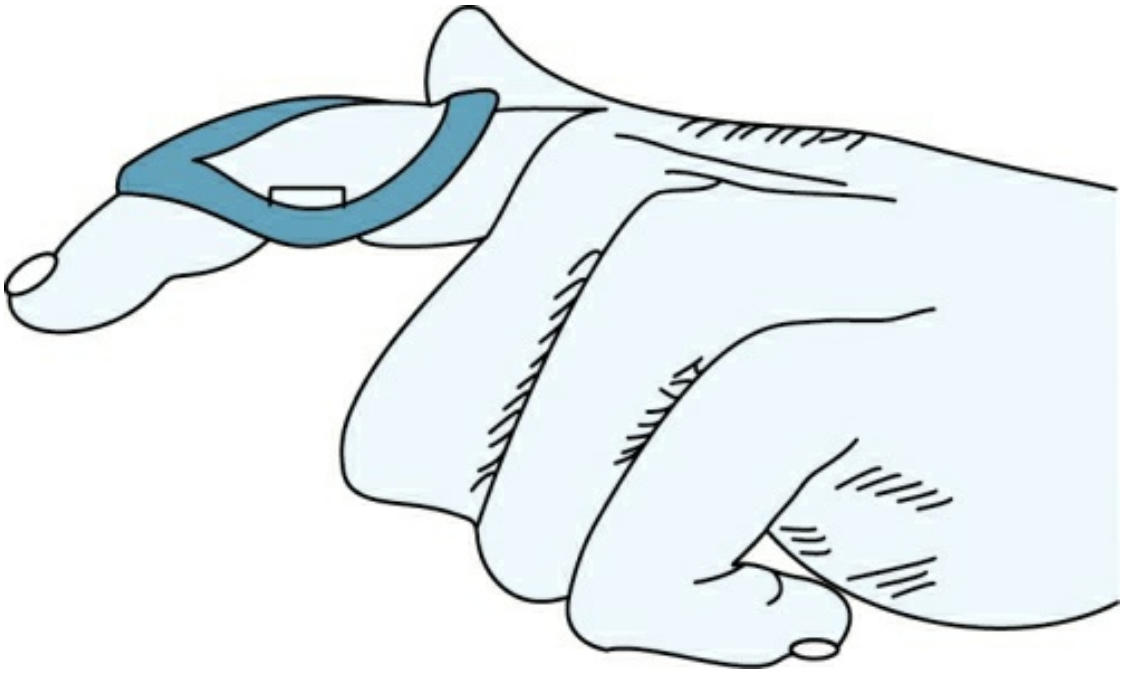

FIG. 34-9 Anti–swan neck splint: to prevent hyperextension at the PIP joint.

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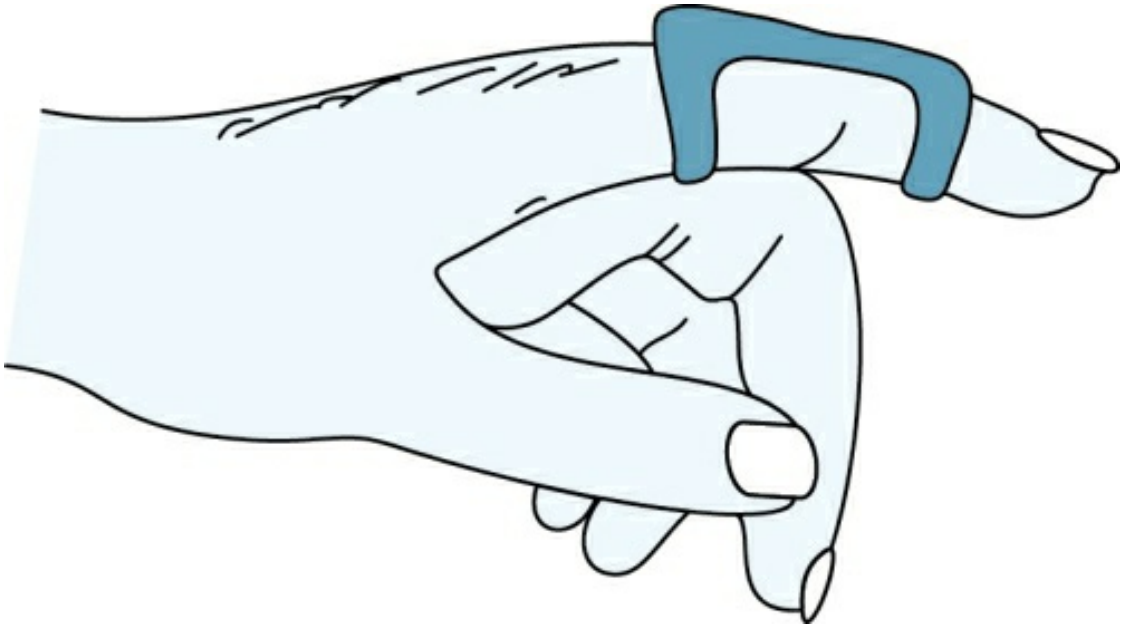

FIG. 34-10 Antiboutonniere splint: to prevent flexion at the PIP joint.

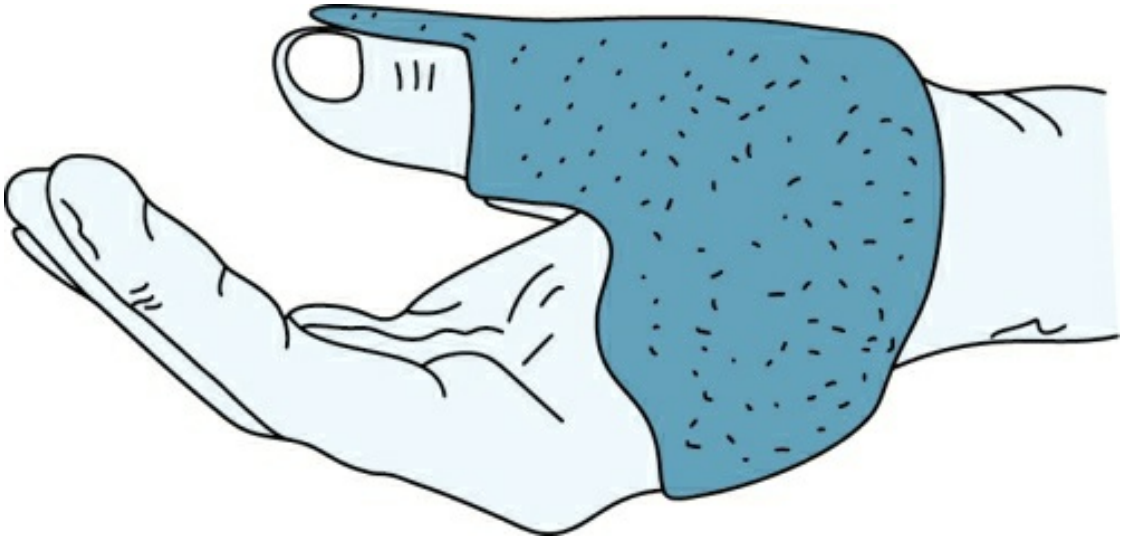

FIG. 34-11 Opponens splint.

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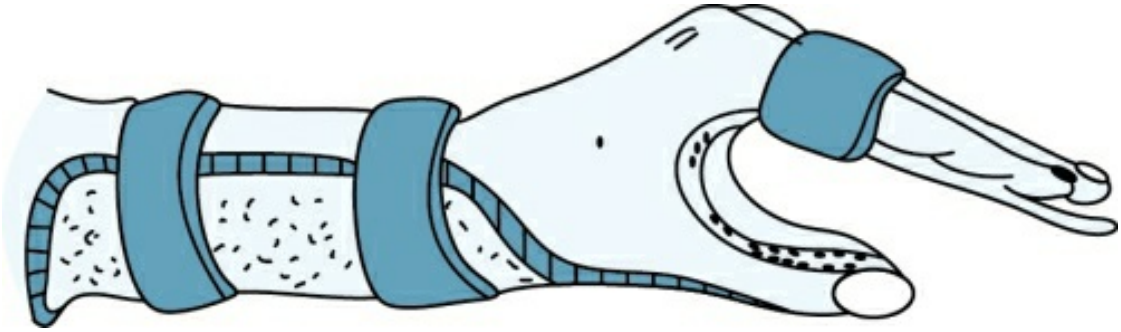

FIG. 34-12 Safe position splint: wrist is fixed in slight extension, MP joints in 90 degrees of flexion, PIP and DIP joints in neutral and thumb in abduction and opposition.

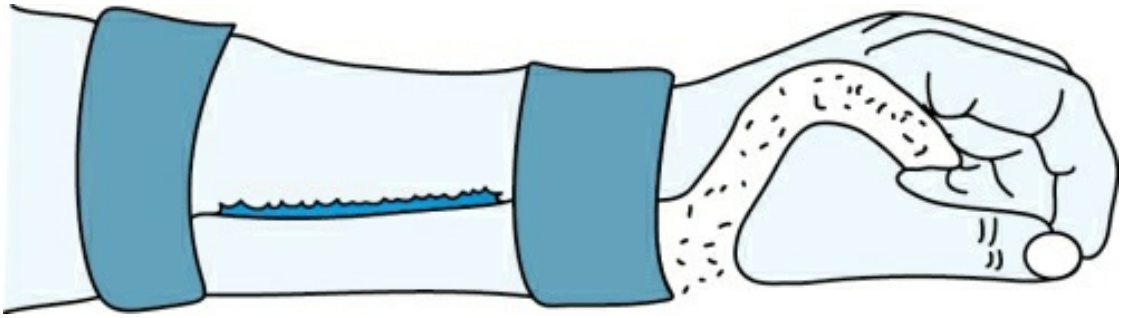

FIG. 34-13 Wrist cock-up splint: with wrist joint in functional position of 25–30 degrees of extension.

Dynamic splints

1. *Dynamic wrist flexion–extension splint*: It allows both the movements of flexion and extension at the wrist with a provision to maintain any of these movements fixed at a desired range. It can be made either low profile or high profile as per the need by adjusting the outrigger. It is advised after flexor or extensor tendon repair or after wrist arthroplasty to assist wrist ROM.

2. *Metacarpophalangeal joint flexion–extension splint*: This splint can be assistive as well as resistive to the movements of flexion or extension or both, depending upon the purpose. This is provided by effective pull of the outrigger applied at the proximal phalanges and adjusted

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at an angle of 90 degrees. It is advised after MCP arthroplasty or following soft tissue injury or extensor tendon repair (Fig. 34-14).

3. *Proximal interphalangeal joint flexion–extension splint*: To localize movements at the proximal interphalangeal joint, immobilization of the proximal phalanx is necessary (Fig. 34-15). The outrigger rubber band is adjusted to provide dynamic assistance and controlled resistance to the middle phalanx, as per the needs. This splint is advised after PIP joint arthroplasty or as a low-profile splint following flexor or extensor tendon repair.

4. *Finger trapper or buddy system splint*: This is a simple but unique dynamic splint which uses the active force of one digit to mobilize the joints of the adjacent digit. This is advised as an assistive therapeutic device to improve the ROM. It is used following soft tissue injury, joint pathology, fracture of the phalanx or in 'pain anxious' patients (Fig. 34-16).

5. *Dynamic thumb splint*: A dynamic thumb splint can be fabricated as a low-profile splint which keeps the thumb in opposition, maintaining the web space. It can be devised to mobilize MCP or IP joints of the thumb by properly adjusting the outrigger with a rubber band.

6. Specially fabricated controlled movement dynamic splints (see Fig. 34-22).

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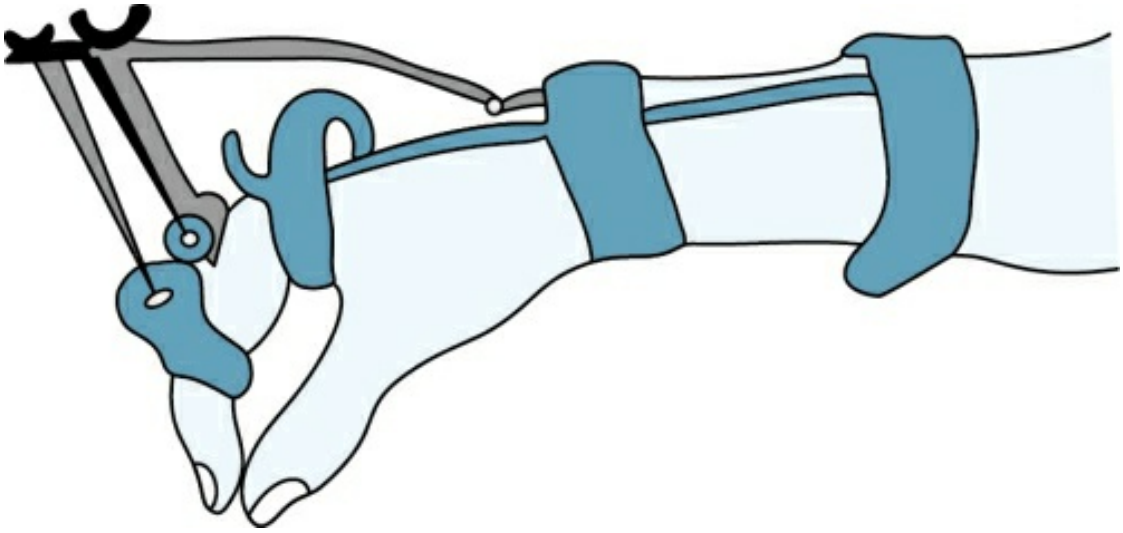

FIG. 34-14 Dynamic MCP flexion/extension splint with outriggers.

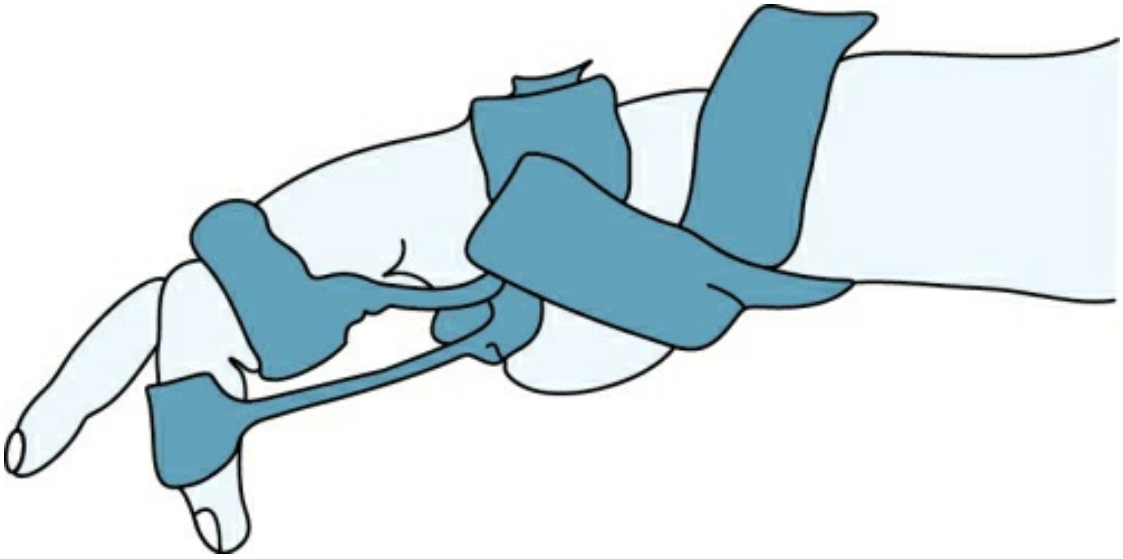

FIG. 34-15 Dynamic PIP flexion–extension splint.

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FIG. 34-16 Buddy splint in the treatment of fracture of the phalanx.

Lower extremity dynamic splints

Various types of orthoses like knee-foot-orthosis (KFO) and ankle-foot-orthosis (AFO) are used to facilitate ambulation and functional activities.

Common lower extremity splints

Static splints

1. Thomas static splint for lower extremity immobilization

2. Posterior knee splint to rest and maintain the knee in optimal position

3. Splint to prevent contracture, known as posterior splint. It can be made of POP cast

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Dynamic splints

1. AFO (Fig. 34-17)

2. Toe pick-up orthosis

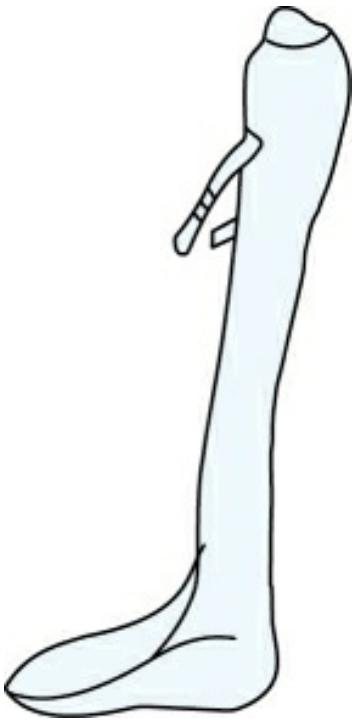

FIG. 34-17 Ankle-foot-orthosis (AFO).

Tendon injuries

A tendon is an important structure in the hand. Its basic function is to transmit the tension developed by muscle. The muscle can thus act, through the tendon, from a distance without increasing its bulk on the joint. Its action is concentrated on a small area of bone and can be applied to several joints.

Tendons have a great tensile strength. A tendon can elongate up to 10–15% of its original length. A force more than four times the greatest isometric tension causes rupture of the tendon.

The tendon also protects the muscle during an unexpected strain by

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the buffer action of its elasticity. The elastic fibres in the tendon have a protective function by causing a gradual increase in tension, thus absorbing the shock of contraction.

Injuries of a tendon result in loss of function of the involved finger/thumb. A tendon rupture may occur in a closed injury or an open injury or a penetrating injury. These injuries result from domestic, agricultural or industrial accidents.

Tendon injuries will be discussed under the following headings:

A. Injuries of the flexor tendons

B. Injuries of the extensor tendons

Injuries of the flexor tendons

Applied anatomy of the flexor tendons (fig. 34-18)

Except thumb, each finger has two flexor tendons:

- Flexor digitorum superficialis (FDS)
- Flexor digitorum profundus (FDP)

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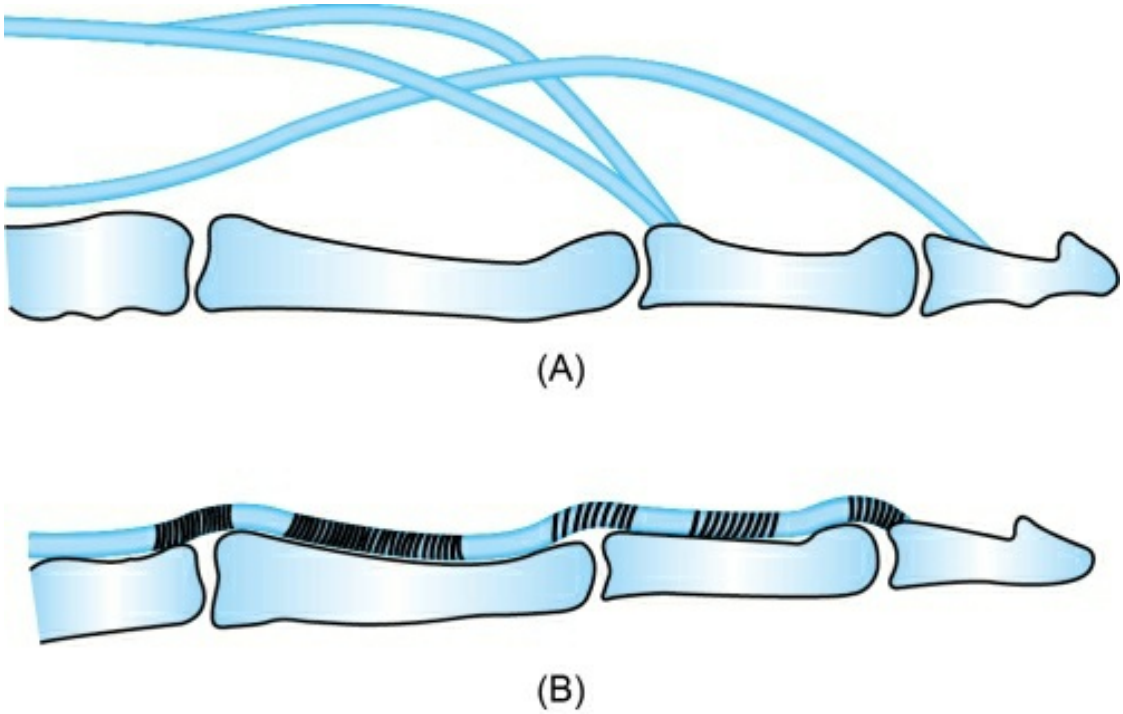

FIG. 34-18 Diagrammatic representation of the anatomy of flexor tendons. **(A)** The tendon of FDS dicussates to form a chiasma through which passes the tendon of FDP. **(B)** Both the tendons are held together close to the bones with the help of multiple pulleys.

Of these, FDS is superficial and divides into two slips before getting inserted into the base of the middle phalanx on the volar aspect.

The FDP, a deeper tendon, passes through the divided tendons of FDS and gets inserted into the base of the distal phalanx. This complex arrangement of the tendons complicates the treatment of these injuries; also these injuries are more common, most disabling and often missed in the early stage.

- Injuries to the flexor tendons are much more common.
- Occasionally, old healed scars over the hand or the wrist could be the cause of a tendon injury.

Muscular action

The FDS flexes the proximal interphalangeal joint (Fig. 34-19A),

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whereas FDP flexes the distal interphalangeal joint (Fig. 34-19A and B).

(A)

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(B)

FIG. 34-19 **(A)** Test for the action of flexor digitorum superficialis tendon. **(B)** Test for the action of flexor digitorum profundus tendon.

Diagnosis

On attempted active performance of the FDP, the affected digit assumes an extended position at rest as compared to the other three digits which, at rest, remain slightly flexed at the interphalangeal joints.

The flexor tendons lie superficial in the palm as well as in the digits. Therefore, any cuts or wounds over the volar aspect of the hand and the wrist must be carefully examined for possible injury to the flexor tendons.

Treatment

The treatment of flexor tendon injuries depends upon the following factors:

1. ***Site of injury***

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For the purposes of treatment, the palmar aspect of the hand is divided into five arbitrary zones (Fig. 34-20). The treatment of a cut tendon varies in each zone.

Zone I: It extends from the tip of the finger to the middle of the middle phalanx and contains the tendon of FDP only.

Cut injuries to the profundus tendon in this zone are rare and, moreover, do not pose much problems since the flexor digitorium sublimis tendon is intact and flexion at the PIP joint is normal. Tenodesis of the DIP joint using the distal end of the cut FDP tendon is performed without disturbing the FDS tendon. Instead, one can do the arthrodesis of the DIP joint. Alternatively, free tendon grafting can also be done.

Zone II: This zone extends from the middle of the middle phalanx to the distal palmar crease.

Also called *no man's land*, this area has maximum number of pulleys which normally prevent bowstringing of tendons during flexion of the digit.

Zone III: It extends from the distal palmar crease to the distal margin of the flexor retinaculum. Also called the *lumbrical zone*, the cut tendons in this zone are sutured primarily; however, some surgeons prefer to suture the profundus tendon alone to avoid adhesions with the sublimis tendon suture line.

Zone IV: This zone lies under the flexor retinaculum, under the carpal tunnel. Both the flexor tendons can be sutured

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primarily in this zone. Some surgeons, however, prefer a secondary tendon graft to prevent crowding and subsequent carpal tunnel syndrome.

Zone V: This zone is proximal to the wrist creases. Generally, multiple tendons and nerves (median and/or ulnar) are cut. All the tendons can be sutured primarily in this zone.

2. ***Duration of injury (i.e., whether a fresh or old injury)***

(a) Fresh noncontaminated tendon injuries in zones I, III and IV can be treated by primary tendon repair (suturing):

Zone II injuries: Primary repair by suturing is done only on the FDP tendon; simultaneous suturing of both FDP and FDS within the flexor tendon sheath can result in adhesions with loss of movements.

Or, first both the cut tendons are excised and a free tendon graft is done to replace only the FDP tendon.

Zone V injuries: Although multiple involving tendons and nerves can be treated by primary suturing.

(b) In old injuries a procedure of two-stage grafting is adopted to overcome the hazards of fibrosis at the tendon bed due to excessive tissue damage.

In the first stage of this procedure, a silastic smooth rod is placed in the tendon bed and pulleys reconstructed, if necessary. The wound is closed. Gradually, a thin sheath of fibrous tissue forms around the silastic rod which acts as

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the tendon sheath. Three months later a free tendon graft is attached to one end of the silastic rod and the rod is pulled out of the digit from the other end. Thus, the free tendon graft replaces the silastic rod in the fibrous sheath.

3. ***Condition of the wound***

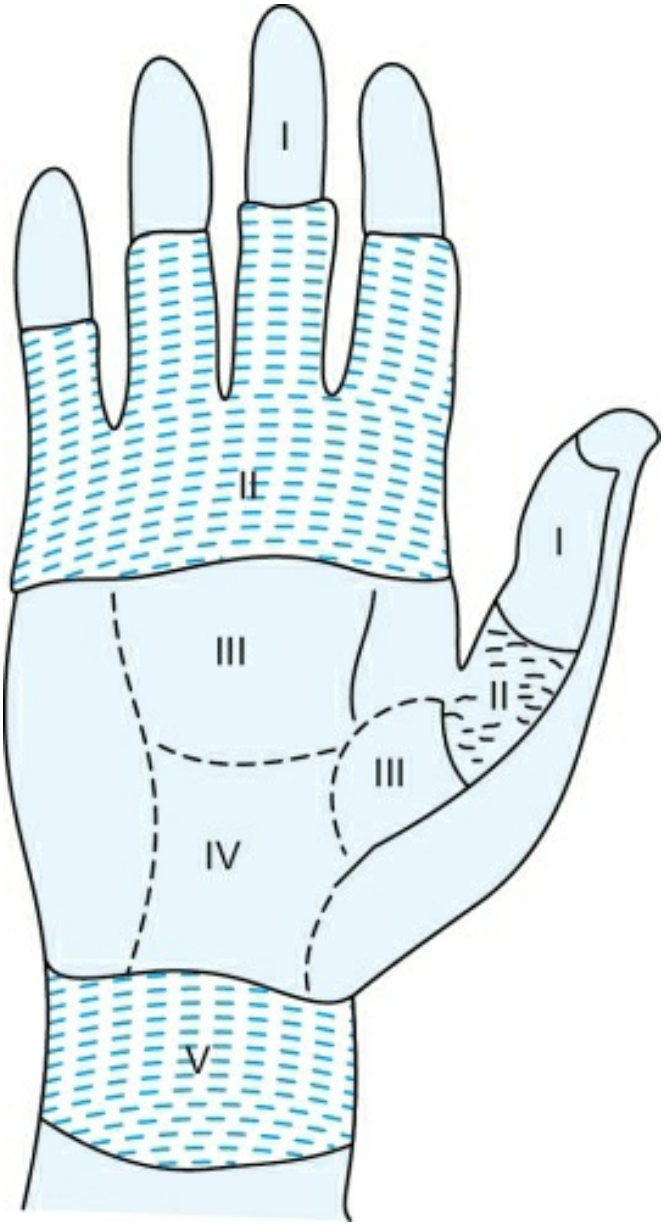

FIG. 34-20 Five arbitrary flexor tendon zones.

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In fresh injuries, if it is a clean-cut wound, not contaminated with dirt, etc., primary repair/graft can be undertaken, whereas in cases where the wound is contaminated with crushing of the surrounding soft tissues, the repair/graft of the tendon is not undertaken. The wound is dealt with first and the tendon reconstruction is left for a later date.

Surgical approach of treatment

- *Primary repair:* Primary repair is indicated in clean-cut, fresh wounds.
- *Secondary repair:* It is usually required in patients reporting late, with severe injury including skin loss and wound contamination.
- *Tendon transplant:* It is done after failure of previous treatment. Normally functioning tendons should be used for the transplant.
- *Tendon graft:* It is done in severe injury resulting in tendon loss. Donor tendon is carefully selected to perform grafting, e.g., palmaris longus and long toe extensor.
- *Old tendon injury:* The grating procedure is conducted in two stages:
- Stage 1: Siliastic rod is placed in the tendon and pulley reconstruction is conducted. Slowly a fibrous sheath develops over the siliastic rod.
- Stage 2: After 3–4 months, a free tendon graft is placed in the sheath after removing the rod. Postoperatively, the hand is immobilized in Jones position with a dorsal slab for 3 weeks.

Postoperative regime

A POP dorsal slab is applied for 3 weeks with the wrist and MCP

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joints in 30 degrees flexion. Elastic traction is applied through finger nails to keep the finger in flexion. The elastic traction, however, may not be necessary in children.

Flexion at the MCP and IP joints is started after about 5 days.

Physiotherapeutic management

The healing process of tendon injury, whether treated surgically or conservatively, follows three distinct phases of wound healing (as described earlier). Therefore, the standard basic principles of physiotherapy must be observed meticulously during all three stages of wound healing.

During the phase of inflammation, physiotherapy is directed towards the following:

- Reduction of pain and oedema
- Prevention of infection
- Ensuring correct positioning of immobilization to facilitate a single fibrous scar formation
- Improving circulation

During the phase of fibroplasia: Controlled movements or protected early mobilization is initiated to maintain balance between immobilization and mobilization. This helps in the following:

- Preventing adhesions (contracture) and stiffness of the concerned joint
- Imparting tensile strength to the repaired tendon and scar
- Accelerating gliding of the repaired tendon with alternate relaxation and stress with appropriate dynamic splint

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During the phase of remodelling: During this phase, the cross-linking of collagen molecule begins. Collagen fibres between the co-opted tendon ends must organize in parallel alignment to improve tensile strength, wherea s collagen fibres along the longitudinal surface of the tendon should disorganize in a random orientation to facilitate tendon glide further, controlled movements avoid peritendinous scarring through maximal gliding, thus reducing adhesion formation (Strickland and Glogovac, 1980). The exercise programme is oriented

- To further improve the tensile strength of the repaired tendon by aiming at accurate remodelling of the healing tendons.

- To intensify active and passive mobilization for furthering the range of joint motion, strength and endurance of the repaired tendon.

- To bring functional restoration of the hand to the fullest extent by introducing graded functional activities.

It is important to note the differences between the flexor and extensor tendons for successful management.

The process of repair in flexor tendons is more rapid than in extensor tendons due to the presence of synovial sheath in the flexor tendons which provides synovial fluid nutrition, whereas extensor tendon mechanism is extrasynovial.

The anatomical disposition and the strength difference between the flexor and extensor groups should always be remembered and taken care of during the management. Swan-neck deformity, Boutonniere deformity, mallet finger or extensor lag needs careful monitoring.

Controlled mobilization with absolute precision in the postoperative phase is the basis of restoration of hand function (Table 34-3).

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Table 34-3

Postoperative Controlled Movement Procedures Following Flexor and Extensor Tendon Repair

Postoperative Period	Controlled Movement Procedures
Day 4 to 2 weeks	Therapist-assisted passive flexion and extension movements
Weeks 3 and 4	Active movement to the antagonistic muscle groups of the repaired tendon against the resistance provided by the rubber band of the dynamic splint
Weeks 5 and 6	Active movements, both flexion and extension, with proper stabilization
Weeks 7–12	Terminal ROM, strength and endurance exercise; functional movements, progressing to power grips

Preoperative evaluation for injuries to the flexor and extensor tendons

- Thorough evaluation of the hand is done.
- The complete restorative programme is explained to the patient.
- The exercise programme is demonstrated on the contralateral normal hand.
- Fabrication of the dynamic splint is done.

Flexor tendon management (table 34-4)

During the phase of immobilization (1–3 days): The aim is to reduce inflammation and pain, improve circulation, prevent infection and ensure proper positioning of the repaired tendon to augment healing without any stress.

- Pain is controlled by diapulse, TENS or any other suitable modality.
- Oedema is controlled by vigorous movements to the adjacent joints and the whole extremity, limb elevation,

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retrograde massage and compressive dressing or cryotherapy during the first 48 h.

- Circulation to the operated area is improved by active movements to the adjacent digits, initially as small-range relaxed passive movements, as the patient is apprehensive.

- Wound examination and proper wound care are of vital importance to prevent infection.

Table 34-4

Specific Physiotherapy Measures at Various Periods of Healing Following Flexor Tendon Repair

Period Following Tendon Repair	Objective
Inflammatory phase: days 1–4	• Rest in optimal relaxed position (hand splint), measures to prevent infection and formation of a single scar
	• Measures to reduce inflammation, pain and oedema
	• Measures to improve circulation
Fibroplasia phase: day 4 to 3 weeks	• A specially designed dynamic dorsal splint is given
	• Controlled passive mobilization is given to maximum ROM twice a day
	• It prevents tendon from getting adhered. Imparts and improves tensile strength of the healing tendon
	• Provides direction and guidance for remodelling and gliding of the repaired tendon, preventing malalignment of newly laid collagen
Early remodelling phase: weeks 3 and 4 (early)	• Active resistive extension against the resistance of a rubber band is encouraged, may be with required minimal manual assistance if necessary
	• It helps in correct early laying of intramolecular and intermolecular collagen
	• Allows extreme range for tendon guide along with inducing relaxation to the repaired tendon
	• By the end of 4 weeks, complete active extension of the joint should be restored
	(Test for the presence of extensor lag, if present, teach assisted active exercise)
Late remodelling phase: weeks 5–6 (late or final collagen remodelling stage)	• Terminal stage of collagen remodelling
	• Active full-ROM flexion and extension should be restored • Strengthening flexion–extension in full ROM furthers the tensile strength of now matured collagen
Final restorative phase: 7–12 weeks and further (if needed)	• Introduce and quickly progress functional use • Increase vigourosity of all the types of exercise to achieve full

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	pain-free function including power as well as other grips • Ensure the full return of the strength and extreme range of flexion as well as extension

Caution

Use of heat or hydrotherapy (whirlpool) may increase pain and hence is contraindicated.

Controlled mobilization (day 4 to 2 weeks): Precisely controlled modes of mobilization techniques form the basis of physiotherapy.

- The patient is provided with flexion assist dorsal plaster of Paris or thermostatic material dynamic splint (Fig. 34-21) extending from the proximal forearm to beyond the fingertips (Kleinert, Kutz & Cohen, 1975). The wrist is positioned in 30–45 degrees of flexion with the MP joints in 0–20 degrees of flexion. This puts the repaired tendon in ideal healing position. A rubber band connects the nail loop to the wrist, which keeps the finger of the repaired tendon in flexion, permitting resistive extension (Fig. 34-22). Earley and Milward (1982) modified this dorsal splint by using dorsal extension to the repaired digit only, thus allowing freedom of movement to other digits.

- The standard basic principles of physiotherapy must be observed meticulously during all three stages of wound healing.

- Graduated passive flexion and extension of the PIP and DIP joints of the involved digit are carefully carried out twice a day. PIP and DIP extension is done only with simultaneous flexion of MP joints. Flexion of PIP and DIP joints is done only after maintaining MP joints in flexion to prevent overstretching of the repaired tendon.

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- Active extension is encouraged against the resistance provided by rubber band within the confines of the splint. This resistive extension induces reciprocal relaxation of the digital flexors, besides providing graduated tension to the remodelling of scar of the repaired tendon.

- It also facilitates tendon gliding by preventing adhesions.

- This dynamic dorsal splint needs to be worn for 24 h for a period of 4 weeks.

- Graduated range of active flexion of the digits is initiated with guidance, retaining the dorsal splint.

Weeks 3 and 4:

- Assisted exercises are discontinued, unless the patient has developed an extension lag.

- Complete active extension of the IP joint should be restored during this period.

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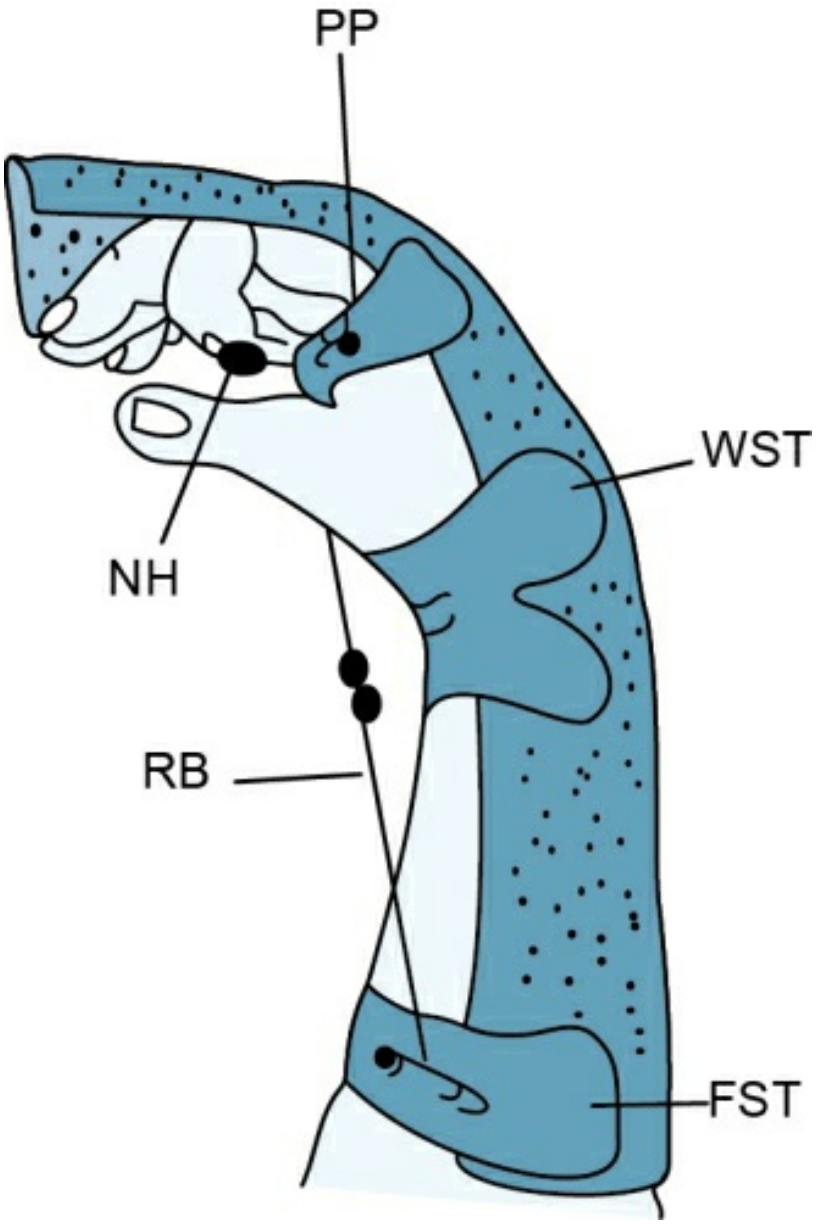

FIG. 34-21 Flexion assist dorsal splint with palmar pulley system, provides elastic traction to the tendon in the direction of flexion by a rubber band. NH, nail hook; PP, palmar pulley; WST, wrist strap; RB, rubber band; FST, forearm strap.

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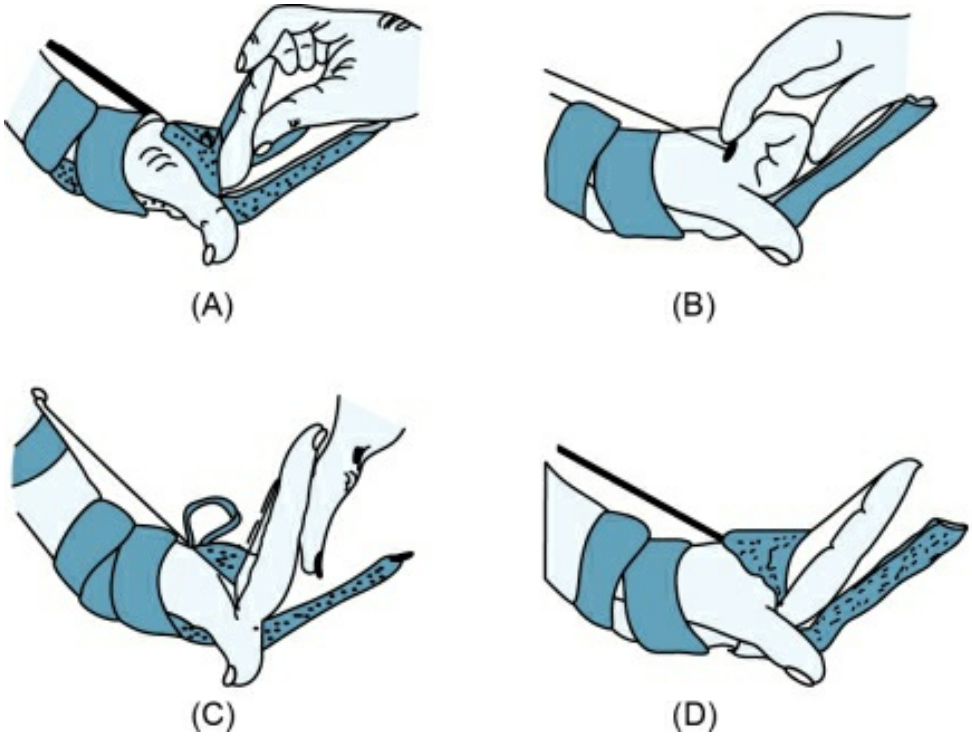

FIG. 34-22 Controlled mobilization of the repaired flexor tendon. **(A)** Passive full-range flexion and extensions of the PIP and DIP joints. **(B)** Passive full-range flexion and flexion of the PIP and DIP joints. **(C)** Active full-range extension by detaching nylon band and attaching rubber band. **(D)** Active band resistive extension against rubber band.

Caution

Simultaneous extension of the wrist, MCP and IP joints should never be attempted.

Weeks 5 and 6:

- Rubber band traction is removed and the exercises are intensified to regain maximum active range of flexion.
- Self-assisted full-ROM simultaneous passive flexion at the MC, PIP and DIP joints is guided by using the normal hand.
- If near-normal range of active flexion is restored,

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sustenance of the digit in the position of maximal flexion is introduced.

- Graded resistance to flexion is initiated.
- Light activities can be introduced carefully.

Weeks 7–12:

- All the modes of exercises are made vigorous.
- Isolated blocking exercises to encourage active isolated flexion of the PIP and DIP joints should be initiated.
- Deep friction massage may be necessary over the scar, if there is a tendency for scar adhesions.
- Functional use of the hand including power flexion activities are introduced gradually.
- All the movements are allowed without splint.
- Full function should be restored in the repaired digit by 12 weeks.

Controlled mobilization steps following flexor tendon repair:

Step 1. Days 4–15: Passive flexion and extension assisted

Step 2. By 21 days: Active resistive extension against the rubber bands

Step 3. By 6 weeks: Active flexion and extension of fingers initiated

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Step 4. By 7–12 weeks: Exercises to strengthen terminal ROM to restore strong power grip

Step 5. By 12 weeks: Return of full hand function and that of the repaired tendon

Injuries of the extensor tendons

These can occur anywhere between the fingertip and dorsum of the forearm.

Diagnosis

Injury to the extensor tendon can be diagnosed by the patient's inability to extend the finger actively even after stabilization of the MP joints, following an injury to the dorsum of the hand.

The extensor tendons in the hand are arbitrarily divided into the following eight zones (Fig. 34-23):

- Zone I – DIP joint
- Zone II – Middle phalanx
- Zone III – PIP joint
- Zone IV – Proximal phalanx
- Zone V – MP joint
- Zone VI – Dorsum of hand
- Zone VII – Over the wrist joint
- Zone VIII – Distal forearm

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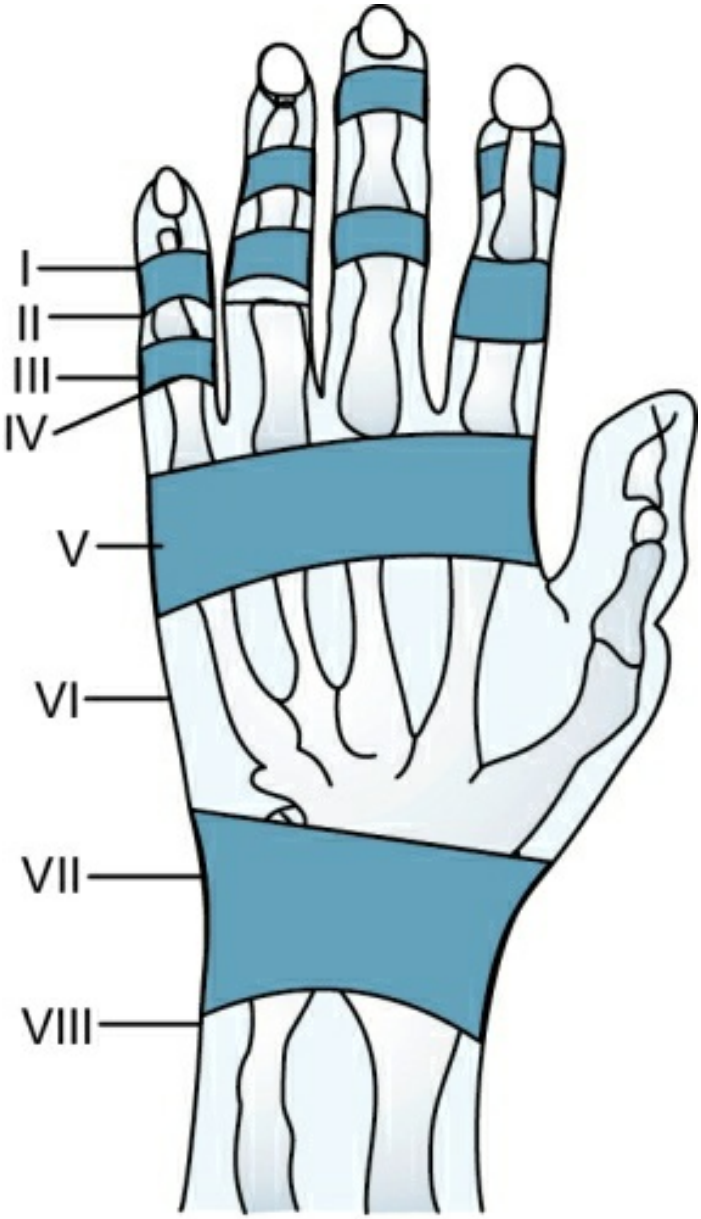

FIG. 34-23 Eight arbitrary extensor tendon zones.

The diagnosis of a cut extensor tendon is easy as the patient cannot actively extend the involved digit. Injuries of the extensor tendons are usually associated with lacerations of the overlying skin or with compound fractures of phalanges and/or metacarpals.

Treatment

A cut tendon in zones I and II results in a mallet finger, which is discussed in Chapter 5.

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Zone III and IV injuries result in a Boutonniere deformity which is characterized by flexion at the PIP joint and hyperextension at DIP joints (Fig. 34-24). The treatment of a Boutonniere deformity consists of surgical repair of the tendon and immobilization of the corrected finger in a splint for 3–4 weeks postoperatively.

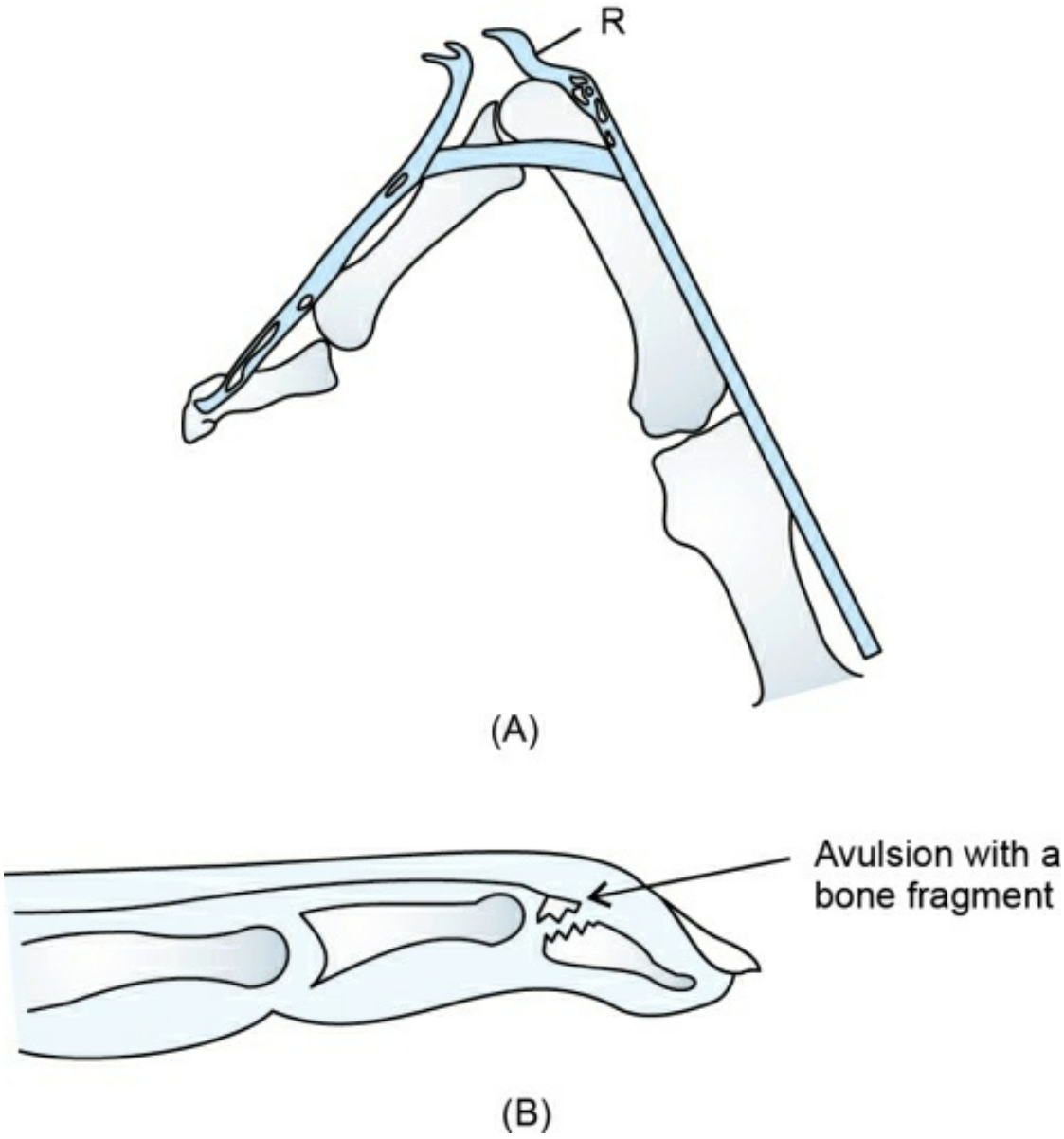

FIG. 34-24 **(A and B)** Boutonniere deformity. R, Rupture of the central slip of extensor tendon.

Zone V–VIII injuries, i.e., over the dorsum of hand and wrist, are

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common and can be treated by the following methods (Table 34-5):

- Fresh injuries (within 3 weeks) can be repaired by tendon suture.
- Old injuries can be treated by one of the following methods:
- Tendon grafting
- Tendon transfer
- Attaching the injured tendon to the adjacent intact digital extensor tendon

Table 34-5

Treatment of Extensor Tendon Injuries by Zones

Zone	Region	Deformity	Treatment
I and II	DIP jointmiddle phalanx	Avulsion of the extensor tendon from the distal phalanx with or without a bony chip (Mallet finger)	• Immobilizing DIP joint in slight hyperextension for 6 weeks • Open reduction and repair if necessary
III and IV	PIP jointproximal phalanx	Avulsion of middle slip of extensor expansion from the base of middle phalanx (Boutonniere deformity) (Fig. 34-24)	• Immobilizing finger straight for 3 weeks • Surgical open reduction repair of the central slip or reattachment of the avulsed tendon and immobilization for 3–4 weeks
V and VIII	MP joint dorsum of hand wrist joint distal forearm		• For fresh injuries of less than 3 weeks: • Direct surgical repair • For late reporting injuries of more than 3 weeks: • Tendon grafting • Tendon transfer or • Attaching injured tendon to the adjacent intact digital extensor tendon

Postoperative regime

A volar plaster slab is applied for 4 weeks with the wrist and finger in extension. Finger mobilization is started after the removal of slab.

Spontaneous rupture of extenor pollicis longus tendon: Following Colles fracture, the tendon of the extensor pollicis longus may get

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frayed over the roughened area of the bone at the site of fracture. The frayed tendon end makes direct end-to-end suture impossible. A tendon transfer procedure is done.

The tendon of the extensor indicis proprius is divided at the level of the neck of the metacarpal and re-routed towards the thumb and sutured to the distal stump of the extensor pollicis longus tendon.

Physiotherapeutic management

Simple laceration injuries treated by surgical repair do not pose complex problems. They can be adequately managed by immobilization of the wrist and digits in extension followed by graded mobilization. Full function returns by 6–8 weeks.

Complex extensor tendon injuries with the involvement of periosteum, adjacent soft tissues or extensor retinaculum invariably result in adherent tendons restricting tendon glide, contracture, joint stiffness or even extensor lag. Early controlled mobilization by slow active assisted movements with appropriate immobilization can prevent most of these complications (Evans, 1989).

Benefits of controlled early passive mobilization and stress to the healing tendon:

- Promotes extrinsic and intrinsic healing.
- Encourages longitudinal reorientation of the adhesions.
- Enhances synovial diffusion to the healing tendon.
- Improves peritendinous vessel density and cellularity to the repaired site.
- Facilitates tendon excursion and its tensile strength.
- Promotes metabolic activity.

However, the early return of full function requires certain procedural norms. The most important is calculation of the angle of stress.

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Calculation of the angle of stress: Bunnell's cadaver studies of excursion (Boyes, 1970) provide data on the degree of excursion at the MCP, PIP and DIP joints of the individual fingers and at CMC, MP and IP joints of the thumb with the wrist joint in neutral position (Table 34-6). The precise value for biomechanically sound excursion of the tendon has to be in the range of 4–5 mm for extensor tendons. From this, the exact angle of the joint needed for excursion of the tendon can be calculated using the following formula:

$$\frac{\text{Normal ROM of the concerned joint (degree)}}{\text{Joint angle for 1 mm excursion}} = \text{Bunnell's value of tendon excursion (mm)}$$

Table 34-6

Excursions of the Extensor Tendons

Digit	Extensor Digitorum Communis and Extensor Pollicis Tendons			
	Wrist	*MCP*	*PIP*	*DIP*
Index finger	38	15	2	0
Middle finger	41	16	3	0
Ring finger	39	11	3	0
Little finger	20	12	2	0
Thumb	33	CMC (7)	MP (6)	IP (8)

Notes: MCP, metacarpophalangeal joint; DIP, distal interphalangeal joint; IP, interphalangeal joint; PIP, proximal interphalangeal joint; CMC, carpometacarpal joint (Bunnell, reported in Boyes, 1970).

Therefore, by applying this formula for MCP joint of the index finger whose normal ROM is 85 degrees and the Bunnell's value of tendon excursion is 15 mm, the exact angle of the joint will be

$$\frac{85}{15} = 5.66 \text{ degrees}$$

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For 5 mm excursion, it would be 5.66 × 5 = 28.30 degrees.

Design of dynamic splint: The dynamic splint is forearm-based with a volar block which blocks any further flexion after the preset range. The wrist joint is fixed in 40 degrees of extension. The dynamic extension sling holds MCP, PIP and DIP joints in neutral position of flexion and extension (Fig. 34-25).

- Controlled stress is applied in a graduated manner to the extrinsic extensor tendons from the third or fourth postoperative day. The patient is made to actively flex the digit at the MCP joint till the finger touches the volar block of the splint, followed by relaxation so that the extensor outrigger passively returns the digit to zero position (Evans & Burkhalter, 1986). This exercise needs to be repeated 10–20 times every hour.

- Gentle passive movements of each IP joint should be practised regularly by holding the wrist joint and MP joints in maximum extension. This is continued up to 3 weeks. After 3 weeks, the volar block is discarded while the dynamic extension component of the splint is retained.

- Graduated resistive range of flexion with controlled extension is initiated and continued.

- By 6 weeks, the dynamic extension component is discontinued and the exercises are made more vigorous.

- Graduated functional activities are encouraged and progressed to powered and sustained grips. By 12 weeks, normal to near-normal function should be restored.

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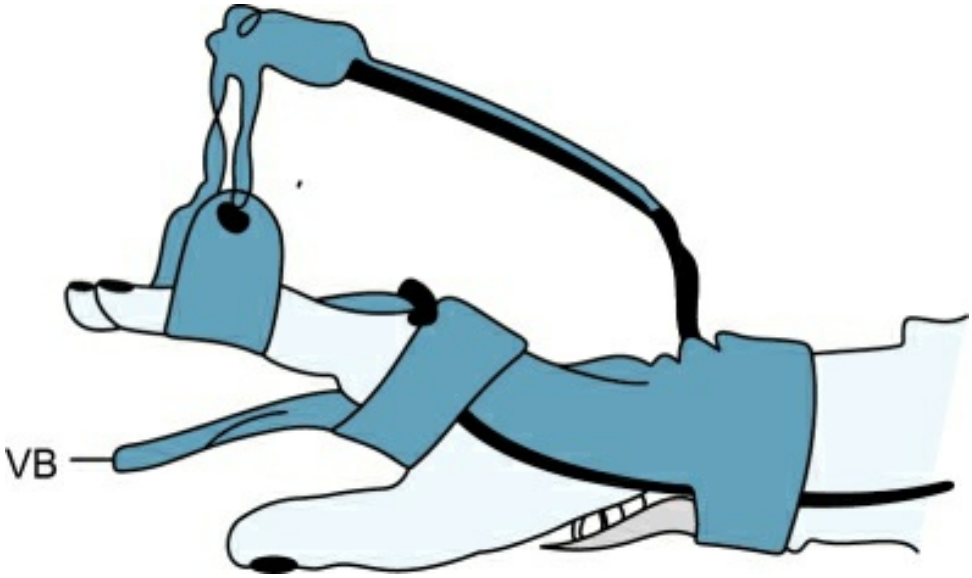

FIG. 34-25 Dorsal forearm-based dynamic extension splint: with volar block (VB) which permits only predetermined range of MCP flexion.

The physiotherapeutic regime after repair of extensor pollicis longus tendon is also similar except that the dorsal dynamic traction splint and a volar block are needed to keep the CMC, MCP and IP joints of thumb in neutral position.

Prevention of common complications

The common complications like extensor lag, extension contracture and swan-neck deformity should be identified early and prevented.

- Resting the digital joints at zero degree (static) prevents *extensor lag*.
- Motion of the MCP joints during the phase of healing reduces the incidence of *extensor lag*.
- Maintaining collateral ligament integrity and stability prevents contractures.
- Controlled intrinsic flexion promotes lymph and venous drainage. It also improves local nutrition and *reduces oedema* and the chances of developing contractures.

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- Immobilization may be extended *to 4–6* weeks if there is a tendency for Boutonniere or swan-neck deformities. Intensive mobilization is also postponed following injury to the PIP joint.

- Injury to the DIP joints may result in *mallet finger* due to distraction of the terminal segment of extensor tendon and strong force of FDP. This may need immobilization for 6–8 weeks.

Amputations: Amputation of the digits are on increase due to steep rise in the RTAs all over. The wound should be carefully examined after thorough irrigation. Depending upon the extent, the site and the condition of the wound, amputation is to be planned observing the general principles (Table 34-7).

Table 34-7
Amputation of Digit Management Procedure

Types and the Level of Injury	Procedure
Fingertip amputation	By full-thickness flap
Fingers with intact good length of the stump	Closure of the stump after trimming of the bone ends
For thumb	Try to save the length of the stump to the bone ends
Replantation of digits	Severed digit can be replanted provided it is appropriately preserved and injury is less than 6 h; it involves microsurgical techniques to repair and suture the arteries, veins, nerves and tendons

Distal interphalangeal joints are never considered for replantations.

Replantation

Reattachment (replantation) of a completely amputated human limb was successfully carried out for the first time by Malt and Meckhann (1964). It is now being carried out routinely at some specialized centres for reattachment of completely severed limbs/digits.

The amputated segment of the digit/limb should be preserved by the method of dry cooling (Fig. 34-26). The indications for replantation are as follows:

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1. Clear-cut amputations

2. Duration of amputations not more than 4–6 h

3. Amputations distal to the DIP joint are not considered for replantation

4. Age: below 55 years

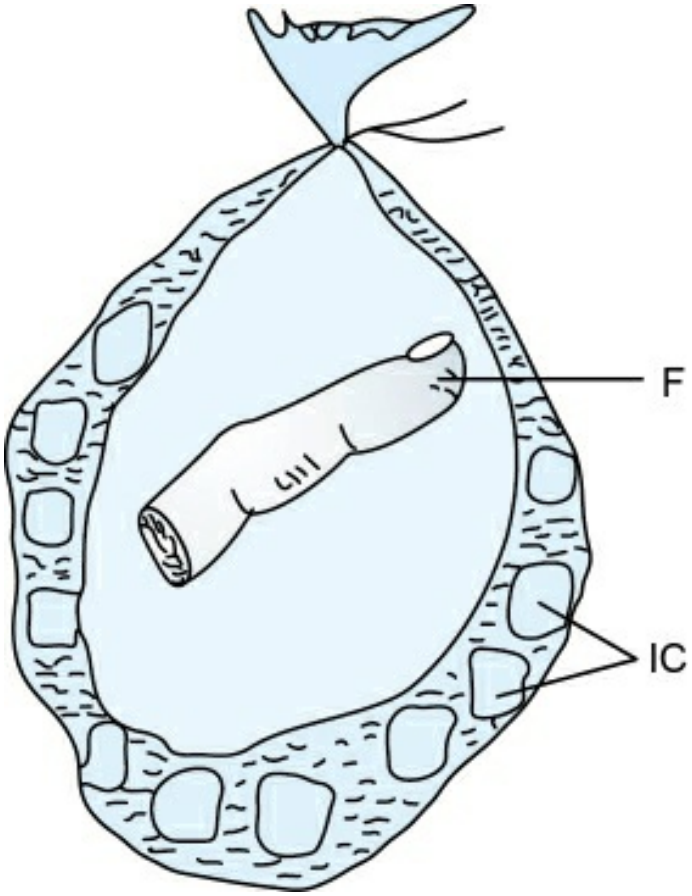

FIG. 34-26 Dry cooling method to preserve amputated digit: the amputated part (finger F in this case) is preserved in polythene bag which is sealed and put in another bag containing ice cubes (IC).

Two teams of surgeons work simultaneously. One team works on the amputated segment while the other on the proximal segment. The vessels, nerves and tendons are identified and tagged for easy identification (Fig. 34-27) for anastomosis later during the course of

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surgery. The structures are then repaired in the following order:

1. The bones are shortened and fixed with screws/wires/plates, etc.

2. Repair (anastomosis) of arteries

3. Repair of veins

4. Repair of nerves

5. Repair of tendons

6. Cover/closure of the wound: the repair of nerves and tendons may be left to be done at a later stage in some cases

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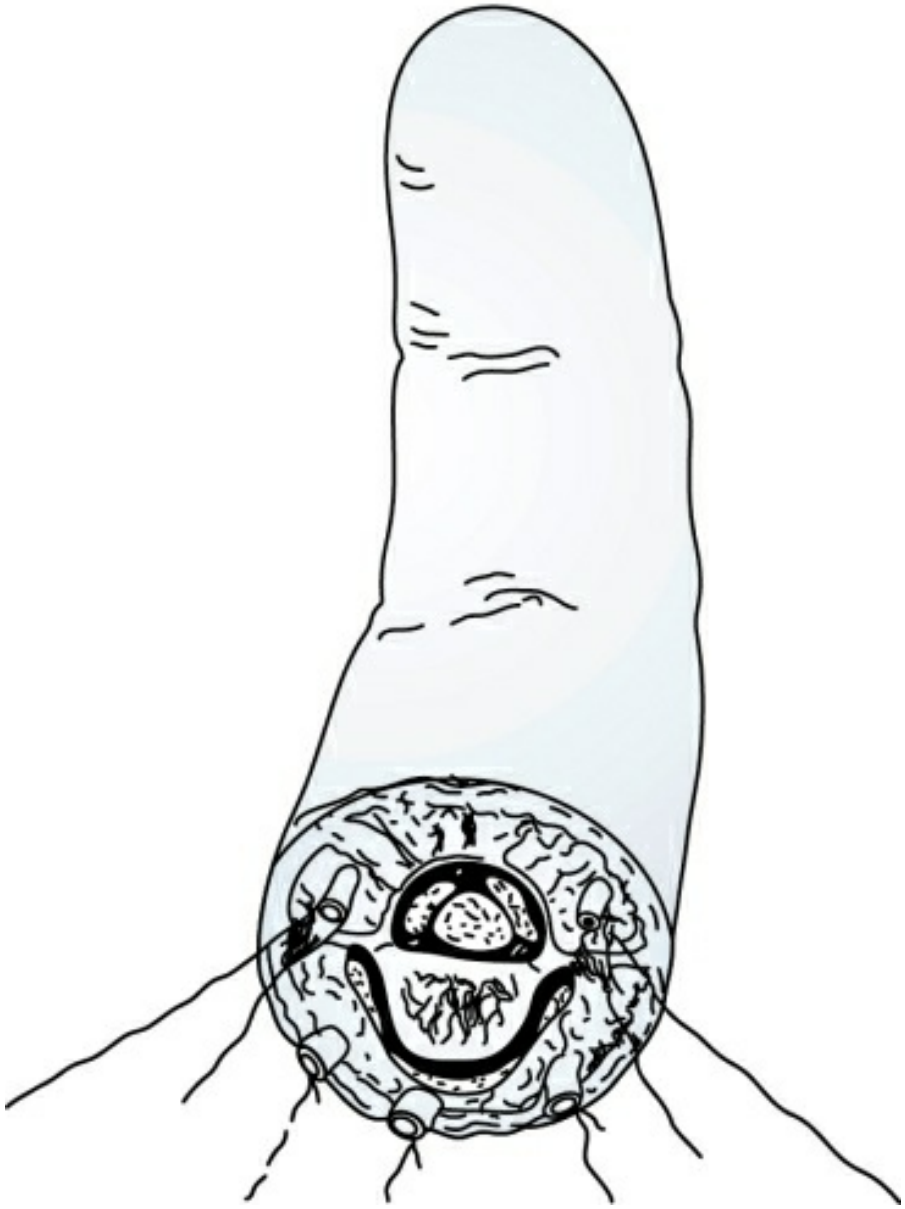

FIG. 34-27 Tagging of vessels, nerves and tendons for easy identification.

After treatment

The part of the digit/limb is encased in a compressive dressing with copious padding and a plaster slab is applied to support the limb. The finger/toe tip is left open for frequent monitoring of circulation. The part may be kept slightly elevated; however, it should be lowered if it becomes pale due to arterial insufficiency. Mobilization of the part is begun after about 3 weeks.

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Physiotherapeutic management

Properly controlled physiotherapy plays an important role in the postoperative phase.

Careful monitoring and correct techniques are the basis of early restoration of function following replantation. Before initiating treatment, the physiotherapist must get acquainted with the type and level of injury and the details of the surgery.

Early postoperative management (first 2 weeks):

- Proper positioning of the limb is ensured to protect the repair. The limb is checked for correct position of elevation, which does not exert any undue stress on the operated part. This will reduce oedema and inflammation.

- Close monitoring of the fingertips for any change in colour, indicating circulatory insufficiency is vital. Signs and symptoms of infection should be checked repeatedly.

- Vigorous movements of the other parts of body and distant segments of the limb, with proper support to the replanted area, are useful to indirectly improve circulation to the replanted area.

Phase of restoration and re-education (3–5 weeks): This phase begins after the dressings and cast are removed. The dressings are removed by 2 weeks in replantation of the digits and after 4 weeks in more proximal areas.

- A dynamic splint is applied with the wrist in slight dorsiflexion, MCP joints in flexion and IP joints in slight flexion (Fig. 34-28). Necessary modifications may be done to ensure optimal fitting without any ill effects.

- Early gentle mobilization is begun in a small range with relaxed passive movements. Application of controlled passive stress is of vital importance. The stress should be applied giving due consideration to the periods of recovery of various tissues as

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follows:

Skin: The skin develops adequate tensile strength within 7–10 days to initiate stretching.

Vascular supply: It needs 14 days to heal (Prendergast, 1978). Tight bandaging or cast blocks the healing of vessels. Therefore, stretching is not initiated earlier than 2 weeks.

Nerves: Healing of nerves takes 3–4 weeks (Beasley, 1981). The compression of a nerve or its overstretching blocks regeneration. Therefore, care should be taken to avoid compression as well as excessive stretching for 3–4 weeks.

Bones: The bony union can be confirmed by radiographic investigations, for initiating mobilization or stretching.

Active movements: If wound healing is satisfactory, early initiation of small-range gentle active movements is ideal.

Whirlpool: If the wound has loose necrotic tissue, it may need debridement. Such wounds respond very well to whirlpool treatment before debridement. The grafted skin should not be treated by whirlpool to avoid skin maceration.

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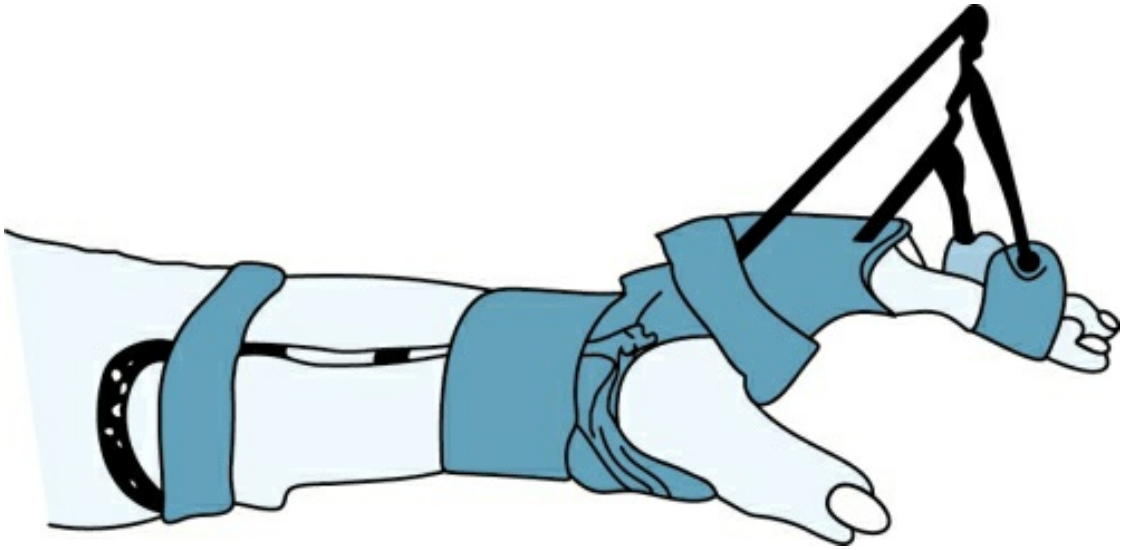

FIG. 34-28 Dynamic splint following replantation of digits: The dorsal outrigger encourages active ROM of flexion.

Mobilization techniques

Grade I or grade II accessory and physiological movements by the techniques of joint mobilization are useful, as they do not involve stretch on the vessels or the nerves.

Care of other joints: Uninvolved proximal joints should be fully stretched to prevent stiffness.

Splint modification: The splint may be modified to a dynamic one with emphasis on MP joint flexion and joint extension to guide the movements, e.g., outrigger extension assists the splint. This will promote tendon gliding and early movements. This splint provides resistance to the flexor tendons which can tolerate tension due to their ability to heal before the extensor tendons. The extensors remain relaxed. This provides reciprocal inhibition to the extensor tendons facilitating the glide (Horovitz & Casler, 1986). Hand should be exposed to early functional restoration first as an assisting hand and later as a primary.

Progressive exercise: The exercise should be progressed to gain more range and strength of the involved joints.

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Sensory re-education: Sensory re-education should be begun by adopting suitable techniques.

ADL training: Guided ADL training by using dynamic splint further improves the tendon gliding. It should begin with easy, simple tasks and movements, and progress gradually. To begin with, the replanted arm should be used only as an assisting hand.

Resolution of oedema and scar adhesions: Intermittent compressive techniques and vigorous active exercises are given to eliminate oedema. Friction massage to the scar is useful in breaking adhesions.

Late phase of restoration (6–8 weeks): By this time, healing is complete in the reconstructed soft tissues and bones. Therefore, concentrated efforts to attain maximum return of function can safely be started.

Vigorous procedures to improve ROM, strength, endurance, grip and sensory re-education (if necessary) are to be emphasized. All grades of joint manipulation and mobilization techniques as well as PNF techniques are safe and effective at this stage provided the force and resistance are monitored carefully. Special elaborate sessions devoted to improve coordination, dexterity and skills should be included.

Functional training should be oriented on the basis of job requirements.

Acceptable function should return to the replanted hand by 16–20 weeks.

Caution

Maximum efforts are directed towards the reduction of postsurgical oedema and infection. If not controlled, it may lead to a higher incidence of stiff joints (Horovitz & Casler, 1986). Another important aspect is scar remodelling by controlled stretch.

Burns of the hand

Most of the burns to the hand occur as a result of direct or indirect

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contact with heat (Table 34-8).

Table 34-8
Burns: Types and Examples

Burns	Examples
Flame	Clothing catching fire
Scalds	Contact with steam, hot water, etc.
Contact	Hot press, bars, utensils during cooking, etc.
Flash	Explosion causing a flash
Electrical	Live AC or DC current
Chemical	Dipping or applying concentrated acids or alkalies

The burns of the hand may involve dorsal or the palmar aspect of the hand, although dorsal burns are more common due to the reflex action to protect face. All the groups may be affected, but children, housewives, elderly persons, psychiatric and epileptic patients are particularly at a risk.

Depending upon the degree of damage to the tissues, hand burns are classified into the following three categories:

First-degree (grade I) burns: Only the dermis is involved. The free nerve endings and sensory organs are intact. The wound is bright red or glistening pink due to vasodilation.

Second-degree (grade II) burns: The dermis and epidermis are involved. The hair follicles, sebaceous glands and sweat glands are spared. The wound appears white due to interstitial oedema.

Third-degree (grade III) burns: There is destruction of dermis, epidermis along with hair follicles, sebaceous glands and sweat glands. The wound appears white or dark brown. There is extensive sensory involvement and profuse oedema within 24 h.

Basic principles of management

1. Prevention of infection

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2. Prevention of circulatory failure and control of oedema

3. Prevention of deformity

4. Restoration of hand function

Prevention of infection

During acute phase, prevention of infection and control of pain are of primary importance. Adequate measures are taken to clean and dress the wound, removing slough and necrotic tissues, observing all the aseptic measures. Anti-inflammatory drugs and antibiotics are given. Enzymatic debridement and tangential excision may be needed.

Prevention of circulatory failure and control of oedema

Signs and symptoms of circulatory failure like paleness, cold and loss of pulse should be monitored at regular intervals. Active exercises to the joints adjacent to the site of burn and relaxed passive movements within the limits of pain assist in controlling circulatory failure and in preventing infection.

Control of oedema can be facilitated by the following measures:

1. Supporting the hand in elevation

2. Slow and graduated active intrinsic muscle pumping exercises performed every hour

3. High-voltage pulsed current synchronized with active efforts

Prevention of deformity

Right from the beginning, the hand is immobilized, with the burnt hand enclosed in a plastic bag or splint, in the optimum position of the hand (Fig. 34-29, A–F). At a later stage, the splint is altered to a dynamic splint with in-built mechanism to provide remodelling of the scar tissue.

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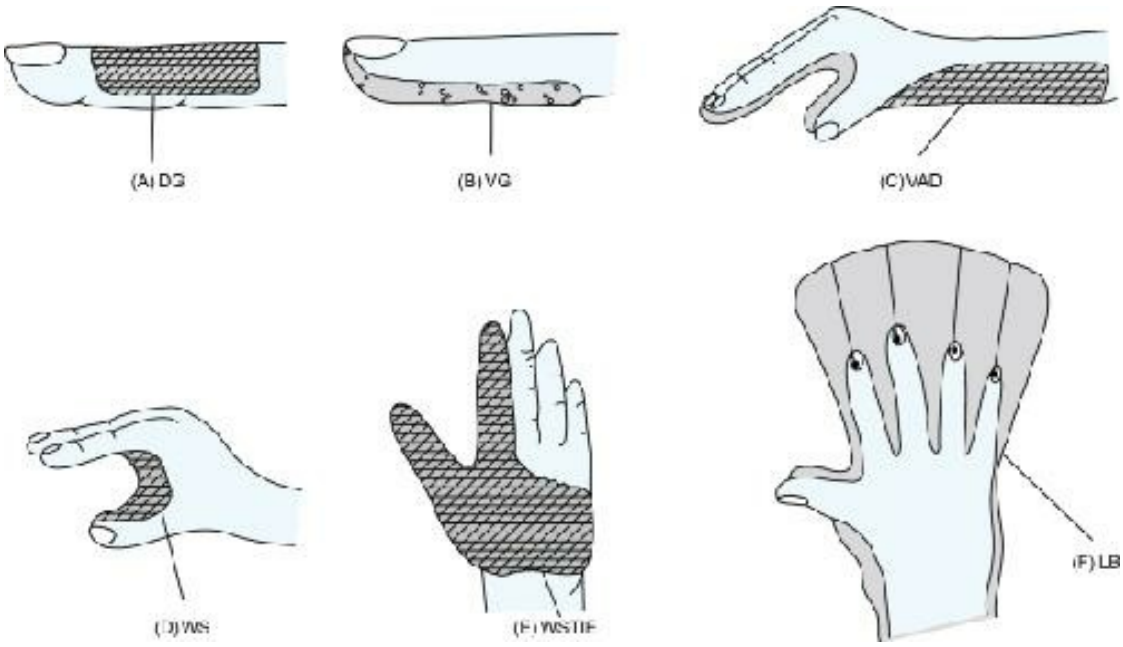

FIG. 34-29 Correct splinting to prevent expected deformity and provide optimal immobilization following hand burns. DG, Dorsal PIP extension gutter splint; VG, Volar PIP, DIP extension gutter splint; VAD, Volar anti-deformity splint; WS, Web spacer splint; WSTIE, Web spacer-thumb and index finger extension splint; LB, Long Banjo.

Common deformities and preventive splinting

1. Hyperextension at the MP joint with flexion at PIP joints: knuckle bender splint

2. Boutonniere deformity: PIP–DIP joint extension gutter splint to individual fingers

3. Mallet finger deformity: Simple splint maintaining extension at the DIP joint

4. Swan-neck deformity, where hyperextension occurs at the PIP joint: Simple splint preventing terminal extension of the PIP joint

5. Syndactyly, where there is a loss of digital web: This may occur as a result of improper immobilization or due to contraction of the adjacent wound; a splint maintaining an individual web space is necessary

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6. Palm cupping: The palmar arches of the hand may get contracted; this needs low lying-load stress splint to flatten the palmar arch

Restoration of hand function

Exercises play a significant role in all the stages following burns. They need to be properly planned and controlled to adequately meet the demands of the individual patient.

Exercise procedures should be planned only after a thorough evaluation. The management proceeds on the same lines as described under hand injuries. However, hydrotherapy in the form of whirlpool is extremely useful and a popular mode of management. It helps in softening the wound, debridement, improving circulation, retaining mobility, reducing oedema and hastening the process of healing. Please ensure disinfecting the pool water before use.

Prevention of hypertrophic scars after burns: Precisely measured pressure garments- Patients should start wearing gloves made up of elasticated mesh material after 2 weeks of burn. These pressure gloves need to be worn for 24 h of the day for 6–18 months (except brief interval for washing). These pressurized gloves cause elongation of the fibroplasts, thus preventing bumpy or raised scar tissue. It is well monitored and retained till the hypertrophic scar tendencies are overcome.

Occasionally, cortisone infiltration or surgery may be required to cover the skin.

Caution

Even after healing, sensation may not be normal. Patient must be warned not to cause direct friction, excessive pressure or any injury to the new skin.

Infections of the hand

Acute infections of the hand need prompt diagnosis and management lest the hand become stiff leading to permanent disability.

Even a trivial injury like scratch over the skin is adequate to result in infection.

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Even a pinprick injury is enough to cause serious infection. The volar aspect of the palm and fingers is maximally used in the majority of the functions of our daily routine. Therefore, it always remains susceptible to injury. In the event of minor injury, we keep on using the hand without protecting the wound; it welcomes pyogenic bacteria causing infection and pus formation and leading to impaired hand function.

Major causative microorganisms following open wounds

- *Staphylococas aureus* in about 60% of infections
- *Streptococcus pyogenes*
- Gram-negative bacilli

Common types of infections of the hand are as follows (Fig. 34-30):

1. Paronychia
2. Whitlow
3. Thenar space infection
4. Mid-palmar space infection
5. Infections of the tendon sheath (tenosynovitis)

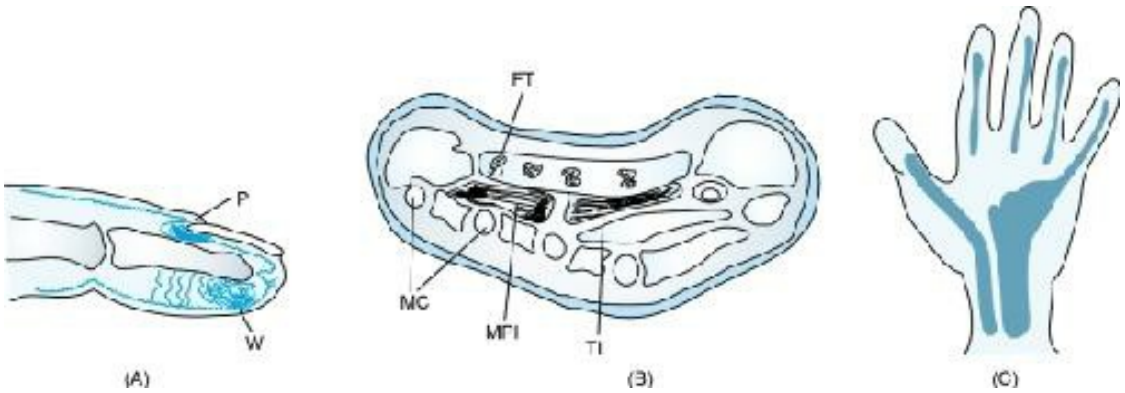

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FIG. 34-30 Common infections of hand. **(A)** Paronychia (P), Whitlow (W). **(B)** Transverse section showing thinner space infection (TI), mid-palmar space infection (MPI), flexor tendons (FT), metacarpal bones (MC). **(C)** Tenosynovitis of flexor tendon sheaths: sheaths of the thumb and little finger are longer and continue up to the radial and ulnar bursa respectively.

These infections are caused by pyogenic organisms (bacteria). Minor injuries such as pricks, abrasions and cuts predispose the hand to infection. The infection in the hand spreads to the tissue planes. If not treated in time, it may involve the adjacent tissue planes.

Paronychia

Paronychia is a nail bed infection. It is the most common type of infection. It starts in the nail bed on one side of the nail and may spread around the nail to the other side or in rare instances to the pulp space. The patient complains of pain, swelling and redness at the base and on either side of the nail. The pain is generally severe. The treatment consists of early drainage under cover of antibiotics.

Whitlow

Whitlow is a pulp space infection, also called *Felon*. The patient has excruciating pain in the pulp of the finger which is also swollen, tense and tender. The treatment is drainage of the abscess and appropriate antibiotics.

Thenar space infection

The patient presents with swelling and pain in the radial half of the palm. The swelling is more marked over the dorsum of the hand, mainly due to the fact that lymphatics drain into the dorsum of hand. The treatment is antibiotics and early drainage of pus.

Mid-palmar space infection

In the mid-palmar space infection, the ulnar half of the palm is swollen, painful and tender. Drainage of pus and antibiotics is the treatment.

Tenosynovitis

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Infections of the tendon sheath are rare but may lead to necrosis of the tendons and adhesions of the tendon sheath if not treated promptly. Ulitmately, it may lead to permanent stiffness of the fingers. The patient presents with a swollen finger with tenderness over the tendon sheath.

A rare, but serious infection involves the flexor tendon sheaths and hence adversely affects the function of the hand.

The flexor tendons of the hand are covered with fibrous and synovial sheaths or bursae. They are organized into two groups, the radial bursae and the ulnar bursae.

There exists a great variation in the arrangement of the synovial tendon sheaths. The tendon sheaths of the index, middle and ring fingers as well as the ulnar and radial bursae may be in contact with each other increasing the susceptibility of spreading the infection.

Penetrating injuries to the tendon sheaths with a needle or sharp object serve as entry point for *S. aureus* or *Streptococcus pyogens*.

Infection can spread by extension from the terminal pulp space.

Early detection

- Painful swelling through the entire length of infected finger develops.
- There is marked tenderness localized over the flexor tendon sheath.
- Finger remains semiflexed, and passive extension is extremely painful.
- In infection of the tensosynovitis of the little finger or to the ulnar bursa, Kanavel sign' is positive. A point of maximum tenderness is present between two of the transverse palmar creases (Fig. 34-31).
- In infection at the radial bursa, excessive swelling is present over the thumb and the thenar eminence.

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FIG. 34-31 Web space infection – in the third web space (between middle and ring fingers). Note the fixed separation of the fingers.

Treatment

Prompt drainage of pus under cover of antibiotics is instituted as its treatment.

- Early acute inflammatory stage – rest is given with crepe bandage.
- A rigid thermoplastic or POP splint is given.
- Modalities like diapulse, ultrasound therapy, cryotherapy, TENS to control pain and inflammation with hand in elevation are used.
- Gentle pain-free relaxed active movements with splint on are ideal.

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- Isometrics with splint and pressing against the splint within pain-free range are ideal.
- As the inflammation is reduced, relaxed passive ROM exercises could be initiated with functional use of the hand.
- Deep friction massage across the affected tendons is very effective.
- By 2 weeks, the inflammation settles and vigourous exercise procedure including regular functional use of the affected hand should be initiated.
- Hydrocortisone infiltration is done.
- Rest is given in elevation and support.
- Intravenous antibiotics are administered.
- Surgical opening of the tendon sheath and irrigation are performed.

Complications

Suppurative or pyogenic tenosynovitis is a complicated problem as pus formation occurs in the sheaths of the flexor tendons of thumb and fingers; the built-up hydrostatic pressure of pus may block circulation to the tendons. It results in extremely painful and stiff fingers.

Under such circumstances, intramuscular injection of antibiotic is advisable.

In traumatic tenosynovitis, tendons of the abductor pollicis longus and extensor pollicis brevis may be involved with typical signs of pain and stiffness over the anatomical snuff box.

Distinguishing signs (table 34-9)

The tendon sheath of the thumb, known as the *radial bursa*, extends into the forearm.

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Table 34-9

Distinguishing Characteristics in Tenosynovitis and Tenovaginitis

Tenosynovitis	Tenovaginitis
Secretion of excessive synovial fluid in the tendon sheaths	Stenosis or thickening of the tendon sheaths
Swelling over the affected sheaths is soft and tender	The swelling is hard and tender to palpation
Excessive pain on attempted finger flexion movements	The movements of thumb and/or wrist are extremely painful
Intramuscular antibiotic injection is very effective	Surgery – decompression of stenosed or thickened tendon sheaths may be necessary

The flexor tendon sheath of the little finger opens into the ulnar bursa.

The tendon sheaths of the index, middle and ring fingers extend from finger top to the bases of the digits.

Pain at rest is the typical identifying feature of suppuration or pus formation.

General principles of prevention of hand infections

Public awareness to the following facts:

- Even a small pinprick can cause serious infections leading to impaired hand function.
- Educate on simple methods of initial wound care to prevent bacterial invasion.
- Emphasize on educating the public on hygienic care while cutting nails, etc.
- Dull pain progressing to intractable pain is a sure sign of pus formation.
- Seek immediate medical assistance in the event of symptoms like nagging pain, tenderness, swelling, redness or painful stiffness.
- Never attempt to treat yourself or seek cheap and easily available treatment.

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General principles of treatment

1. Rest and support in elevation

2. Systemic antibiotics in adequate dose and in an appropriate combination using four antibiotics to prevent pus formation when used within 48 h

3. Measures to reduce inflammation, pain and oedema

4. Measures to improve localized circulation

5. Protective immobilization

6. Drainage of pus: To ensure complete drainage of pus, certain factors need to be strictly observed

- General anaesthesia (GA) or regional block is preferred to local anaesthesia, which has a tendency to spread infection by secreting excessive fluid to the already existing fluid.

- Application of tourniquet without exsanguination is indicated to prevent spread of infection. Instead, continuous well-supported elevation of hand is preferred.

Incision

- Incision should never cross the skin crease.

- It should not damage any important structure in the vicinity of the abscess.

- Exploration should be wide enough for the complete evacuation of pus.

- Wound is left partially open after ensuring complete removal of the

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pus.

- Aftercare of the wound with regular dressing and monitoring (check) is most important.
- Pus collected should be sent for culture and sensitivity to select ideal combination of antibiotics.
- General principles of physiotherapy management in hand infections.

Physiotherapeutic management

Early acute stage:

- Rest with support in elevation is given.
- Rigid thermoplastic splint or POP slab is used.
- Suitable modality to reduce pain, products of inflammation – like diapulse, US therapy, TENS or cryotherapy – should be given.
- Providing active maximum ROM exercises to the uninvolved fingers is very important to prevent stiff hand.
- Repetitive and sustained isometrics within the splint should be encouraged with pain-free magnitude of force.

Late stage:

- Graduated repetitive mobilization should be started for the involved finger.
- Relaxed, free, assisted movements to improve ROM to the

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involved finger are begun.

- Functional use of the whole hand including diseased finger is begun with soft spongy ball.
- As soon as inflammation and pain are settled, vigourosity of exercise is progressed to the maximum.
- Concentrated exercises with hand dipped in disinfected warm water are the best.
- Cyriax (1978) and Tidy (1968) advocated deep friction massage across the affected tendons in tendon injuries, when the wound is healed.
- Normal to near-normal hand function should be restored within 4–6 weeks.
- Physiotherapy follows incision and drainage.
- Self-assisted ROM as well as muscle function exercises is emphasized.
- Active holds in the maximally stretched position are extremely useful in restoring hand function including the involved digit.
- Exercise programme from early immobilization should be progressed within a short duration by ensuring patient's own efforts at home within 6–8 weeks; normal restoration of hand function should be restored.

Vasospastic diseases of the hand

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Vasomotor instability precipitates vasospastic hand diseases like reflex sympathetic dystrophy (RSD), Raynaud disease (RD) or Raynaud phenomenon (RP).

Reflex sympathetic dystrophy

RSD may occur as a result of the following:

1. Repeated trauma to the dorsum of the hand, e.g., occupational, truck drivers and chainsaw operators

2. Direct trauma, crush injuries, injuries to the nerves, Colles fracture and cerebrovascular accidents (CVA)

3. Systemic disease

It is also called Sudeck dystrophy, complex regional pain syndrome (CRPS). The exact aetiology is not known but it occurs due to sympathetic disturbances.

Stagewise signs and symptoms (delp, 1986)

Stage 1

This stage may last up to 3–6 months.

- There is burning or aching pain with tenderness, aggravated by movement or emotional stress
- Pitting oedema is observed
- Warm erythemic hand becomes cool and cyanotic with excessive sweating
- Osteoporosis may set in

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Stage II

This stage may also last for a period of 3–6 months.

- Pain and oedema continue, resulting in decreased joint mobility (contractures).
- Muscles atrophy.
- Trophic changes like smooth and shiny skin, brittle and grooved finger nails are seen.

Stage III

- There is diffuse marked osteoporosis.
- Ankylosis of the distal finger joints occurs.
- Intrinsic muscles atrophy, especially interossei.
- Pain during attempted movements continues.

Evaluation

A thorough evaluation is done to assess the nature of impairment. Besides the usual strength and ROM, pain perception should be evaluated on a 10 cm horizontal visual analogue scale (Scott and Huskisson, 1976). Grip strength, finger dexterity and resting finger temperature should be assessed before and after cold immersion. The hand is kept immersed in cold water till the skin temperature reaches 13°C. Then it is removed from cold water noting the time taken to reach the baseline temperature level. The test can also be done by 20 s of ice-water bath (Porter et al., 1975). Volumetric measurements can be used to assess the degree of oedema.

Investigations

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X-ray shows patchy osteoporosis (Fig. 34-32); however, the diagnosis is picked up on a bone scan (Fig. 34-33).

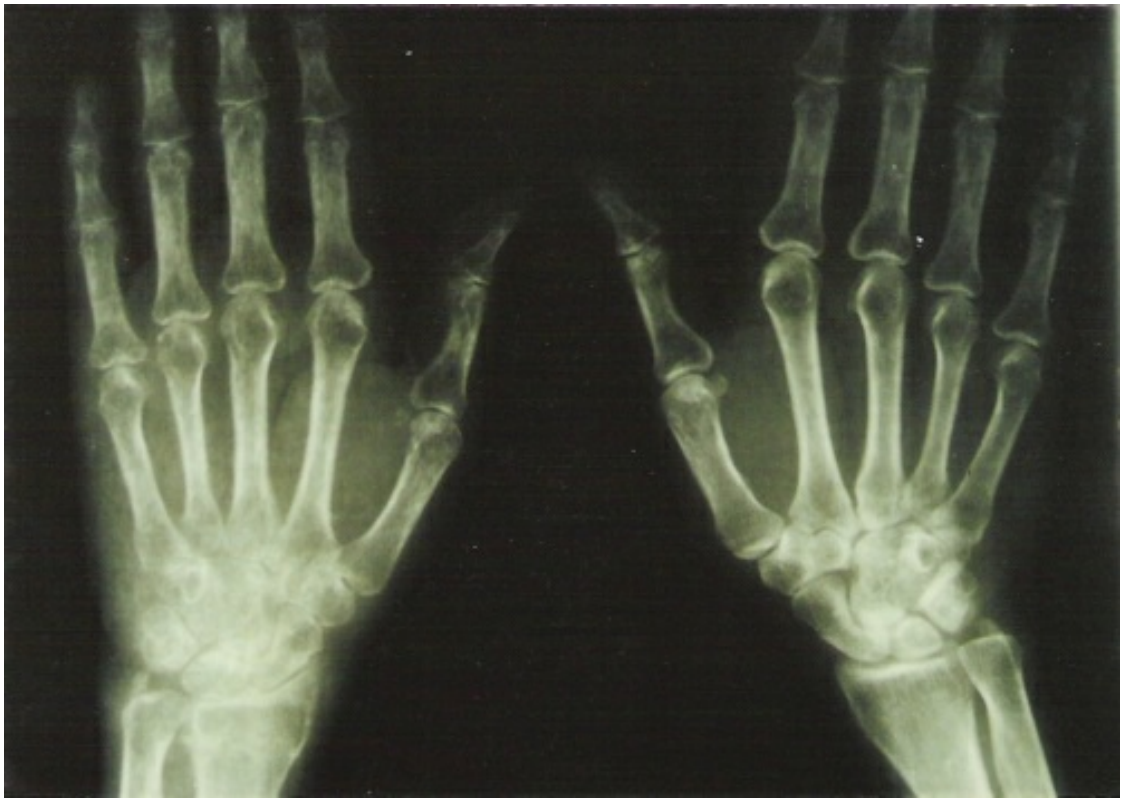

FIG. 34-32 CRPS: X-rays shows patchy osteoporosis of the left hand; normal right hand for comparison.

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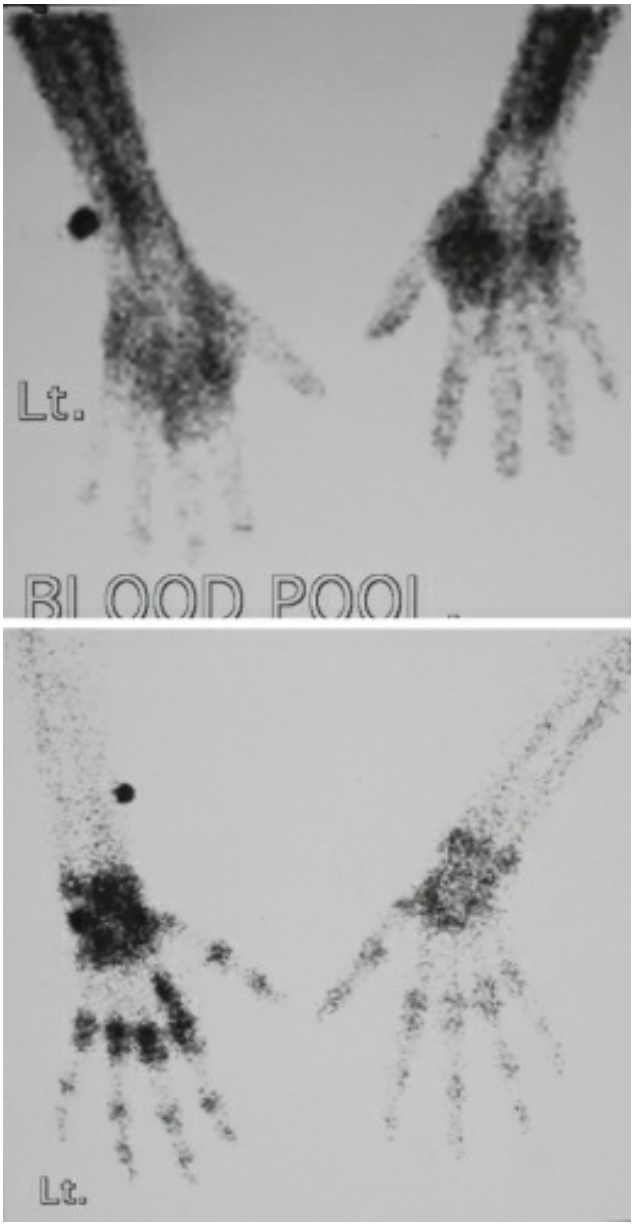

FIG. 34-33 CRPS: bone scan—shows increased update on the left side.

Treatment

Medications are given to alter the circulatory disturbances. Chemical sympathectomy in the form of stellate ganglion block may also be done. Physiotherapy and exercises are continued despite pain.

Physiotherapy management

Early detection of the symptoms like pain, oedema and digital skin

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discolouration in suspected patients (e.g., Colles fracture, CVA) and initiation of early treatment are of primary importance.

Control of pain

First priority in the treatment is to control pain by a suitable modality. Prolonged heat, cold, high pulse rate (50–100 Hz) and narrow pulse width (45–75 s) TENS, paraffin-wax bath, repeated gentle relaxed passive movements and connective tissue massage are useful. Intravenous injection of procaine and lidocaine, ganglion block, use of corticosteroids and sympathectomy are the other measures.

Control of oedema

Methods like supported elevation, active movements, retrograde massage, Jobst gloves and air splints are effective.

Splinting

At the initial stage, wrist stabilization is given to reduce pain and to facilitate finger movement. Later on, a dynamic hand splint with outrigger assists in providing resistance to finger flexion and assisting extension.

Counselling

The long course of the disease with nagging pain causes emotional imbalance and distress to the patient. Therefore, the therapist's counselling skill is an important aspect of the treatment.

Exercise programme

Well-planned graduated exercise programmes with functional use of the hand are important.

Raynaud phenomenon

Primary RD: This has bilaterally symmetrical involvement without any history of injury or associated disease. Emotional stress can precipitate primary RD.

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Secondary RD: This has a definite history of injury, extensive use of a vibratory tool, prolonged exposure to cold, endocrine disease, arterial disease, collagen disease, blood disorders or arterial compression.

Signs and symptoms

- Pain
- Pallor and cyanosis
- Skin discolouration due to exaggerated vasoconstriction

Evaluation

Evaluation is done as described for RSD.

Treatment

- Electrically heated hand gloves are useful in maintaining hand temperature.
- TENS has been reported to be effective in producing vasodilation besides controlling pain.
- Pairing whole-body exposure to cold (0°C) and hands to warm water (43°C) results in learned response (Jobe et al., 1982).
- Pendular rapidly swinging arm exercises with relaxation are useful in improving blood flow to the hand. This occurs due to the gravitational and centrifugal forces (Mc Intyre, 1978).
- Drugs to reduce sympathetic tone or to improve circulation are effective.

Surgical management

- Vein grafts are used to bypass the thrombosed arteries (Wilgis,

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1981).

■ Digital artery sympathectomy (Flatt, 1980) or axillary sympathectomy has been reported to be successful.

Arthritic hand

The hand may be affected by seven various types of joint affections. Each type has its own differentiating characteristics to pinpoint the arthritic class (Table 34-10).

Table 34-10

Postarthritis Typical Diagnostic Characteristics of Deformities at the Hand

Rheumatoid Arthritis	Osteoarthritis	Lupus Erythematosus	Psoriatic Arthritis	Reiter Syndrome	Gouty Arthritis	P H
• Swan-neck deformity: Hyperextension of PIP joint with flexion of the DIP joint: Due to rupture of the volar plate of the PIP joint • Boutonniere deformity: Flexion at the PIP joint: Due to the rupture of the central extensor expansion, resulting in flexion at the PIP joints • Trigger fingers and/or trigger thumb: Due to the formation	• Hard round nodes, Heberden and Bouchard nodes, are formed around the DIP, PIP joints • Degenerative destruction of the joint cartilage • Formation of bony spurs • Resulting in the limited excursion of the involved joint/joints	• Gross deformation of the metacarpophalangeal joints • Involvement of periarticular soft tissues and tendons • It may involve the skin over the nose	• Deformities are similar to those encountered in rheumatoid arthritis except unlike rheumatoid, involvement of distal interphalangeal joints (DIPs) is an identifying feature • Always associated with typical skin lesions of psoriasis • Pitting and finger nail discolouration	• Triad of conjunctivitis urethritis and synovitis • Synovitis is asymmetrical • Heel pain, back pain • Nail deformities • Attacks young males; commonly involves lower extremities • Reversible disease resolves itself • Symptoms of arthritis in a single or multiple joints	• Usually attacks single joint • In acute stage, the joint becomes swollen, red hot and tender due to the deposition of monosodium urate crystal • Common site of involvement is the first metatarsophalangea joint (Podagra) in >70% cases • Nodular thickenings (tophi) may occur in tendon sheaths, bursae and ear cartilage	

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of nodules over the tendons • Unlar deviation at MCP: Due to rupture of the collateral ligaments • Symmetrical joint swelling at the MCP and IP joints due to inflammation around the joints				• Multiple joint involvements; attacks spine, resembles ankylosing spondylitis		

Jersey finger

Jersey finger is a deformity which is exactly the opposite of 'mallet finger'. In jersey finger deformity, the patient is unable to flex the DIP joint due to the avulsion of a FDP from the point of its insertion due to the direct hit to the fingertip (e.g., volleyball player).

Crush injuries

Crush injuries of the hand is an emergency situation with growing number of industrial accidents, RTAs and machine tool accidents. The incidence of crush injuries is on the rise. And considering the hand being the most important functional asset, one must do full justice before deciding its amputation.

One can prevent amputation with critical repetitive clinical examination and proper care.

- What is the status of blood loss following an injury? If the blood loss is absolute or irreversible, amputation is the only salvage procedure.

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- Examine the hand for the possibility of return of hand function.
- Can the residual intact finger/fingers compensate for the loss of function due to an accident of the important five tissues: skin, tendon, nerve, bone and joint?
- Permanent loss of neuronal and muscular function in adult will require bionic arm with sensor, but otherwise amputation is the only solution in adults.
- Salvage of the thumb is most important and should always be taken care off.

Treatment of crush injuries

Step 1

- While covering wound with sterile dressing, hand should be maintained in elevation to assist drainage of the waste products.
- Brief overall examination and care is done in general to check the status of skin, damage to the bones, tendons and nerves; i.v. fluids and antibiotics are started.
- Detailed examination of each tissue is conducted under GA or a regional block in the OT after thorough debridement. This will help in assessing the damaged tissues and extent of the damage and the tissue loss. After this scrutiny, nonviable tissues are excised and those which are viable are repaired as per each one's required procedure. If the damage is beyond repair, primary amputation is unavoidable.

Note: Other soft-tissue lesions at the hand are covered in Chapter on Regional Orthopaedic Soft Tissue Lesions.

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CHAPTER

35

Regional orthopaedic conditions at the hip

OUTLINE

- Hip joint
- Coxa vara
- Coxa valga
- Perthes disease
- Avascular necrosis
- Osteochondritis
- Rare hip pathologies

Hip joint

Applied anatomy

The hip joint is a true ball and socket joint which offers free mobility during activities and stability during weight bearing. The all-important mobility of this joint is secondary to stability as mobility without stability is useless (Anson & McVay, 1971).

Stability to the hip joint is provided by the following structures:

1. Bony configuration

2. Articular capsule and ligaments

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3. Muscles

4. Atmospheric pressure

Bony configuration (fig. 35-1)

The ellipsoid shape of the femoral head fits tightly into the well-formed hemispherical acetabulum. These two bony structures make a stable ball and socket joint. The femoral neck has two angulations: neck–shaft angle (normal value: about 135 degrees) and an angle of anteversion which is about 10–20 degrees. The femoral anteversion allows an extended range of flexion at the hip before the neck of the femur impinges against the acetabular rim. The cartilage of the head and the acetabulum, with collagen fibres, offers resistance to mechanical stress. The presence of mucopolysaccharides offers a shock-absorbing property apart from providing smooth surfaces for joint movements (Warwick & Williams, 1973).

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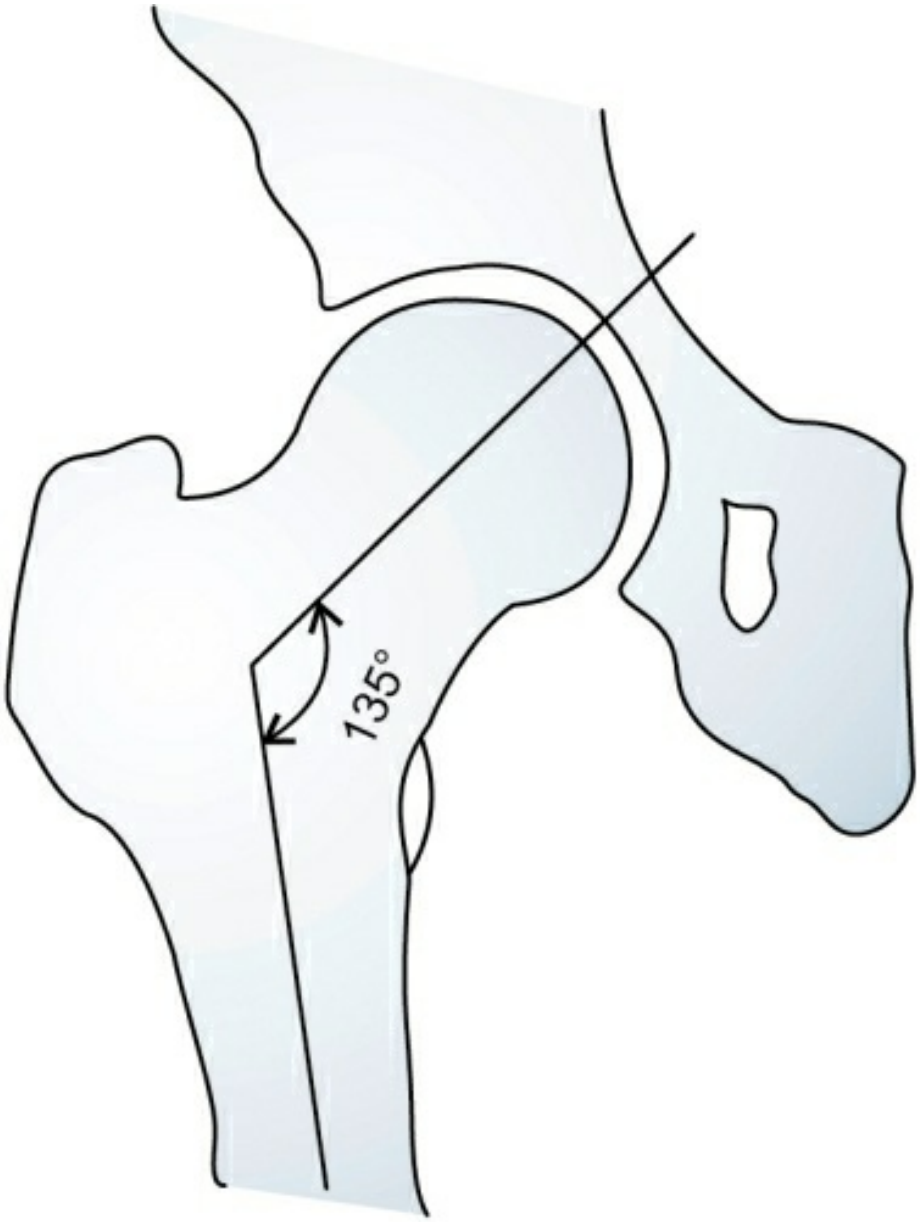

FIG. 35-1 Bony configuration of the hip joint, the only true ball and socket joint.

Articular capsule and ligaments

The joint derives its strength from the thick articular capsule and strong ligaments like the iliofemoral, pubofemoral, ischiofemoral and the glenoid labrum.

Anteriorly the joint capsule is attached along the intertrochanteric line, whereas posteriorly the capsule covers only the medial or upper

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two-thirds of the neck. Thus, it falls short of the intertrochanteric crest. Posteriorly, it has only a few longitudinally oriented ligaments. When the hip is flexed and adducted, the posterior part of the head of the femur is supported only by the capsule and not by the acetabulum. Therefore, anteroposterior force on the distal end of the femur makes the hip susceptible to posterior dislocation (Romains, 1972).

Muscles

Strong and heavy musculature provides protection and strength to the hip joint. The tension in the iliopsoas and rectus femoris provides anterior protection. The short lateral rotators offer protection posteriorly. The obturator externus stabilizes inferiorly and posteriorly while the gluteus medius and minimus protect the joint laterally.

Flexion at the hip is produced primarily by the iliopsoas and assisted by the straight head of the rectus femoris, sartorius and pectineus.

Extension is produced by the gluteus maximus and assisted by hamstrings. Hyperextension is checked by the iliofemoral ligament.

Abduction is produced by the gluteus medius and minimus and assisted by the tensor fascia lata and sartorius. Excessive abduction is checked by the pubo-femoral and iliofemoral ligaments and by the tension in the adductor group of muscles. The gluteus medius and minimus together are called the *iliotrochanteric group of muscles*. They are instrumental in offering stability to the pelvis in standing on both legs and especially during single leg balance. Weakness of abductors dips the pelvis on the side opposite to the weak leg as it fails to maintain the pelvis squared. This dipping of pelvis on the opposite side of the standing leg is called *positive Trendelenburg sign* (Fig. 35-2). It is positive in the following conditions: paralysis or paresis of hip abductors, dislocation of the hip, congenital coxa vara, ununited fracture of the neck of the femur and limb length shortening. It is important to note that the force on the joint during standing on a single leg is around 2.4 to 16 times the body weight (Paul, 1966; Rydell, 1965).

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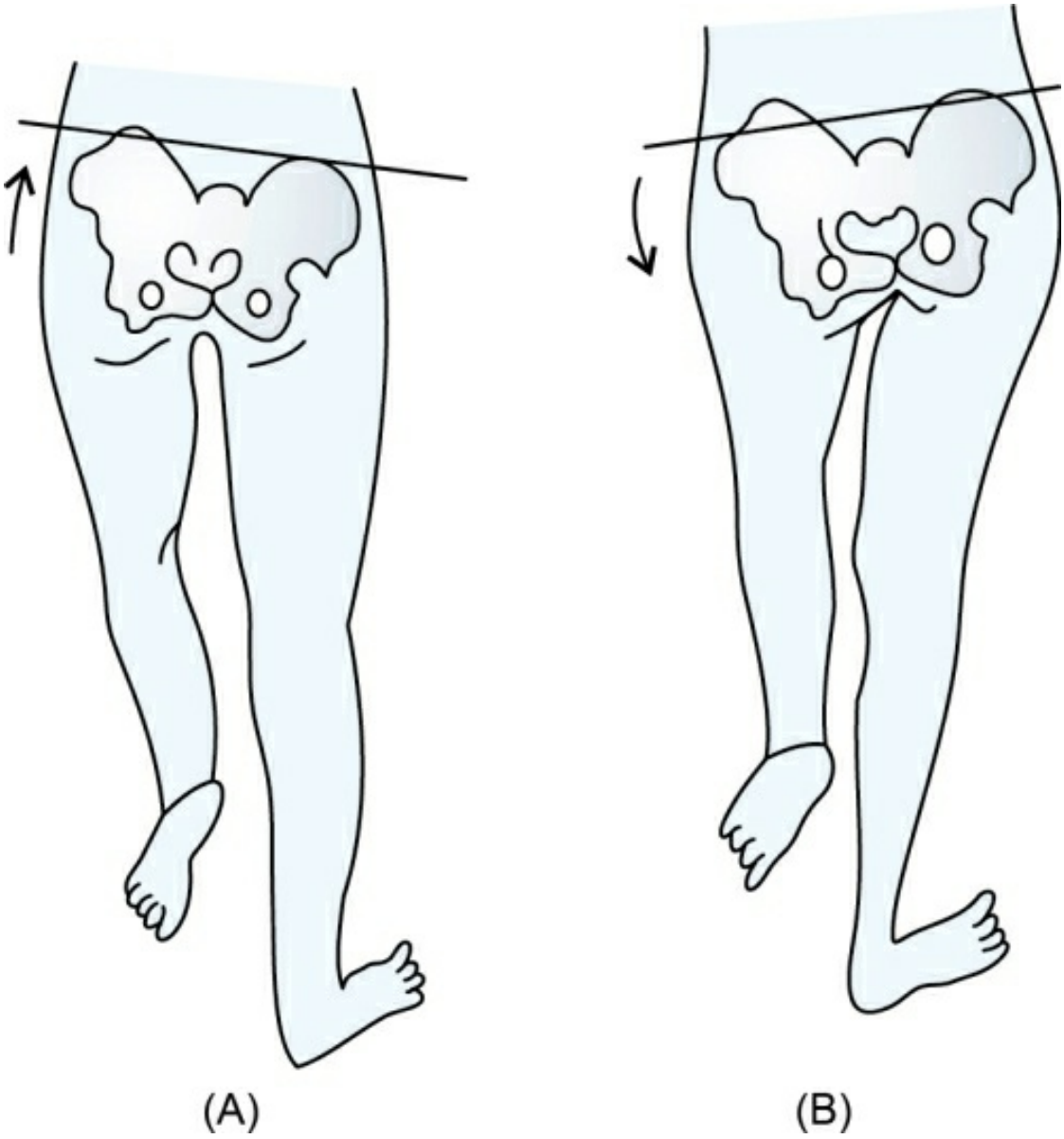

FIG. 35-2 Trendelenburg sign. **(A)** Normal – the pelvis on the side opposite to the normal leg is lifted upwards when standing on the normal leg alone. **(B)** Positive – the pelvis on the side opposite to the affected standing leg drops downwards when standing on the affected leg alone.

Medial rotation at the hip is produced by the anterior fibres of the gluteus medius and minimus along with the tensor fascia lata.

Lateral rotation is principally produced by the obturators, gemelli and quadratus femoris and assisted by the piriformis and gluteus maximus.

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Atmospheric pressure

The coverings of the joint and atmospheric pressure prevent any communication with the exterior. They keep the joint surfaces together and offer stability.

Blood supply

The hip joint and all its components receive rich blood supply through the superior and inferior gluteal, circumflex, iliac and obturator arteries.

Innervation: The pattern of innervation of the hip joint includes branches from the femoral, obturator, accessory obturator and superior gluteal nerves and the nerve to the quadratus femoris. The joint receives its proprioceptive and pain fibres from the same nerves which supply the muscles moving the joint and the overlying skin. This explains the reflex spasm of the overlying muscles and the referred pain to the adjacent skin in diseases of the joint (Hilton, 1971).

Compressive forces on the hip joint (fig. 35-3)

Since the hip is a principal weight-bearing joint, it is subjected to tremendous forces in standing. When standing on one leg, the weight-bearing femoral head is subjected to forces equal to about three times the body weight (Paul, 1966; Rydell, 1966). These forces are produced by the pull of the abductors and the body weight.

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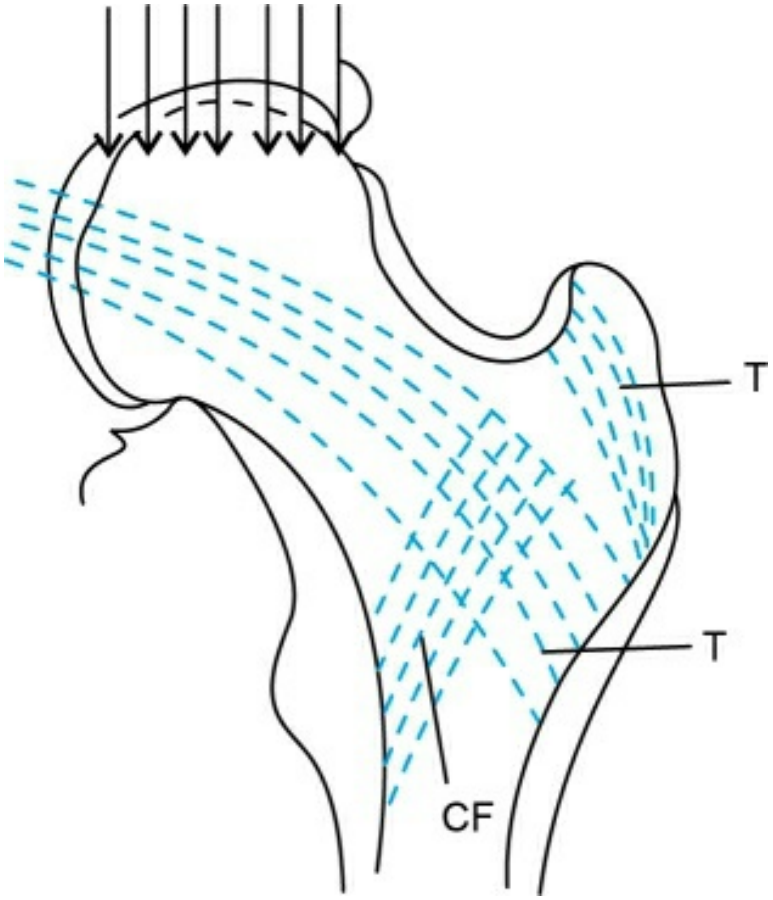

FIG. 35-3 Compressive forces (CF) and areas of tension (T) on the hip joint.

Therefore, in abductor weakness, during the stance phase of the gait cycle, the weak abductors fail to hold the pelvis squared, resulting in downward tilt of the pelvis to the opposite side. This, in turn, results in either a short swing phase on the normal side, or lurch on the side of weakness. Compensatory gluteal lurch shifts the centre of gravity lateral to the fulcrum, allowing gravity to substitute for the inefficient hip abduction mechanism. Therefore, strengthening programmes for the gluteus medius, gluteus minimus as well as the tensor fascia lata are of importance in such cases.

In cases where the weak abductors cannot be strengthened, use of a cane in the contralateral hand reduces forces on the affected hip joint by 50%. This is achieved by transmission of the forces acting on the hip to the cane through the lateral trunk flexors, shoulder depressors, elbow extensors and wrist extensor muscles on the side of the cane.

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Therefore, these muscles should be strengthened in the preambulatory stage (Kessler & Hertlings, 1983).

While performing SLR in the supine position, the hip is subjected to compressive forces greater than the body weight (Rydell, 1966). One must remember this while initiating SLR exercises in patients with internal fixation for hip fracture (Morris, 1971). This observation is also applicable to initiation of strengthening programme at the hip.

The proximal end of the femur is positioned to provide maximal compression and minimal tension and shear to combat the great external load placed on it, like when on one limb stance. Thus, compression becomes a maximal stress while tension and shearing are minimal.

Therefore, if the proximal end of the femur or acetabulum develops abnormalities like coxa valga or coxa vara, the uncontrolled external forces may lead to problems such as subluxation or dislocation of the hip joint, slipping of the epiphysis, osteoarthritis or even femoral fractures.

In coxa valga, the angle between the femoral shaft and the neck is greater than the normal (135 degrees). In paralysis of hip abductors or spasticity of hip adductors, greater force is directed towards the upper lip of the acetabulum. It increases the tendency towards subluxation or dislocation (Fig. 35-4).

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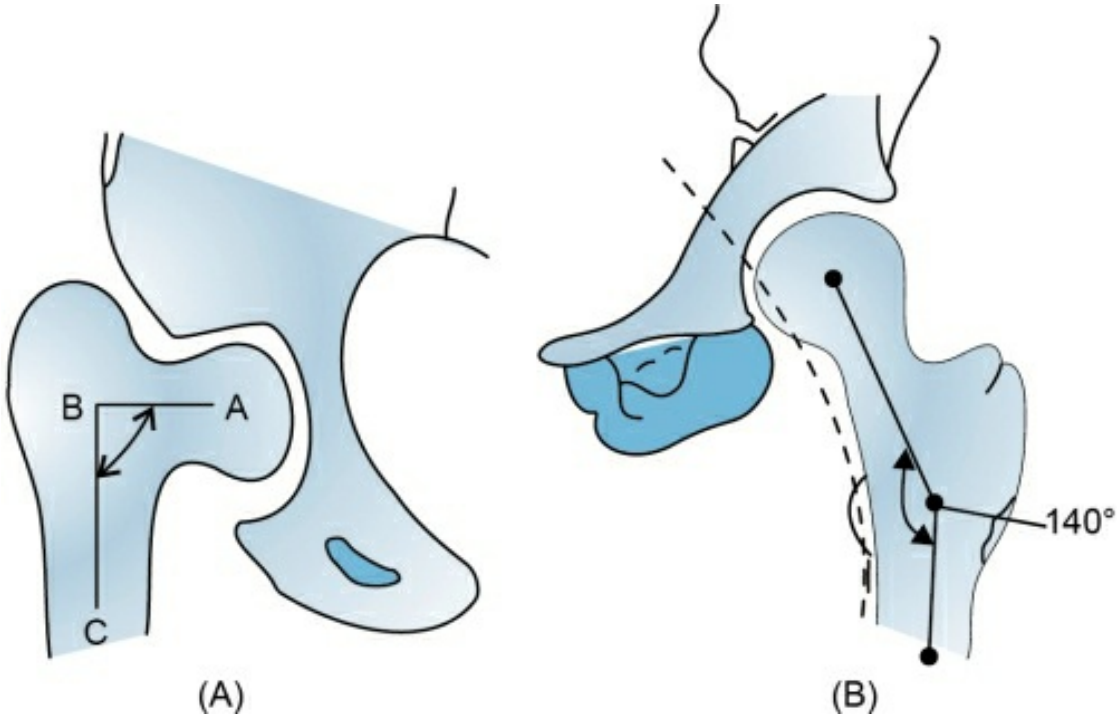

FIG. 35-4 **(A)** Coxa vara: decreased (less than 135 degrees) angle between the neck and the shaft of the femur. **(B)** Coxa valga: increased (more than 135 degrees) angle between the neck and the shaft of the femur.

In coxa vara, the angle of inclination decreases from the normal angle of 135 degrees. This gives rise to an increase in the bending movement together with a more horizontal position of the neck; putting excessive stress at the upper cortex of the neck, increasing the shearing component at the capital femoral epiphysis and decreasing the compressive component. This may predispose the patient to fracture of the femoral neck or slipping of the epiphysis.

Increased compressive force may break down joint tissues and predispose the patient to osteoarthritis. Reduction of bone strength due to osteoarthritis or metabolic bone disease may contribute towards fractures in geriatric patients (Mcleash & Charnley, 1970).

Therefore, a careful analysis of the factors involved in the mechanics of hip joints play a prominent role in the planning and implementation of the objective physiotherapy programme.

There is a definite link between the age group and the possibility of a particular hip disorder (Table 35-1).

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Table 35-1

Expected Hip Disorder as Related to the Age Group

Age Group (Years)	Possible Disorder
0–5 and 25–45	CDH or DDH
2–10	Perthes disease, transient synovitis
2–18	Tuberculosis
6–12	Still disease
4–18	Infective arthritis
12–17	Slipped femoral epiphysis
22–55	Rheumatoid or osteoarthritis
45–70	Fracture of the femoral neck
	Secondary bone tumours

Coxa vara

A decrease in the angle between the neck and the shaft of the femur (normal about 135 degrees in adults and 150 degrees in children) is called *coxa vara*. On the other hand, if the angle is more than the normal values it is called *coxa valga*.

Coxa vara is of the following types:

1. Congenital (infantile)

2. Epiphyseal (slipped capital femoral epiphysis)

The change in the angle causes mechanical restriction of abduction at the hip, shortening of the limb and a waddling gait.

Congenital (infantile) coxa vara

It is characterized by a triangular defect in the inferior portion of the neck of the femur (as seen on an AP view X-ray of the hip) (Fig. 35-5) (Wynne-Davis Fairbank, 1976). It is usually bilateral and may present with pain and stiffness of the hip. On examination the greater trochanter is overridden with resultant shortening of the limb. There is limitation of rotation and abduction of the limb joint.

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FIG. 35-5 Congenital coxa vara.

Treatment

Conservative: Conservative treatment has a very limited role in the management of congenital coxa vara. Milder forms of deformity can be treated by bed rest to relieve strain on the epiphysis; or it can be treated by traction in abduction for 4–6 weeks followed by weight relieving orthosis or POP for 12–18 months.

Surgical treatment

It is indicated in progressive or severe deformity. A corrective (valgus) osteotomy is performed at the intertrochanteric level to increase the neck–shaft angle. The osteotomy is generally fixed internally by a plate and screws (Fig. 35-6). Postoperatively, a dressing is given for about 2 weeks. Mobilization of the hip and non–weight-bearing crutch walking can be started as soon as pain permits, while weight-bearing is allowed after 2–3 months.

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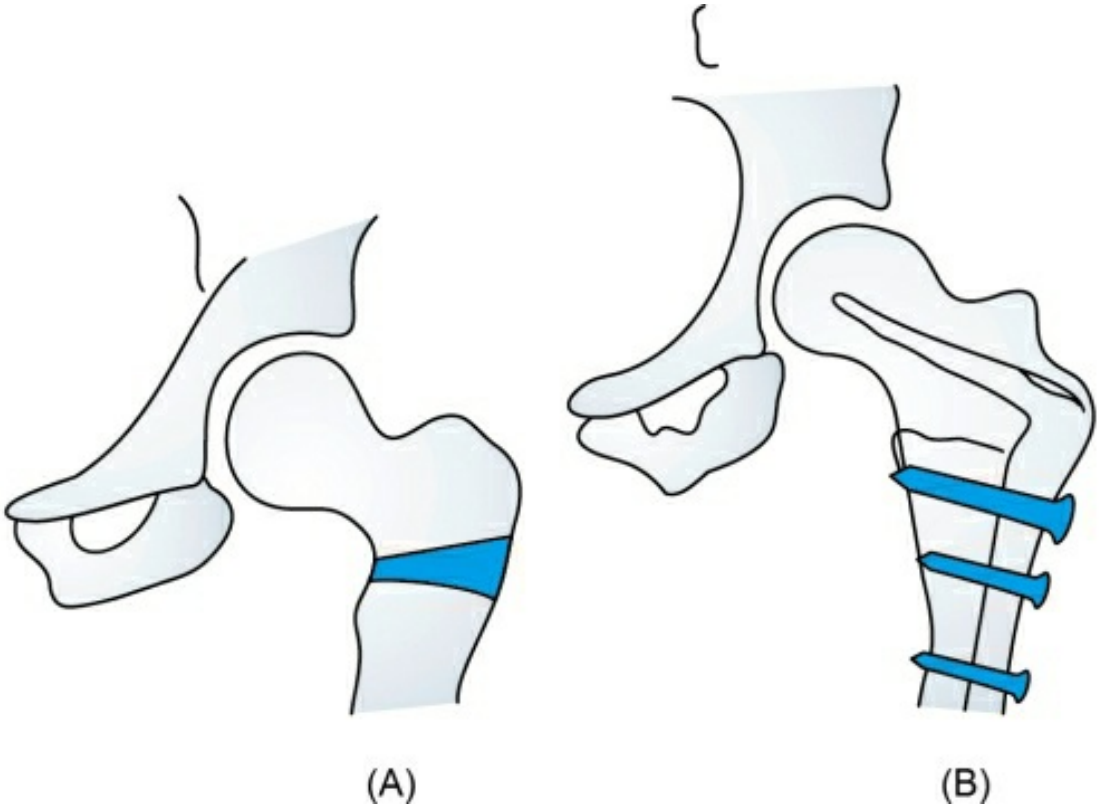

FIG. 35-6 Corrective valgus osteotomy for coxa vara. **(A)** Area of bony wedge at the intertrochanteric region and **(B)** Fixation of the corrective osteotomy by plate and screws.

Epiphyseal coxa vara or slipped capital femoral epiphysis

A condition prevalent in adolescents, it is characterized by sudden or gradual slip of the upper femoral epiphysis resulting in coxa vara (Fig. 35-7) due to strain on the growing bone.

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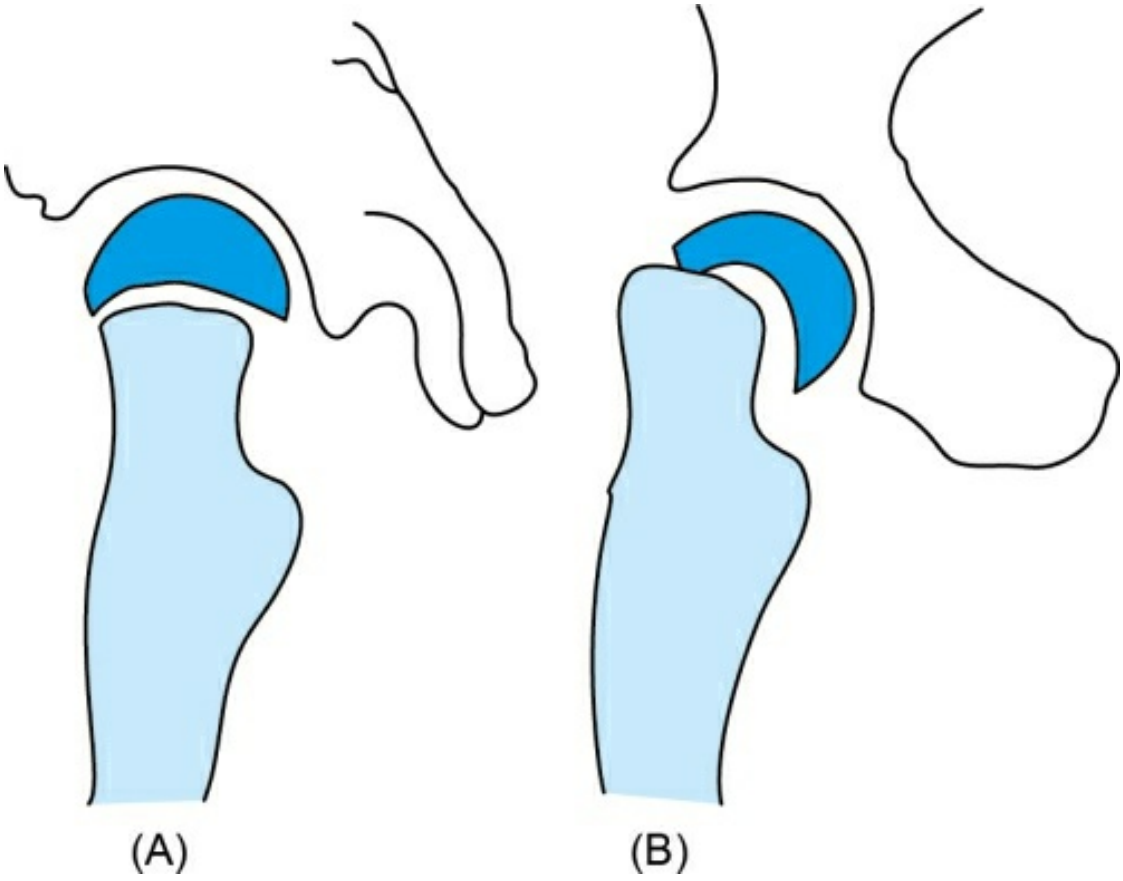

FIG. 35-7 Slipped capital femoral epiphysis. **(A)** Normal position of the epiphysis. **(B)** Posterior and downward slipping of the epiphysis.

Trauma and imbalance between growth and sex hormones have been thought to be the causes of this condition.

This disorder is more common in males between the ages of 12 and 17 years. The child presents with pain in the region of the hip, and a limp. However, initially, the clinical experiences increased tiredness after walking a short distance or standing for some time. On examination, the greater trochanter is at a higher level on the affected side. Abduction, internal rotation and hyperextension are restricted at the affected hip. A characteristic sign is external rotation of the limb when the hip and knee are flexed.

X-rays: X-ray of the pelvis with both hips shows medial, inferior and posterior displacement of the capital femoral epiphysis (Fig. 35-8).

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FIG. 35-8 Slipped capital femoral epiphysis of right hip.

Treatment

In early cases with mild displacement of the capital epiphysis, the epiphysis is fixed with Moore's pins or screws under radiographic control, without attempting reduction of the slip (Fig. 35-9).

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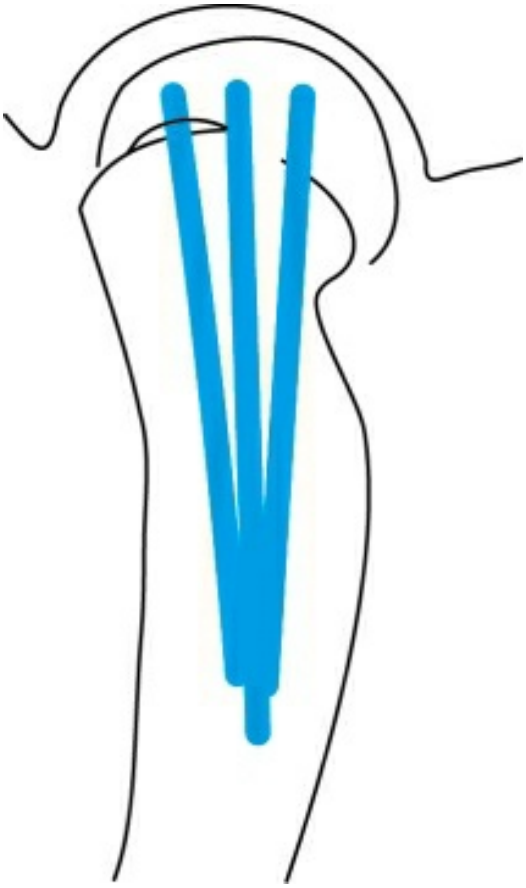

FIG. 35-9 Slipped capital femoral epiphysis fixed with Moore's pins.

The following procedures are performed in cases with marked displacement of the epiphysis:

1. Open reduction: The slip is reduced by open reduction and fixed by pins or screws.

2. Osteotomy of the neck of the femur: An osteotomy is performed at the junction of the neck of the femur with the greater trochanter and a wedge of bone is removed to achieve correction (Fig. 35-10).

The afore-mentioned procedures (1 and 2) carry a risk to the femur (Duttire & Bentley, 1996).

3. Subtrochanteric osteotomy: In this procedure, the epiphyseal slip is left as such and a corrective osteotomy is performed in the

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subtrochanteric region to change the alignment to a certain extent (Fig. 35-11). It does, however, compensate to some extent for the deformity and may, if done in the early stages, considerably improve the gait and relieve symptoms (Griffith, 1991).

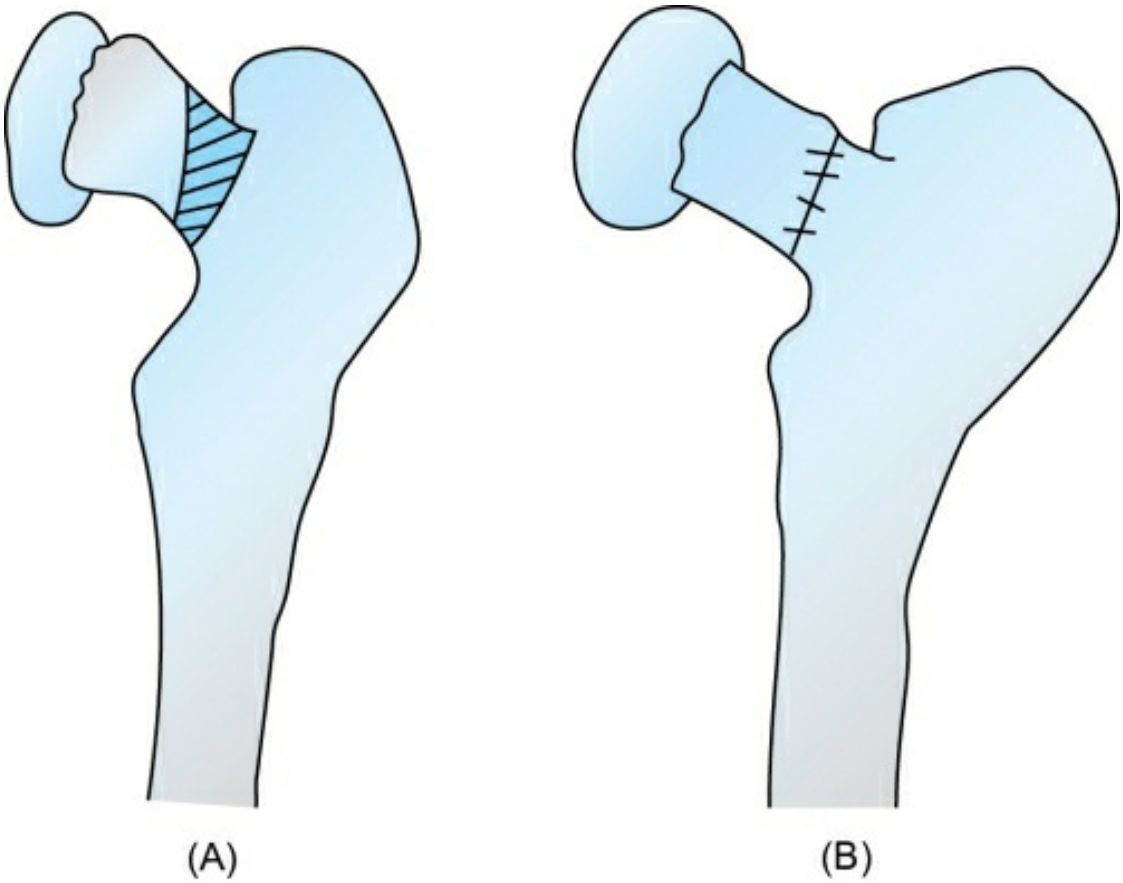

FIG. 35-10 Slipped capital femoral epiphysis—osteotomy performed through the neck of femur, in two planes to normal relationship of the epiphysis and neck of femur. **(A)** Preoperative, **(B)** Postoperative.

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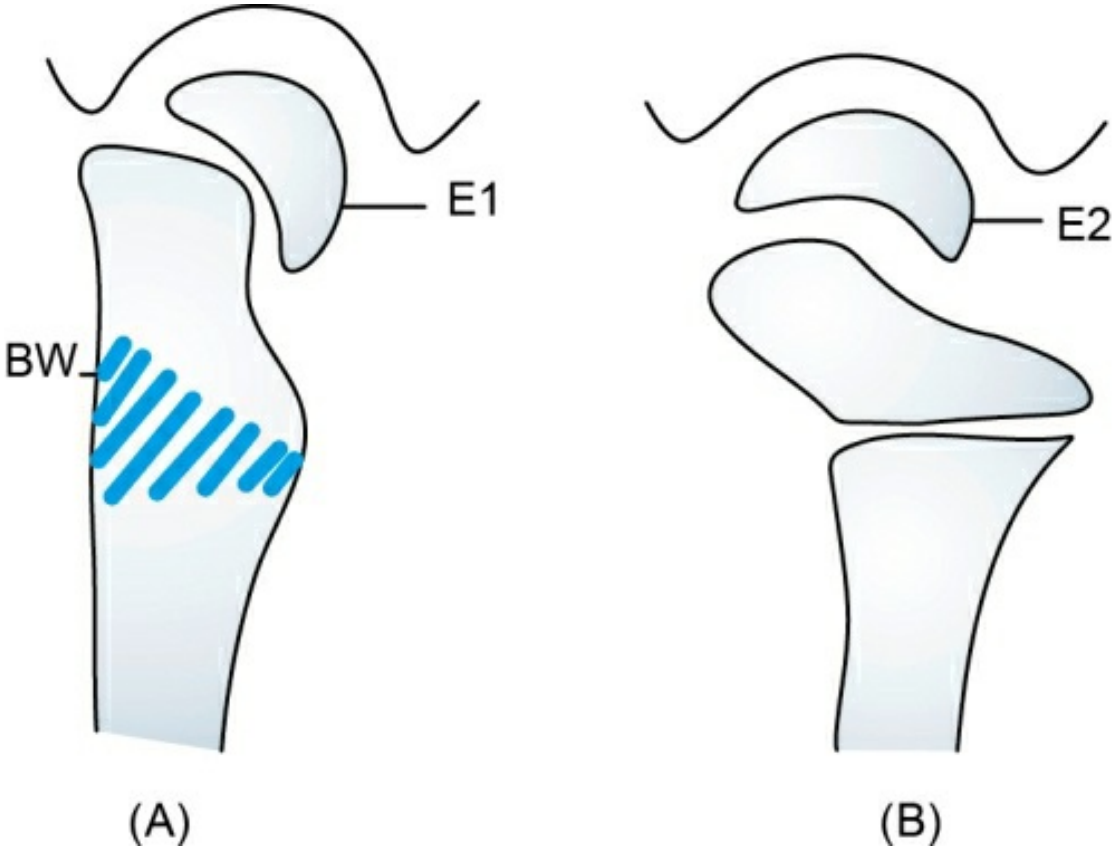

FIG. 35-11 Subtrochanteric osteotomy for slipped capital femoral epiphysis. **(A)** BW, bony wedge for subtrochanteric valgus osteotomy; E1, slipped epiphysis. **(B)** Restoration of epiphysis (E2) to normal position following subtrochanteric valgus osteotomy.

Physiotherapeutic management

During immobilization

- Strong vigorous active movement to the ankle and toes.
- Isometrics to be concentrated for the quadriceps and the glutei.

Mobilization

- Relaxed passive movements with emphasis on the hip abductors and the internal rotators.
- Putting on weight-relieving orthosis, standing balance with PWB;

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making sure that the correct level of pelvis is maintained.

- Re-education in walking to eliminate pelvis drop and waddling gait.
- When present, the limb length disparity should be compensated.

Coxa valga

An increase in the neck–shaft angle of the femur is called *coxa valga*. It is seen in poliomyelitis or other paralytic conditions and some dysplasias.

Treatment

Corrective (varus) osteotomy is done at the intertrochanteric level. The osteotomy is fixed internally with a plate (Fig. 35-12).

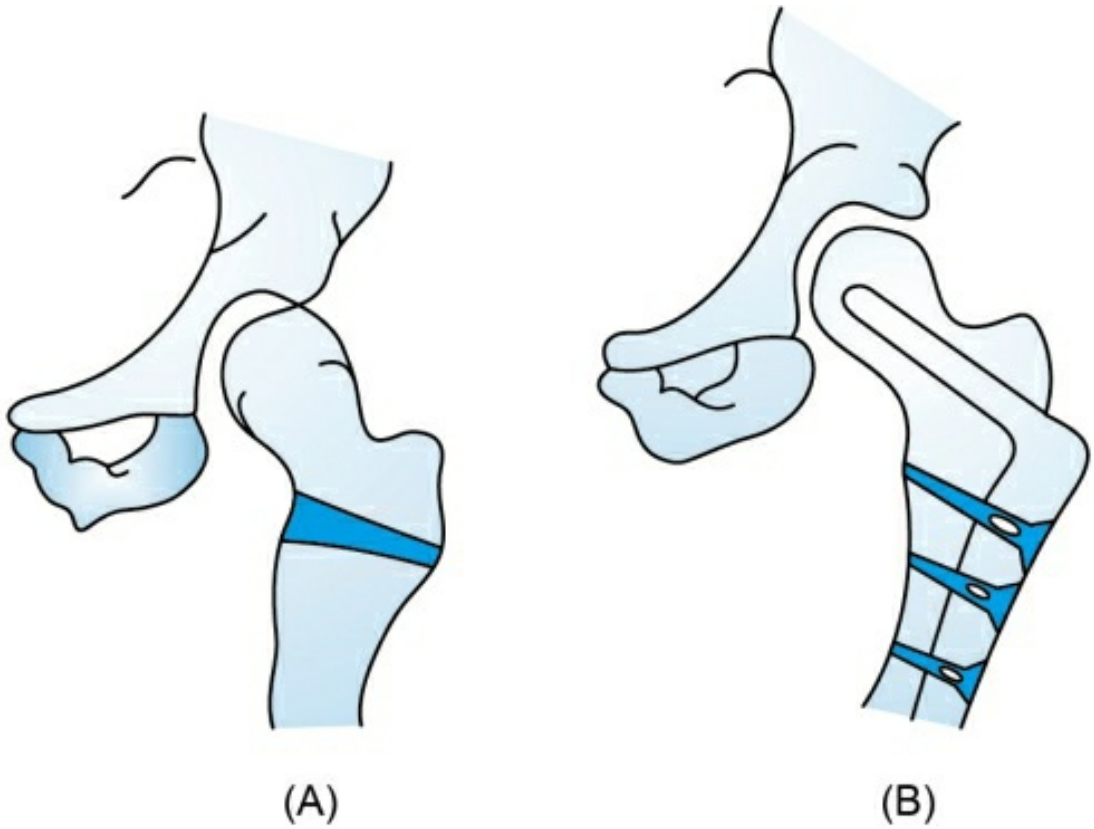

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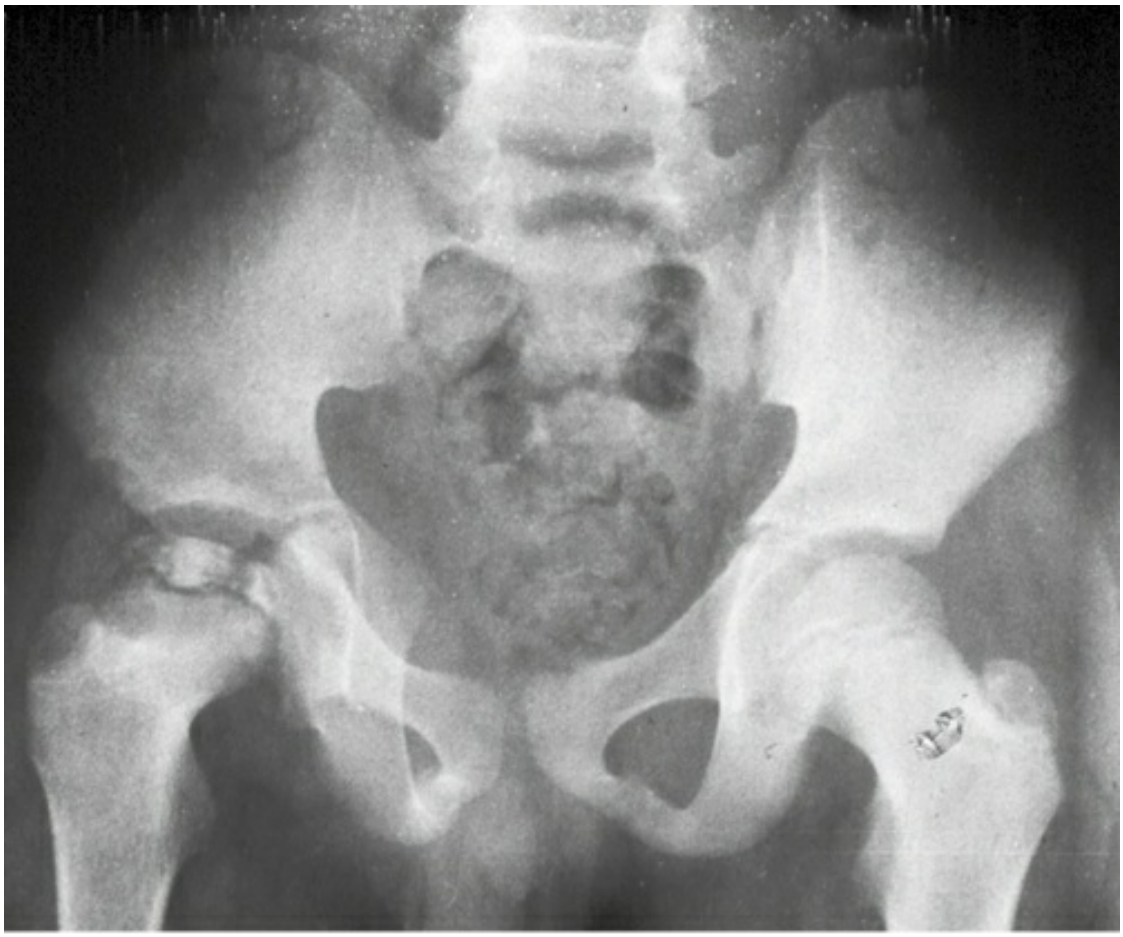
FIG. 35-12 Corrective varus osteotomy for coxa valga. **(A)** Area of bony wedge at the intertrochanteric region for osteotomy. **(B)** Internal fixation of the osteotomy by plate and screws.

Perthes disease (syn: Legg–calve–perthes disease, coxa plana, pseudocoxalgia) (fig. 35-13A)

Perthes disease is a disease of childhood characterized by avascular necrosis of the femoral head. The exact cause is unknown. However, a local disturbance of blood supply is thought to be the main causative factor.



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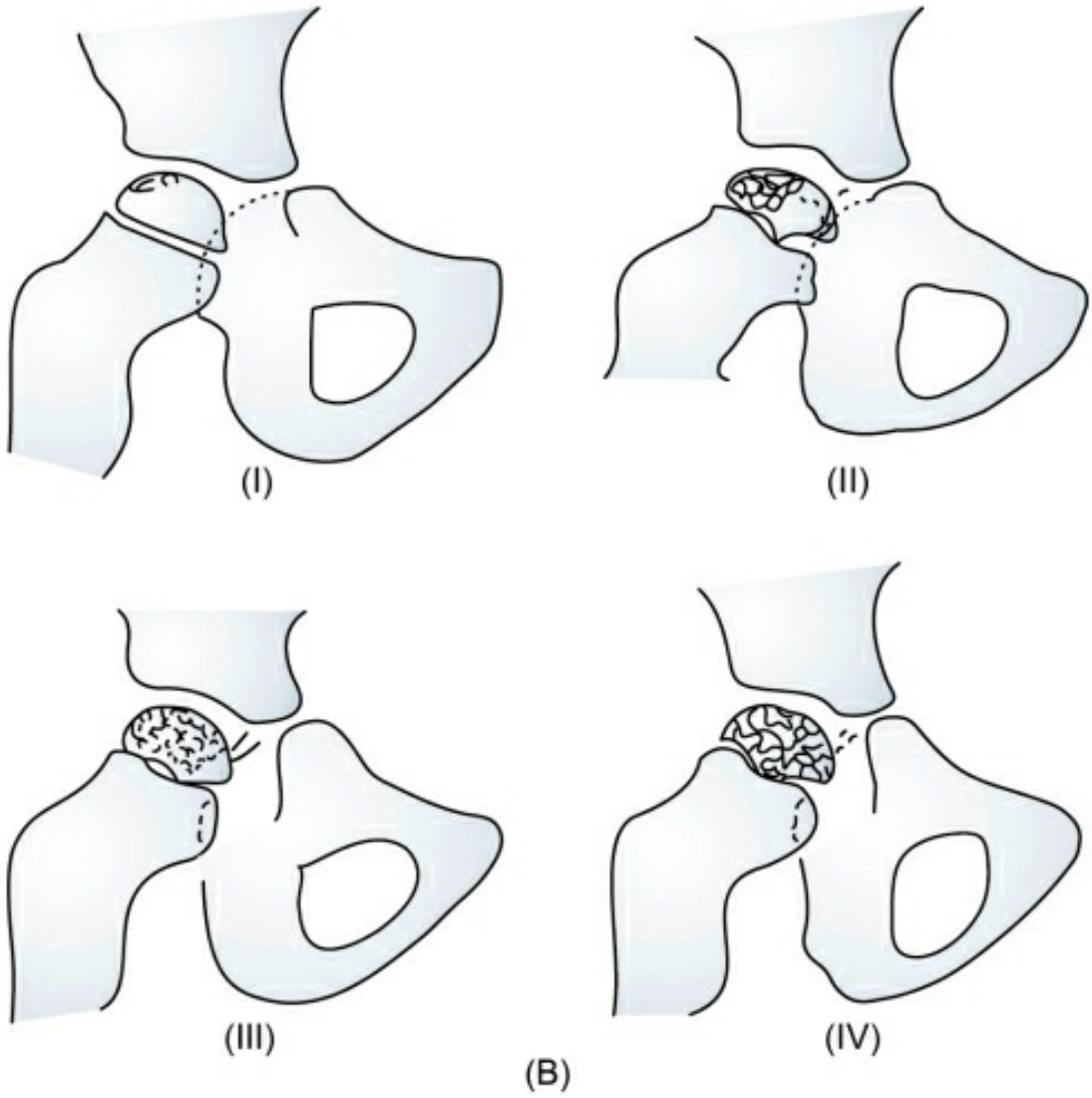

FIG. 35-13 Perthes disease: **(A)** Radiograph. **(B)** four grades of progression: (I) appearance of cyst formation in the anterolateral aspect of the femoral capital epiphysis; (II) involvement of about half portion of the capital femoral epiphysis; (III) most of the capital femoral epiphysis (nearly three-fourth) is involved and (IV) complete involvement of the capital femoral epiphysis.

The epiphysis of the femoral head becomes necrotic and soft. There occurs hypertrophy of the articular cartilage, particularly on the medial side of the head of the femur, pushing the femoral head laterally outside the lateral edge of the superior (weight-bearing) part of the acetabulum (Fig. 35-14). In this state, it is susceptible to deformation if subjected to the stresses of weight bearing. Although, the disease is self-limiting in nature and the head revascularizes and

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hardens again after sometime, it never regains the normal shape if deformed. The whole process takes about 2–4 years.

FIG. 35-14 Perthes' left hip. Note the fragmentation of the femoral head, broadening of the femoral neck and part of the head of femur outside the lateral edge of superior part of acetabulum.

It affects children between 5 and 10 years of age and may be unilateral or bilateral. The child complains of pain in the hip and walks with a limp. All movements of the hip are limited, especially those of abduction and medial rotation.

Radiograph confirms the diagnosis (Fig. 35-13A) and shows the stage of the disease (Grades I–IV) (Fig. 35-13B).

Treatment

1. When the hip is irritable (acute stage), the limb is immobilized in skin traction. The hip is mobilized as soon as the pain and spasm

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disappear.

2. In Grades I and II of the disease, no specific treatment is required; however, the child is kept under observation (also called *supervised neglect*).

3. In Grades III and IV of the disease, the goal of treatment is to prevent the collapse/deformity of the femoral head. This happens when the femoral head is subjugated to the stresses of weight-bearing and muscular forces. When the head is not deformed, it is contained inside the acetabulum by maintaining the hip in abduction. It can be achieved by a plaster, splint, or by surgery (varus osteotomy of the proximal femur or osteotomy of the pelvis).

4. In Grades III and IV of the disease, when the head is deformed, no treatment is possible. Osteoarthritis of the hip will develop eventually, which may need surgery in the form of total hip replacement.

Physiotherapeutic management

Basic objective: Regaining the maximum possible range of motion at the affected hip along with the strength to achieve physical independence. The therapeutic approach has the following functions.

1. **Reduction of muscular spasm, pain and inflammation:** Muscular spasm due to the disease process is the primary cause of pain and deformity. It can be controlled by applying cryotherapy techniques or moist heat with the leg maintained in traction and gentle active toe and foot measurement with traction on.

2. **Isometric painless contractions:** Isometric painless contractions should be taught for the hip extensors, abductors and quadriceps with the leg in traction.

3. **Intermittent compression of the joint:** It can be achieved by early slow relaxed passive movements. This helps in improving nourishment of the joint cartilage, moulding the joint surfaces and

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maintaining normalcy of the soft tissues (Ferguson, 1968; Petrie & Bitenc, 1978).

4. **Maintenance of the range of motion:** The full range of movements of hip extension, abduction and internal rotation is carried out and measured at regular intervals. These movements usually get limited due to the adaptive resting posture of the limb in flexion, abduction and external rotation. This resting posture in one position can cause adaptive shortening of the muscles and lengthening of the opposite group of muscle in which the limb is kept, e.g. if limb is in flexed position then the extensor group of muscles may get elongated. Consequently, the flexor group of muscles will pull all the more aggravating the flexion deformity (Kendall, McCleary, & Provance, 1993, pp. 334–335).

Earlier the mobilization, faster and better the results.

Reduction in the hip range of motion: Mainly in abduction, flexion and internal rotation may lead to hypotrophy or atrophy of the thigh muscles. The latter posture results due to distension of the joint capsule following synovitis (Eyring & Murray, 1964).

If the tendency for malpositioning of the limb persists, a splint may be used to maintain the hip in abduction, extension and internal rotation.

5. **Prevention of contractures:** The tendency to develop flexor tightness and flexion contracture at the hip is common. This complicates ambulation and the gait pattern when the child is allowed to bear weight. Therefore, proper care is necessary to avoid flexion contracture at the hip. Regular sessions of flexing the normal hip and gently stretching the affected hip into extension are taught and checked. This can be made effective by using the force of gravity and a tolerable weight (Fig. 35-15). Frequent sessions of assisted prone lying

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are also helpful in preventing flexion contractures at the hip.

6. **Increase of muscle strength:** As the pain and spasm reduce, active-assisted, active or resisted exercises may be started depending upon the degree of discomfort. The emphasis should be on the eccentric and isometrics at the terminal range of movement to the abductors and extensors of the hip, quadriceps and hamstrings, and dorsiflexors and plantarflexors and intrinsic muscles of the foot.

7. **Ambulation:** Initially the child is not allowed weight bearing since the leg may be immobilized in a POP cast or abduction splint. Therefore, non–weight-bearing standing and walking are to be taught in parallel bars. This could be progressed to a walker and then to axillary crutches by using a special Synder sling. This allows non–weight-bearing ambulation on the affected leg. All the basic methods of ambulation with crutches and transfer activities are taught.

FIG. 35-15 Prevention of hip flexion contracture by sustained light weight.

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Special braces for weight-bearing with hip containment

1. A special brace (Scottish Rite brace) allows flexion of the hip joint while it is maintained in abduction.

2. The second method is the Petrie plaster method (Fig. 35-16). This maintains the hip in 30 degrees of abduction and 20 degrees of internal rotation, with 15 degrees of flexion at the knees.

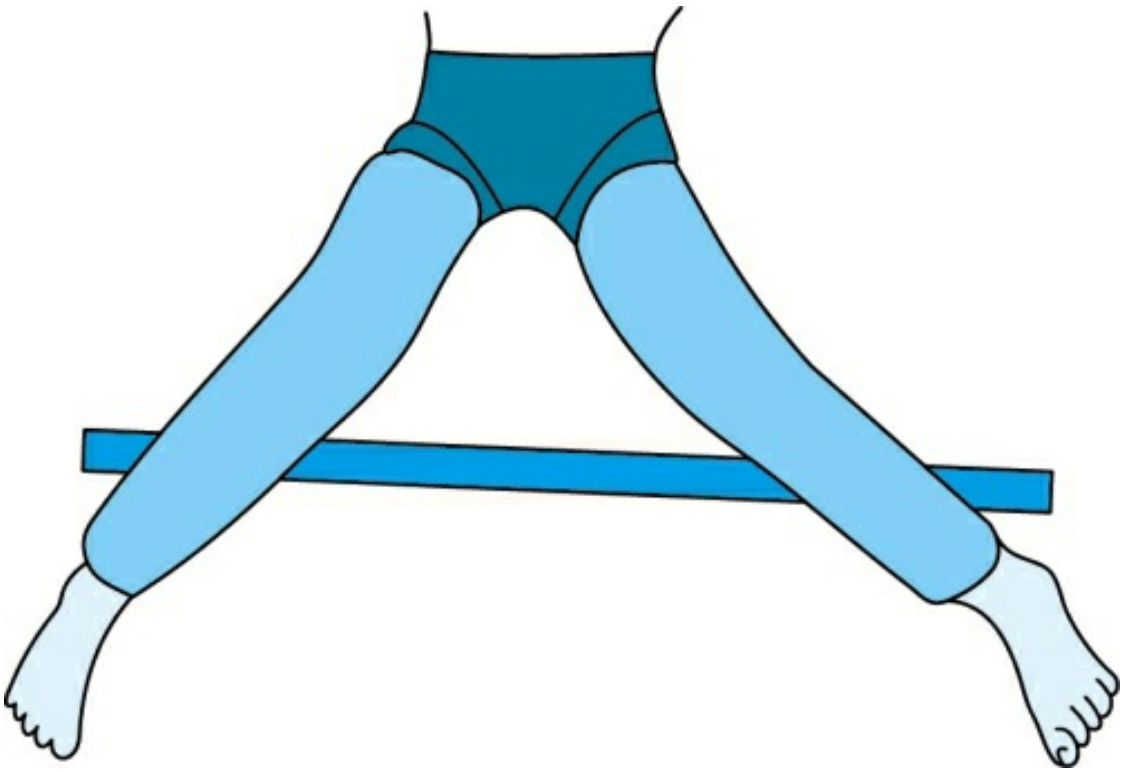

FIG. 35-16 Broomstick plaster (Petrie).

Computerized gait analysis of a patient suffering from Perthes disease reveals two distinct gait patterns.

1. This pattern corresponds well with the Trendelenburg pattern, i.e., pelvic drop to the swinging limb during single stance phase of more than 4 degrees and maximum of more than 8 degrees.

Trunk lean in relation to the pelvis to the stance limb during

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single stance phase of more than 5 degrees. Thin pattern does not educe hip loading and femoral head coverage is reduced, so should be treated during physiotherapy.

Hip adduction during single stance phase more than 9 degrees and maximum up to 11 degrees.

2. This gait pattern which is found in 36.4% of patients is characterized by trunk lean of 3 degrees towards the stance limb. The pelvis is either level or elevated on the swinging limb side. This leads to reduction of abductor management and production of hip unloading effort; it corresponds to the Duchenne gait pattern.

The child needs training in balanced standing, weight bearing and ambulatory activities. Appropriate guidance to the parents regarding support and assistance to the child is a must during home ambulation.

On removal of the splint/POP cast/brace, active mobilization is to be initiated. It is progressed from relaxed passive movements to active resisted movements in stages. Hydrotherapeutic pool exercises are very useful at this stage.

Instructions regarding proper postural management to avoid tightness or contractures of the susceptible muscle groups need to be emphasized. Regaining full range of movements at the knee is very important at this stage. Initial weight bearing has to be assessed carefully for pain. If pain is felt on weight bearing, ischial weight relieving brace may be given.

In a short limb, weight bearing should be initiated with an

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adequate shoe raise to avoid pain and excessive compressive forces on the affected hip. Functional positions like squatting on the floor, cross-leg sitting and stair climbing should be initiated with enough support and minimal discomfort. The assistive aids should be gradually reduced. The total outcome of management depends upon the course of the disease.

The importance of continuing regular resistive exercises to the hip needs to be explained. Undue fatigue or straining positions should also be discouraged, with proper guidance for smooth rhythmic ambulation. These three factors need to be educated keeping in view the possibility of early osteoarthritis in the affected hip joint at a later date (Somerville, 1971).

Physiotherapeutic management following surgery: Varus derotation osteotomy of the femur is the usual surgical procedure. It allows better containment of the femoral head within the acetabulum.

After surgery, the limb is immobilized in a hip spica for a period of 6 weeks and the physiotherapy is limited to:

1. Resistive toe movements and isometrics for the hip and knee muscles inside plaster for the affected side.

2. Resistive full range movements for the contralateral knee, ankle and toes with isometrics for the hip abductors and extensors.

Mobilization: After removal of hip spica, gradual mobilization of the hip and knee is initiated with relaxed passive movements. Continuous passive motion (CPM) equipment is very useful to initiate the relaxed passive ROM exercises.

Mobilization, strengthening and ambulation are progressed as described for conservative treatment.

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Avascular necrosis (fig. 35-17)

Avascular necrosis (AVN) of the femoral head, also called osteonecrosis, is caused by disruption of blood supply to the femoral head.

FIG. 35-17 Avascular necrosis of bilateral femoral heads. Note the sclerosis and deformation of the femoral head.

Aetiology

It can be caused due to injury to the hip joint or due to other causes.

1. Post-traumatic: Fracture of the femoral neck

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- Dislocation of the hip

2. Nontraumatic: Steroid-induced

- Organ transplant
- Alcoholism
- Sickle cell disease
- Systemic lupus erythematosus (SLE)
- Postirradiation

3. Idiopathic

Clinical features

The patient presents with pain and limitation of movements at the affected joint with a limp. In two-thirds of the cases, the disease is bilateral. Initially, the patient has night pain aggravated by activity. Later in the course of the disease, the pain is continuous, deep seated and rather ill defined. On examination, there is limitation of movements at the hip joint and internal rotation is painful.

Investigations

1. X-ray of the hip shows increased sclerosis, cyst formation and deformation (in the later stages of the disease) of the femoral head (Fig. 35-18). The disease can be staged radiographically (Ficat & Arlet, 1964) (Table 35-2).

2. MRI is the gold standard in the diagnosis of AVN with a sensitivity and specificity of more than 98%.

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FIG. 35-18 AVN of the femoral head right side. Note the sclerosis and deformation of the head of femur.

Table 35-2

Stages of Osteonecrosis

Stage I	X-rays normal
	Biopsy positive
	Bone scan may be positive
Stage II	Bone quality abnormal (on X-rays)
	Bone outline intact
	Joint space preserved
Stage III	Bone outline disrupted
	Sequestrum formation
	Joint space preserved
Stage IV	Secondary osteoarthritis

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Treatment

The treatment, in a case of osteonecrosis, depends upon several factors such as the patient's age, stage of the disease, patient's occupation and life expectancy. However, the following procedures may be performed, depending upon the merit of a particular case.

In the early stages of the disease

Core decompression of the femoral head: Raised intraosseous pressure is reported to impair the vascularity of the bone leading to avascular necrosis. Drilling the centre of the neck and head of the femur decompresses the bone thereby decreasing the intraosseous pressure. This procedure relieves pain and may arrest progression of the disease (Fig. 35-19).

Core decompression and nonvascularized fibular bone grafting: In addition to the operation of core decompression of the femoral neck and head, a fibular graft is inserted into the hole thus drilled (Fig. 35-19). This may provide support to the femoral head, prevent collapse and help in the repair of the recipient bone.

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FIG. 35-19 Avascular necrosis of the femoral head, treated by core decompression and fibular grafting. The fibular graft is seen in place.

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Core decompression and vascularized bone grafting

Vascularized fibular graft (with vascular anastomosis) provides structural support and enhancement of vascularity in the recipient area to promote healing.

In the late stage

An intertrochanteric valgus osteotomy is performed. This shifts the area of weight bearing from the affected superolateral part of the femoral head to other normal areas.

Revascularization, muscle and pedicle bone graft are the other alternative procedures.

In the advanced stage of the disease

When significant collapse of the femoral head is present, associated with secondary osteoarthrosis of the hip, total joint replacement is indicated (Fig. 35-20).

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(A)

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(B)

FIG. 35-20 **(A)** Advanced case of avascular necrosis of the femoral head with secondary osteoarthritis, seen on both sides and **(B)** treated by total hip replacements on both sides.

Physiotherapeutic management

The approach of physiotherapy depends upon the surgical procedure adopted.

Non–weight-bearing phase: During the immediate postsurgical phase, vigorous exercises to the ankle and foot, along with isometrics to the quadriceps and hamstrings are begun. As the pain reduces, isometrics to the glutei should be initiated.

Gentle mobilization in the form of relaxed passive movements is initiated gradually and worked up to the

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maximal pain-free range.

Isometrics with longer holds are important to minimize muscle atrophy. Mobilization should be concentrated to regain abduction and medial rotation as restriction of these movements and muscle atrophy have been reported as salient features following AVN.

Isotonic exercises including all movements at the hip are initiated when good ROM returns and progressed to isokinetic exercises.

Weight-bearing phase: Initially, weight bearing is taught in standing with axillary crutches or a walker. Gradually, weight transfers on one leg are taught. Four-point crutch walking is initiated to minimize weight on the hip joints. As the pain is reduced, one crutch should be discarded. Meanwhile the exercise programme to the hip and knee is made progressive to improve strength and endurance of the muscles at the hip and knee joints.

Once an acceptable gait and balance are achieved, ambulation is progressed to two canes or a single cane without compromising the pattern of gait.

Activities like supported squatting or cross-leg sitting should be initiated with adequate support to avoid over-stretching.

Adequate independence in functional activities should be regained by 12–16 weeks. Physiotherapy following osteotomy and total joint replacement is described under the respective headings.

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Osteochondritis

It is a noninfective and noninflammatory condition causing disturbance of vascularity in the epiphysis or in the ossification nucleus which may get softened and deformed.

Common sites of osteochondritis

- Head of femur (Perthes)
- Lunate (Kienbock disease) (Fig. 35-21)
- Vertebral epiphysis (Scheuermann disease)
- Tibial tubercle (Osgood–Schlatter disease)
- Lower end of femur (Osteochondritis dissecans)
- Elbow (Capitulum)
- Rarely Ankle (talus)

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FIG. 35-21 Kienbock disease. Avascular necrosis of the lunate bone. Note the collapse of the lunate (arrow).

Treatment

Treatment is on the same lines as avascular necrosis or Perthes disease.

Rare hip pathologies

Irritable hip

History of mild trauma, limp and restriction of movements in a child due to transient synovitis may cause irritable hip.

The patient presents with painful weight bearing while performing movements of the hip joints.

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It is treated with NSAIDs, rest and gentle traction till the diagnosis is confirmed.

Dysplasia

The presence of excessive acetabular slope localizes the weight-bearing forces on the central area of the femoral head.

Painful limp with movement restriction are the typical features.

Failure of conservative treatment may need surgical intervention to improve the containment of the femoral head like Chiari's osteotomy, acetabular shelf operation or high femoral osteotomy.

Iliotibial tract syndrome

The iliotibial tract syndrome presents as pain over the upper part of the lateral aspects of the thigh or at the lateral aspects of the knee with occasional limp after excessive cycling. This condition is common amongst young persons.

Examination of the spine, hip, knee or sacroiliac joints does not reveal any positive findings. However, Ober's test indicates selective tightening of the iliotibial band. In this test, the affected thigh fails to reach the horizontal plane when tested in a side lying position (Fig. 35-22). The tightening may be present in the vastus lateralis also, which may result from the excessive lateral pressure syndrome.

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FIG. 35-22 Ober's test to detect tightening of the iliotibial tract. Thigh fails to reach the horizontal plane when abduction is attempted following passive adduction–extension and internal rotation.

Treatment

The basic approach of treatment is the regularly performed graduated sustained stretching of the affected muscle.

1. Discontinue cycling.

2. Hydrocollator pack over the iliotibial band and vastus lateralis.

3. Ultrasonic exposure over the tender area.

4. Short but sustained sessions of iliotibial band stretching.

Wester and Beaton (1988) modified Ober's test to achieve effective stretching. It combines hip adduction, extension and lateral rotation with knee flexion. This was done with a 10-second hold in the

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maximally stretched position, six times a day.

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CHAPTER
36

Regional orthopaedic conditions at the knee

OUTLINE

- Functional anatomy
- Examination of the knee
- Ligament injuries
- Arthroscopy and arthroscopic surgery
- Osteotomy around the knee
- Quadricepsplasty
- Chondromalacia patellae
- Osteochondritis dissecans
- Popliteal cysts

Functional anatomy

The knee is a modified hinge joint which plays an important role in stabilizing the body in an erect posture. The osseous portions of the knee include the femur, tibia, patella and fibula (Fig. 36-1). These osseous portions together form two joints:

1. Tibiofemoral joint

2. Patellofemoral joint

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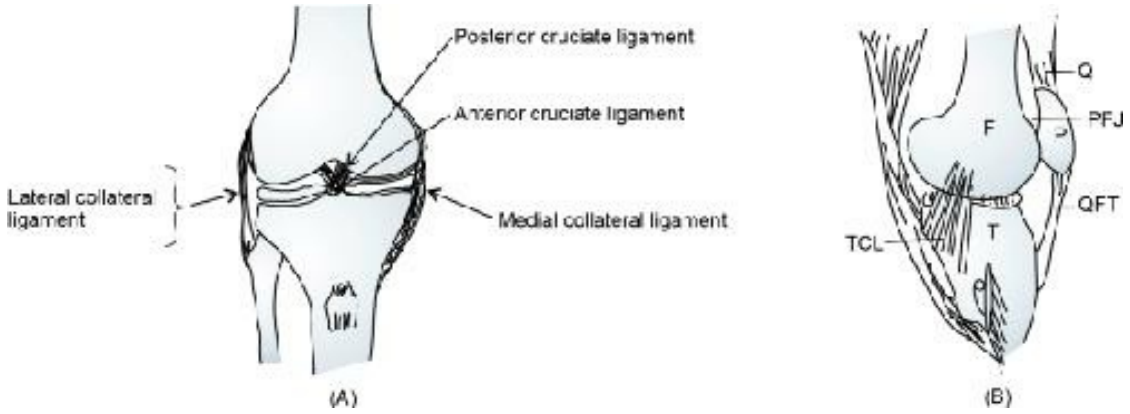

FIG. 36-1 Knee joint. **(A)** Anteroposterior view. **(B)** Lateral view from medical aspect. F, femur; T, tibia; P, patella; TCL, tibial collateral ligament; PFJ, patellofemoral joint; Q, quadriceps; QFT, quadriceps femoris tendon.

The tibiofemoral joint is divided into the medial and lateral compartments (Blackburn & Craig, 1980). The function of the knee joint primarily depends upon its static and dynamic stability. The knee derives its static stability from the ligaments, whereas the dynamic stability is attained through the musculotendinous units and their aponeuroses (McCluskey & Blackburn, 1980).

Static stability

The distal end of the femur has medial and lateral condyles. They are convex from side to side and are separated by an intercondylar notch in between. The proximal end of tibia has two condyles which are concave from side to side and are separated by raised medial and lateral intercondylar eminences or tibial spines. Therefore, convexities of the condyles of the femur with the intercondylar notch are well secured to the concavities of tibial condyles and tibial spine. This offers static stability to the knee joint in extension. A thin fibrous capsule, which is the largest synovial joint capsule in the human body, provides an additional covering to the joint.

Dynamic stability

The basic frame for static as well as dynamic stability is provided by the condyles of the femur and the tibia, strong ligaments, powerful muscles and the medial and lateral menisci. Functions of the menisci

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are as follows (Fig. 36-2):

1. They act as space occupying washers to maintain the joint space and serve as shock absorbers against compressive forces (Grood, 1984), taking about 50–70% of the load across the knee.

2. They provide a concave surface over the convex tibial plateaus for stable articulation with the femoral condyles. This improves joint stability by decreasing the contact stress on the articular surfaces of the knee (Grood, 1984; Manquet & Pelzer, 1977; Walker & Erkman, 1975).

3. They improve nutrition and lubrication of the articular cartilage by spreading synovial fluid over it.

4. They bear weight and transmit between 50% and 70% of the load applied across the joint.

5. They also facilitate rotation of the opposing articular surfaces of the knee joint during locking and unlocking. To understand the interaction between osseous and soft tissue components, in relation to the dynamic stability, the knee is subdivided into:

(a) Medial compartment

(b) Lateral compartment

(c) Extensor apparatus

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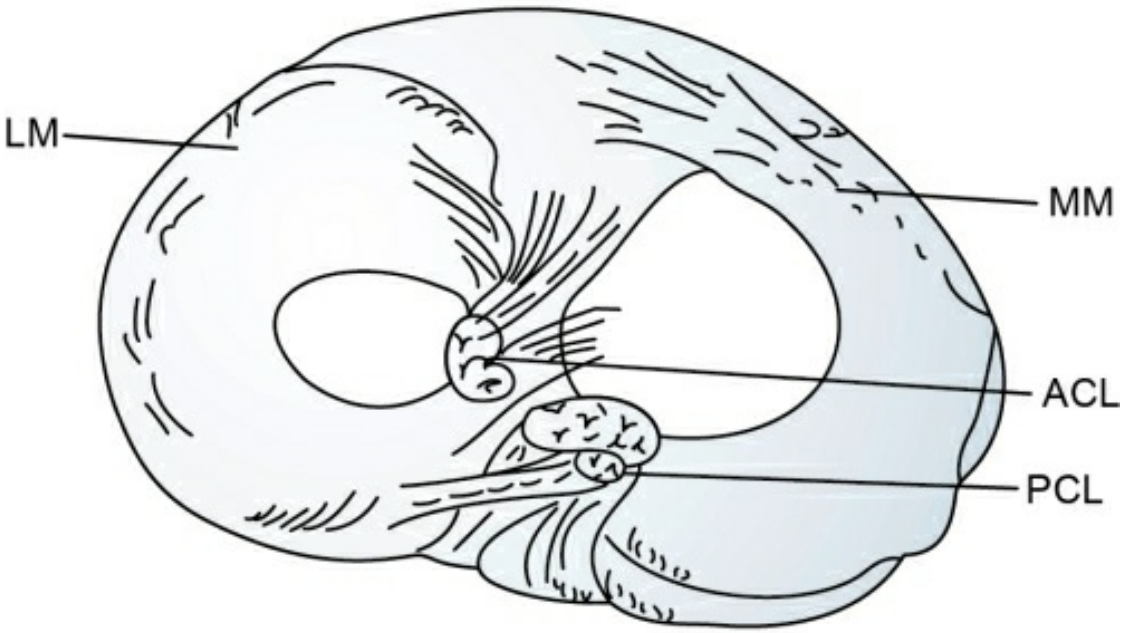

FIG. 36-2 Major knee ligaments and their attachments. LM, lateral meniscus; ACL, anterior cruciate ligament; PCL, posterior cruciate ligament; MM, medial meniscus.

Medial compartment

Ligaments: The medial meniscus is closely attached to the femur and tibia by meniscofemoral and meniscotibial ligaments, respectively, which lie deep to the tibial collateral ligament. Therefore, its motion is less. The posterior cruciate ligament, 'the main stabilizer' of the knee, consists of posteromedial and anterolateral fibre bundles. During knee flexion, the anterolateral bundle is tense while in extension, the posteromedial bundle becomes taut to prevent posterior displacement of the tibia on the femur. However, they may be torn on forceful hyperextension of the knee.

Muscles: The pes anserinus group consisting of the sartorius, gracilis and semitendinosus provide medial stability because of their anatomical disposition. The semimembranosus with its five branches offers support to the posterior and posteromedial capsule, medial meniscus and tibia. The muscular attachments to the medial

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meniscus pull the medial meniscus posteriorly during flexion.

Lateral compartment

Ligaments: Like the medial meniscus, the lateral meniscus is also closely attached by meniscofemoral and menisco-tibial lateral capsular ligaments. The anterior third of the lateral capsule provides some static support. The middle third of this lateral capsular ligament provides support against anterolateral rotatory instability. The posterolateral third of the lateral compartment is supported by the arcuate complex. It consists of the arcuate ligament, fibular collateral ligament, tendon of the popliteus and posterior third of the lateral capsular ligament. The anterior cruciate ligament, also a part of the lateral compartment, has two major fibre bundles, namely, anteromedial and posterolateral. There is an intermediate bundle in between these two bundles. The tension in the anterior cruciate ligament provides stability to the knee as it moves from flexion to extension. It also prevents anterior displacement of the tibia on the femur.

Muscles

1. They provide force for the strong movements of the knee joint

2. They provide dynamic stability

3. They cause absorption of the weight-bearing forces as well as the forces generated during activity

The muscular support is provided mainly by the iliotibial band, iliotibial tract, biceps femoris and popliteus muscles. The popliteus muscle, which originates from the lateral femoral condyle and is inserted on the posterior medial edge of the tibia, reinforces the posterior third of the lateral capsular ligament. The posterior third of the lateral capsular ligament is responsible for internal rotation of tibia during the initial flexion of the knee producing unlocking or 'screw home' mechanism of the knee.

At the posterior compartment, the joint stability is mainly achieved

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by thick and doubly strong posterior cruciate ligament.

Extensor apparatus

Its components are as follows:

1. Patella

2. A group of six extensor muscles and the quadriceps femoris tendon

3. Patellofemoral and patellotibial ligament (ligamentum patellae)

4. Patellar bursae and fat pads in the infrapatellar and suprapatellar regions

5. Synovial membrane and capsule in the antero-medial and anterolateral portions of the joint

The efficiency of the extensor mechanism largely depends upon the unity and function of three structures, i.e., the patella, quadriceps femoris and ligamentum patellae.

1. *Patella*: It provides dynamic stability to the knee joint during the varied movements because of its shape and location.

2. *Extensor group of muscles*: The critical strength and support necessary for the extensor mechanism are provided by the quadriceps apparatus. The latter consists of the rectus femoris, vastus intermedius, vastus lateralis, vastus medialis longus, vastus medialis oblique fibres, articularis genu and the patellar ligament (patellar tendon) (Fig. 36-3). The selective action of these attachments also provides varying degrees of dynamic stability.

The knee joint is most stable when it is locked in full extension by the action of the quadriceps femoris. The active contraction of the quadriceps also controls the knee in a position which is short of full extension. Thus the

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efficiency of the extensor mechanism plays a vital role in the stability of the knee.

3. *Patellofemoral and patellotibial ligaments*: Along with the thickened extensor retinaculum, which covers the anterior portion of the knee, it mainly offers stability to the patella.

4. *Patellar bursae and fat pads*: Prepatellar bursa, infrapatellar bursa, along with the bursae at the anterior, medial and lateral portions of knee and the infrapatellar fat pad provide ease of action to the extensor mechanism by reducing friction. The prepatellar and intrapatellar bursae are prone to inflammation.

5. *Synovial membrane*: The synovial membrane of the knee is developed from three separate pouches (plica). The plica courses medially beneath the extensor mechanism and runs distally across the medial patellar border and medial femoral condyle, finally attaching to the fat pad.

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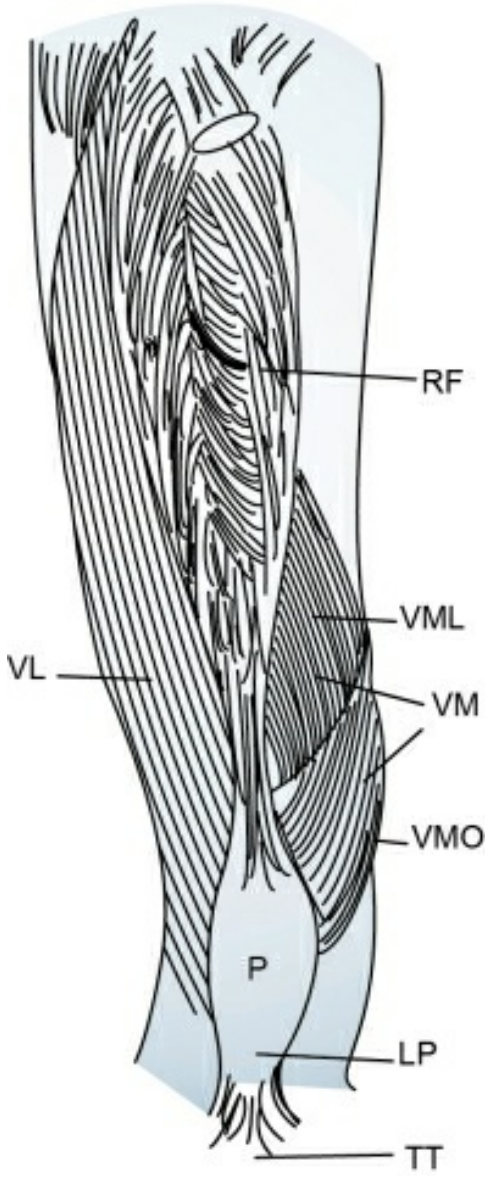

FIG. 36-3 Extensor group of muscles. RF, rectus femoris; VL, vastus lateralis; VM, vastus medialis; VML, vastus medialis longus; VMO, vastus medialis oblique; P, patella; LP, ligamentum patellae; TT, tibial tubercle.

Movements of the knee joint

The primary movements occurring at the knee joint are flexion and extension. Besides these, a small degree of lateral and medial rotations are also possible.

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In extension: In extension of the knee, the lateral femoral condyle, along with the lateral meniscus, moves around its axis, and becomes close packed first. The medial femoral condyle, along with the medial meniscus, starts rotating medially and moves backwards on the tibia at least 30 degrees short of full extension. However, maximum backward shift and rotation occurs during the terminal 10 degrees of extension with screw home mechanism which tightens the ligaments and provides stability at the terminal range of extension.

In flexion: When the knee is flexed from full extension, the opposite movement takes place at the femoral condyles and their menisci. The femur rotates laterally with the lateral meniscus moving backwards on the tibia. However, these movements are completed within the first few degrees of flexion (Barnett, 1953). The retraction of the lateral meniscus and the lateral rotation of the femur are brought about by popliteus which is attached to the lateral meniscus and lateral femoral condyle (Last, 1950).

In rotation: During rotation, the menisci and femur move together in a small arc. The tibia does not participate in this movement.

As the lateral meniscus is close to the vertical axis of rotation and is loosely attached, it moves swiftly along with the lateral condyle. Whereas, the periphery of the medial meniscus, which is closely attached to the femur, moves with the femur; and its widely separated anterior and posterior horns move with the tibia. Therefore, the rotation of the femur causes more distortion of the medial meniscus, making it more prone to injury (Last, 1950).

Role of iliotibial tract in stabilizing the knee joint

1. During standing, when the knee is in extended position and the weight-bearing axis passes in front of knee joint, the taut iliotibial tract maintains extended position without any muscular effort.

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2. In walking or running, when the knee is flexed, the weight-bearing axis falls in front of the iliotibial tract. It causes elongation of the gluteus maximus which contracts powerfully as the movement proceeds.

3. In rising from sitting position when the line of weight-bearing falls behind the hip and knee, the gluteus maximus extends the hip. Later on as the knee starts extending, the iliotibial tract provides the needed support for the quadriceps to act optimally.

Locking and unlocking mechanism of the knee (fig. 36-4)

Locking mechanism: In the mechanisms of locking and unlocking, the femoral condyles roll and glide over the articular surfaces of tibial condyles.

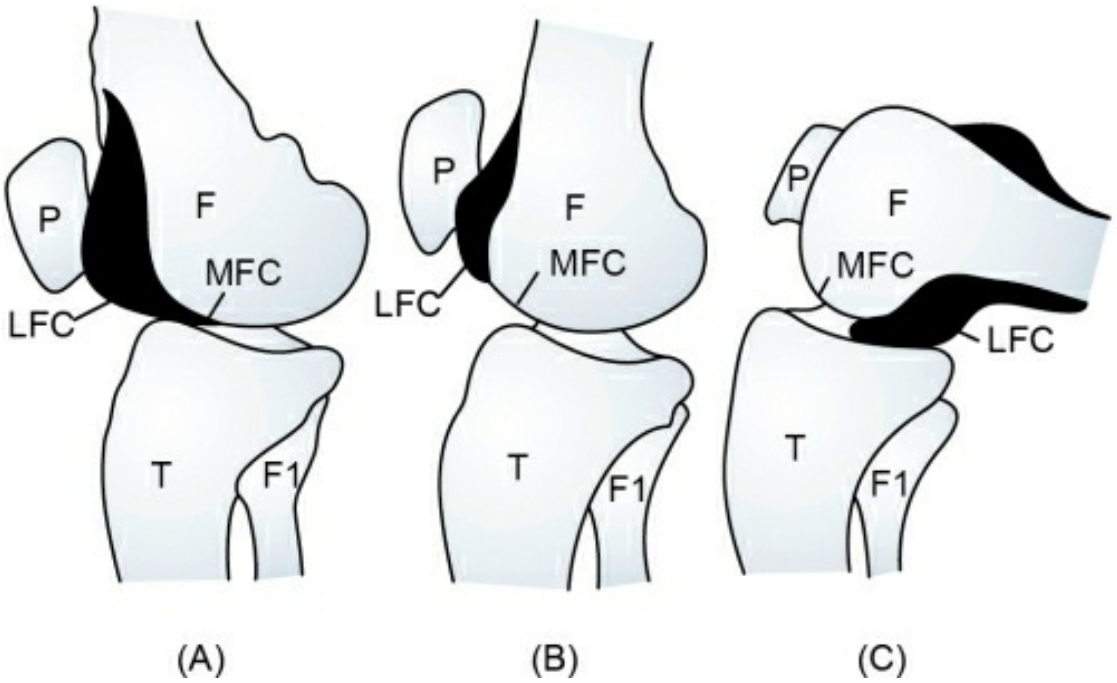

FIG. 36-4 Locking and unlocking at the knee: MFC, medial femoral condyle; LFC, lateral femoral condyle; P, patella; T, tibia; FL, fibula.

In the final stages of extension, the lower fibres of the vastus medialis play a major role because:

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1. The lower fibres of the vastus medialis originate from the adductor magnus which is taut during extension.

2. They exert pull on the medial side of the patella which is pressed firmly against the patellar surface of the femur. This indirectly results in medial rotation of the femur. This medial rotation of the femur in the terminal 15 degrees of extension tautens the forwardly directed tibial collateral ligament and backwardly directed fibular collateral ligament. The anterior cruciate ligament and the oblique popliteal ligament also become taut. As a result the lower limb is converted into a rigid pedestal.

Unlocking mechanism: At the commencement of flexion, the popliteus muscle rotates the femur laterally over the articular surface of the tibia by drawing the posterior horn of the lateral meniscus backwards.

Locking (A): In a position of full extension with the foot firmly placed on the ground, the knee joint gets rigidly locked in extension – therapeutically the most important functional position of maximum stability. It is masterminded by:

- Backward sliding of the medial condyle of the femur with sudden medial rotation of the femur on the tibia

- Tautening of the anterior cruciate ligament, tibial and fibular collateral ligaments, the oblique popliteal ligament and the posterior part of the joint capsule

Unlocking: The knee begins to flex from the locked position by the controlled action of the popliteus muscle bringing about lateral rotation of the femur on the tibia (as evident from the near superimposition of the femoral condyles (B).

The lateral rotation of the femur on the tibia continues as the movement of knee flexion is continued further, evident from the outline of the lateral femoral condyle and the intercondyler space (C).

The patella gradually rises higher on the patellar surface of the

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femur as the knee assumes the position of extension.

Movements of the patellofemoral joint

There is no large excursion of the patella as it is fixed inferiorly by the ligamentum patellae. Its apparent movement is only due to the relative displacement of the femoral condyles. In full extension, the lower part of the patella is above the joint line. In full flexion, it comes to lie against the femoral condyles.

Muscles acting in movements of flexion and extension

Flexion: The principal muscles are the biceps femoris, semitendinosus and semimembranosus. Assisted chiefly by the sartorius, gracilis and popliteus, the gastrocnemius and plantaris also provide some assistance.

Extension: The principal extensor of the knee is the quadriceps femoris. It is assisted by the tensor fascia lata and the gluteus maximus via the iliotibial tract.

Nerve supply: The nerve supply to the knee joint comes from the genicular branches from the tibial and common peroneal nerves, the obturator nerve, medial intermediate and lateral femoral cutaneous nerves and the saphenous nerve via the patellar plexus.

Blood supply: The blood supply to the knee is by both the femoral and popliteal arteries. Their branches form an anastomosis around the knee joint and also supply the joint.

Examination of the knee

The history taking is as usual; however, a few additional points may be noted. The symptoms of a knee disorder are pain, swelling, haemarthrosis limitation of movements and occasionally deformity. In case of a knee injury, there may be symptoms of locking of the joint or a feeling of ‘giving way’ at the knee joint while walking or getting

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down the stairs. The nature of pain can often give a clue to the diagnosis (Table 36-1). Various postures of leg precipitating pain should also be noted.

Table 36-1
Pain Characteristics and the Possible Lesions

1. Sharp catching pain	Mechanical defect
2. Aching type pain with morning stiffness which eases with movements but gets worst with exertion	Degenerative changes
3. Night pain	Degenerative changes, lateral cystic cartilage, meniscal tear
4. Pain on weight bearing	Mechanical or arthritic lesion
5. Pain while climbing up or down the steps or rising from chair	Patellofemoral origin
6. Pain on twisting	Meniscal origin
7. Pain over tibial tuberosity after exercise in young adults	Osgood Schlatter disease

Inspection

The knee joint is inspected from all sides to note: attitude of the leg, wasting of the quadriceps, any swelling around the knee joint and its characteristics, and any anatomical deviations such as genu varum or valgum.

The gait pattern is analysed in respect to the individual segments – hip, knee, ankle and foot.

Palpation

The findings of inspection are confirmed by palpation. Note the skin surface, temperature of the skin/swelling, sensibility, etc. Areas of tenderness are identified. Swelling, if any, should be evaluated to know whether it is a soft tissue swelling or a bony swelling or a joint effusion. The type of swelling can give a clue to the diagnosis of the possible lesion (Table 36-2).

Table 36-2
Type of Swelling and the Possible Lesions

Tense swelling within 2 h of injury	Haemarthrosis
Effusion within 12–24 h	Serous fluid effusion

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Large blood strained effusion	Anterior cruciate ligament lesion
Small effusion streaked with blood	Meniscal lesion
Effusion associated with fever and general illness	Infection with pus formation
Hot, overall swollen joint	Tuberculosis or pyogenic infection
Bony swelling	Bone infection, tumour, cyst, exostosis or osteophytes at the joint margin
Fluid within the joint	Fluctuating effusion of blood, serous fluid or pus
Synovial thickening	Nonfluctuating boggy or spongy swelling

Flexibility tests

Flexibility tests for lumbar spine, hip flexors, gastrosoleus, hamstrings, quadriceps femoris, rectus femoris, tensor fascia lata, iliotibial band, hip adductors and external and internal rotators are essential. Decreased flexibility increases resistance to various anatomical structures resulting in localized stress on the knee joint and overuse syndrome, e.g., tight hamstrings increase patellofemoral compressive forces because of passive resistance during the swing phase of ambulation and running. Loss of extension by 15–25 degrees and flexion possible up to 85–90 degrees, indicate capsular involvement. Tight gastrosoleus leads to increased pronation of using foot causing strain on the knee joint.

Examination of patella

The patella is examined for the presence of pain/tenderness, crepitus, mobility and apprehension. Mobility is assessed by passively moving the patella up and down the knee joint and also sideways.

Patellar apprehension test

An attempt is made to passively displace the patella laterally while flexing the knee from full extension. The patient will become apprehensive and will not allow further examination due to pain. This test is positive when there is a tendency for patellar subluxation or dislocation.

Tests for effusion in the joint

Accumulation of fluid due to irritation of the synovial membrane is

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known as *effusion*; it could be serous, blood or pus. The suprapatellar pouch is the common site of effusion. Effusion is detected by the following three methods:

1. Patellar tap test (Fig. 36-5A and B)

2. Fluid displacement test (Fig. 36-5C)

3. Hydraulic impulse test (Fig. 36-5D)

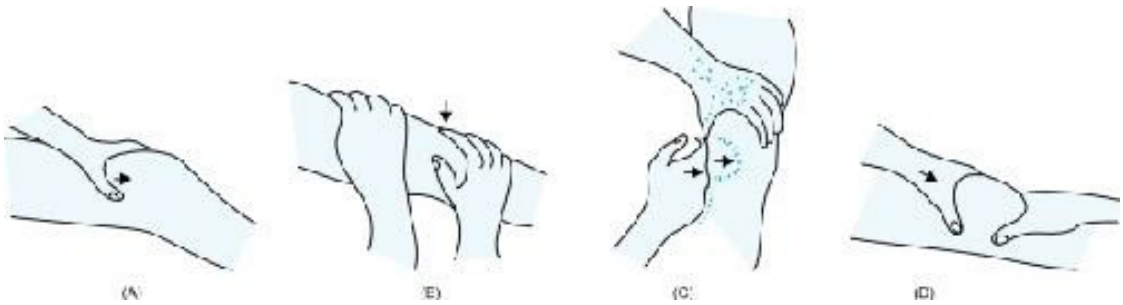

FIG. 36-5 Patellar tap test. **(A)** Place the hand firmly about 15 cm above the patella, slide it to the level of the upper patellar border and jerk the patella downwards with the other hand. **(B)** Presence of click indicates effusion. **(C)** Fluid displacement test. **(D)** Hydraulic impulse test.

All the three tests are based on passive displacement of the fluid in the knee joint.

1. Patellae tap test: In the patellar tap test, the fluid is displaced from the suprapatellar region to the knee joint by sliding the hand from a point about 15 cm proximal to the superior border of the patella (Fig. 36-5A) towards the knee joint. The patella is then jerked quickly downwards using finger tips (Fig. 36-5B). The patella strikes against the anterior surface of the femoral condyles and bounces back into its original position, which indicates effusion. In the fluid displacement test, after evacuation of the suprapatellar pouch (Fig. 36-5A), firm stroking is done alternately on the medial and then on the lateral aspect of the joint (Fig. 36-5C), carefully watching the opposite side of the joint for appearance of a bulge due to the displacement of fluid.

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2. Fluid displacement test: In the hydraulic impulse test, one hand is placed just over the suprapatellar pouch and the other over the front of the knee joint just under the inferior border of the patella (Fig. 36-5D). On applying pressure over the suprapatellar pouch towards the joint, fluid displacement occurs from the suprapatellar pouch to the main joint cavity which bulges with easily detectable hydraulic impulse to the lower hand.

Range of motion

Active movements

Active ROM of the knee along with hip and ankle joints should be recorded by goniometery. Presence of painful arc should be looked for; it may be present in meniscal or articular deficiencies.

Passive movements

Passive movements put stress on the noncontractile structures like ligaments, capsule and fascia, helping to identify the site and severity of lesion in these tissues. It also helps in evaluating the degree of accessary motion (joint play), the character of end feel and in identifying the capsular pattern of knee joint restriction.

The pain and resistance sequence is also an important factor during passive movement test:

- In acute injury, pain develops before resistance.
- In subacute conditions, pain and resistance occur simultaneously.
- In chronic conditions, resistance appears before pain.
- Pain in the direction opposite to the resisted movement implicates contractile unit (musculotendinous). Passive range testing has to be performed at the hip, knee and ankle joints, to detect any abnormality.

Feel for crepitus in the knee joint while performing relaxed passive

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movements. Also feel for crepitus at the patellofemoral articulation by passive patellar movements from superior to inferior and from medial to lateral directions with the knee joint in relaxed extension.

Resisted movements

Evaluation of the contractile unit is done by manual muscle testing (MMT). The resistance is given in shortened range, mid-range and in a stretched position of the muscle. Objective testing of the strength and endurance is done by isokinetic dynamometer or isometric torque evaluation.

Remember

Functional independence being most important, the quadriceps group of muscles needs to be extensively tested for strength, atrophy, reflex inhibition and function.

Specific passive tests

Certain specific passive tests provide useful clues to identify the structures involved and also their degree of involvement, especially the ligaments shown in Tables 36.3–36.5.

Table 36-3

Passive Tests and the Possible Lesions

Locking in flexion with passive extension not possible	Bucket handle type of meniscal tear possible, flexion may be free and full
Jamming in one position with occasional unlocking	Loose body in the joint
Instability with a feeling of knee giving way during straight running	Patellar subluxation
Jerking instability, giving way during sporting activity with snapping back	Anterior cruciate ligament (ACL) lesion
Anterior instability	ACL lesion
Posterior instability	Posterior cruciate ligament lesion
Medial instability	Medial collateral ligament lesion
Lateral instability	Lateral collateral ligament lesion
Rotational instability	Meniscal lesion

Table 36-4

Passive Integrity Test for Collateral Ligaments and Menisci

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Test Findings	Possible Inference
1. Final end feel (Marshall & Baugher, 1980)	Intact ligament
2. Marked pain without opening up of the joint	Incomplete rupture
3. (a) Mild pain with definite opening up of the joint	
(b) Definite joint opening even with knee in extension (Smilie, 1978)	Complete rupture
Site of Lesion	***Diagnostic Test***
Anterior cruciate ligament	Stabilized Lachman's test
Posterior cruciate ligament	Stress test with knee in extension
Medial or lateral collateral ligament	Stress test with knee in slight flexion
Menisci	McMurray's test

Table 36-5

Identification of Ligament Injury to the Knee

Knee Position at Injury	Ligaments Injured	Test
Hyperextension	Posterior cruciate	Posterior drawer
Hyperflexion	Anterior cruciate Posterior cruciate	Anterior drawer Posterior drawer
Tibia in valgus	Medial collateral	Abduction in extension or 30 degrees flexion
Tibia in valgus and external rotation	Medial collateral, meniscus and anterior cruciate	Abduction with knee in 30 degrees flexion anterior drawer in 15 degrees rotation
Tibia in varus and internal rotation	Lateral collateral, anterior cruciate (anterolateral instability)	Pivot shift Anterior drawer
Tibia in varus and external rotation	Lateral collateral posterior cruciate (posterolateral instability)	Reverse pivot shift
Tibia moving forward on femur	Anterior cruciate	Lachman's test Anterior drawer

Measurements

Real and apparent limb length is measured to rule out shortening.

Muscular atrophy

Circumferential measurements are done to evaluate wasting of the thigh and leg muscles. These measurements are done at the following sites, and compared with the normal side: (a) at the joint line, (b) 5 cm proximal to the joint to assess effusion in the suprapatellar pouch, (c) 15–20 cm proximal to the joint line to evaluate wasting of the thigh (quadriceps and hamstrings) muscles and (d) 15 cm distal to the joint line to assess wasting of the leg (gastrosoleus) muscles.

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Tests to evaluate the degree of deformity at knee

The knee should be evaluated for the deformity in weight-bearing (e.g., standing) position by measuring with tape and goniometer. Genu varum and valgum can also be measured by a measuring tape. Measure the distance between the knee joints for genu varum and between the medial malleoli for genu valgum. Measure the distance at the centre points between the knee joints and the medial malleoli for tibia vara. Angular measurements can also be done accurately with the goniometer on weight-bearing radiographic film. Genu recurvatum and flexion deformity are assessed with a goniometer in weight-bearing on the affected limb alone (Fig. 36-6).

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FIG. 36-6 Goniometric measurement of genu recurvatum (hyperextension) is done with body weight on the leg to be tested.

Examination of the related joints

The related joints like the lumbar spine, sacroiliac, hip, superior tibio fibular, ankle, subtalar and foot joints are carefully checked to rule out lesions causing referred pain to the knee.

Neurological status

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It may be necessary to conduct tests to assess cutaneous sensation in the clinical dermatomes, the quadriceps reflex and the related muscle strength.

Functional testing

The compensatory mechanisms, adopted by the patient to perform various functions, should be observed and recorded. This will provide a clue to the pathology of the knee problem. The activities to be tested are squatting, cross-leg sitting, standing, standing on the affected leg alone, brisk walking, stair climbing and descending and spot running. The objective analysis of gait for individual segmental movements at all the three weight-bearing joints is advisable. Activities like sprinting, flexed knee hopping, figure-of-eight running and cross-over running may be included (Davies & Malone, 1980) in the analysis, especially in sports personnel.

Arnold's test

It is a functional test to assess anterolateral rotary instability. The examiner standing in front of the patient steps on his involved foot. The patient rotates his upright torso of face about 90 degrees in the opposite direction by crossing his good leg over the fixed one. The symptoms of lateral pivot shift, with feeling of discomfort and the sensation of knee 'wanting to go out' are felt (Arnold et al., 1979).

Passive tests for ligament injuries

Knee is a common site for ligament injuries. The three 'C's', that is, collateral, cruciate and cartilages (mensci) are the usual sites of injury. Various types of passive stresses provide definite clues to diagnose the injured ligament. The position of the knee joint during injury, the direction and severity of stress can provide important clues to identify the involvement of a particular ligament from amongst (A) collateral ligament, (B) cruciate ligaments or (C) cartilages or menisci (Table 36-5).

Ligament injuries

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The injuries to the ligaments of the knee are classified into three grades.

Grade I – Minimal tear

- Local tenderness+
- No instability
- Stress test causes pain
- Joint separation up to 5 mm

Grade II – Moderate tear

- Local tenderness ++
- Localized oedema +
- Minimal instability
- Stress test causes extreme pain
- Joint separation between 5 and 10 mm

Grade III – Complete tear

- Local tenderness +++
- Local oedema ++
- Marked joint instability
- Stress test causes excruciating pain

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- Joint separation of 710 mm

Complete tear is invariably associated with additional cruciate ligament injury thereby, increasing the degree of joint instability.

Medial (tibial) collateral ligament (fig. 36-7a)

Tenderness is maximum at the upper end near its attachment to the medial condyle of the femur. The test for integrity of this ligament is done by it valgus stress test with knee in full extension. If no instability is detected the test is applied with knee in 30 degrees of flexion. There is abnormal external rotation of it tibia with opening up of knee joint on the medial side. This manoeuvre may cause severe pain with or without opening up of knee joint medially. The end feel at the terminal range during the manoeuvre may be soft or firm (Marshall & Bangher, 1980). This test is positive in the tear of the medial collateral ligament. This ligament mainly controls the external rotation of the tibia on the femur. Considerable opening up of the joint medially with excessive valgus indicates involvement of the posterior cruciate along with medial collateral ligaments.

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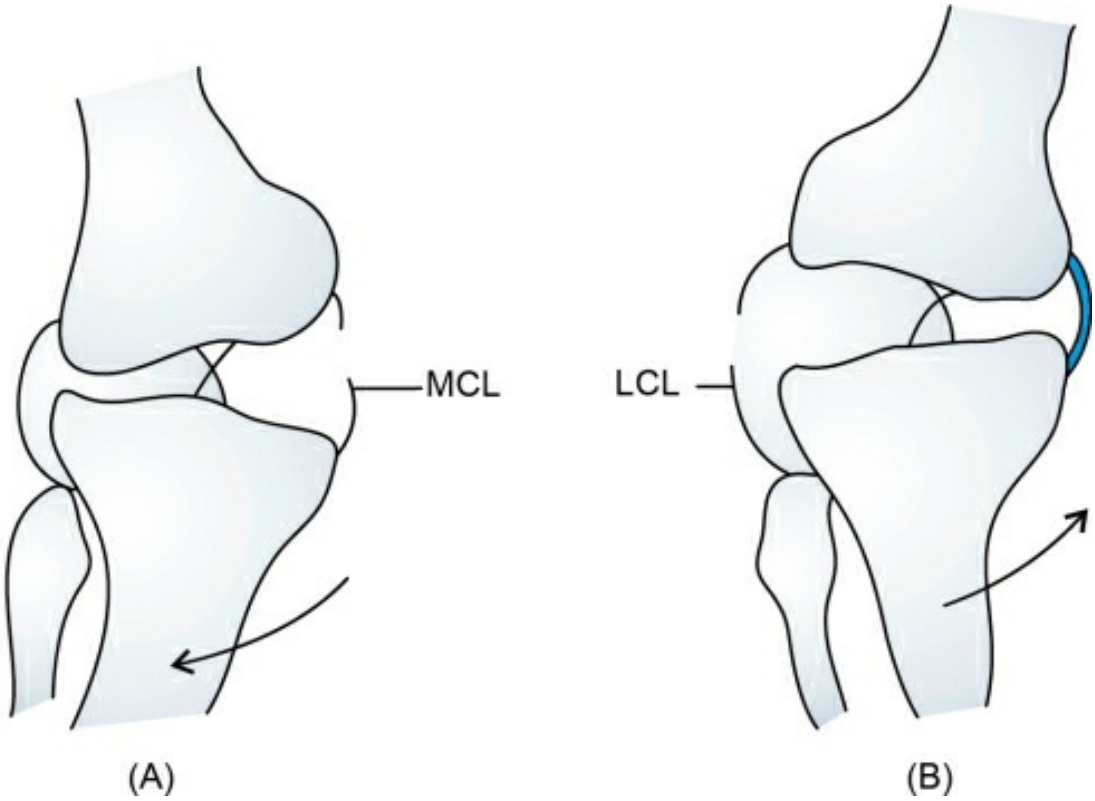

FIG. 36-7 Tests to assess the integrity of medial and lateral collateral ligaments (MCL) and (LCL). (A) Valgus stress test for tear of the medial collateral ligament: positive test may cause severe pain, excessive valgus with opening up of the knee joint medially. (B) Varus stress test for tear of the lateral collateral ligament causes severe pain on opening up of the joint laterally.

Lateral (fibular) collateral ligament (fig. 36-7b)

In this injury, tenderness is felt over the fibular head or lateral joint line. The varus stress is applied with knee in full extension, if no lateral instability is detected, the test is applied with knee in 30 degrees of flexion. It will cause opening up of the lateral aspect of the joint with pain. It will be positive in isolated tear of the lateral collateral ligament. Excessive varus instability in knee extension as well as flexion indicates involvement of the posterior cruciate ligament as well. The presence of pain, status of the joint and character of the end feel to be assessed carefully for a possible diagnosis (Table 36-3). Complete rupture of the lateral collateral ligament is very rare. When it occurs, it usually involves the capsule,

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posterior cruciate ligaments and/or common peroneal nerve (Smillie, 1978).

Injuries to the cruciate ligaments

Injury to the anterior cruciate ligament results in undue anterior mobility of the tibia while injury to the posterior cruciate ligament produces excessive posterior mobility of the knee joint.

Anterior cruciate ligament: Injury to the anterior cruciate ligament commonly results from a fall from height with the knee in flexion and the body rotating on the stationary foot. This results in abnormal internal rotation of it tibia. Similarly, hyperflexion or hyperextension with internal rotation of the tibia can also produce it. Abnormal anterior glide of the tibia on the femur is confirmed by positive anterior drawer test (Fig. 36-8A) when anterior translation of tibia of 6–8 mm occurs, which is associated with acute pain, swelling and haemarthrosis of the knee.

Posterior cruciate ligament: The posterior cruciate ligament prevents posterior displacement of the tibia on the femur. It occurs following a direct blow to the front of the knee. It may be associated with fracture of patella or even posterior dislocation of the hip. At 90 degree flexion of the knee, with foot resting on the treatment table, the contour of the tibia looks concave because of the posterior subluxation of the tibia (Fig. 36-8B).

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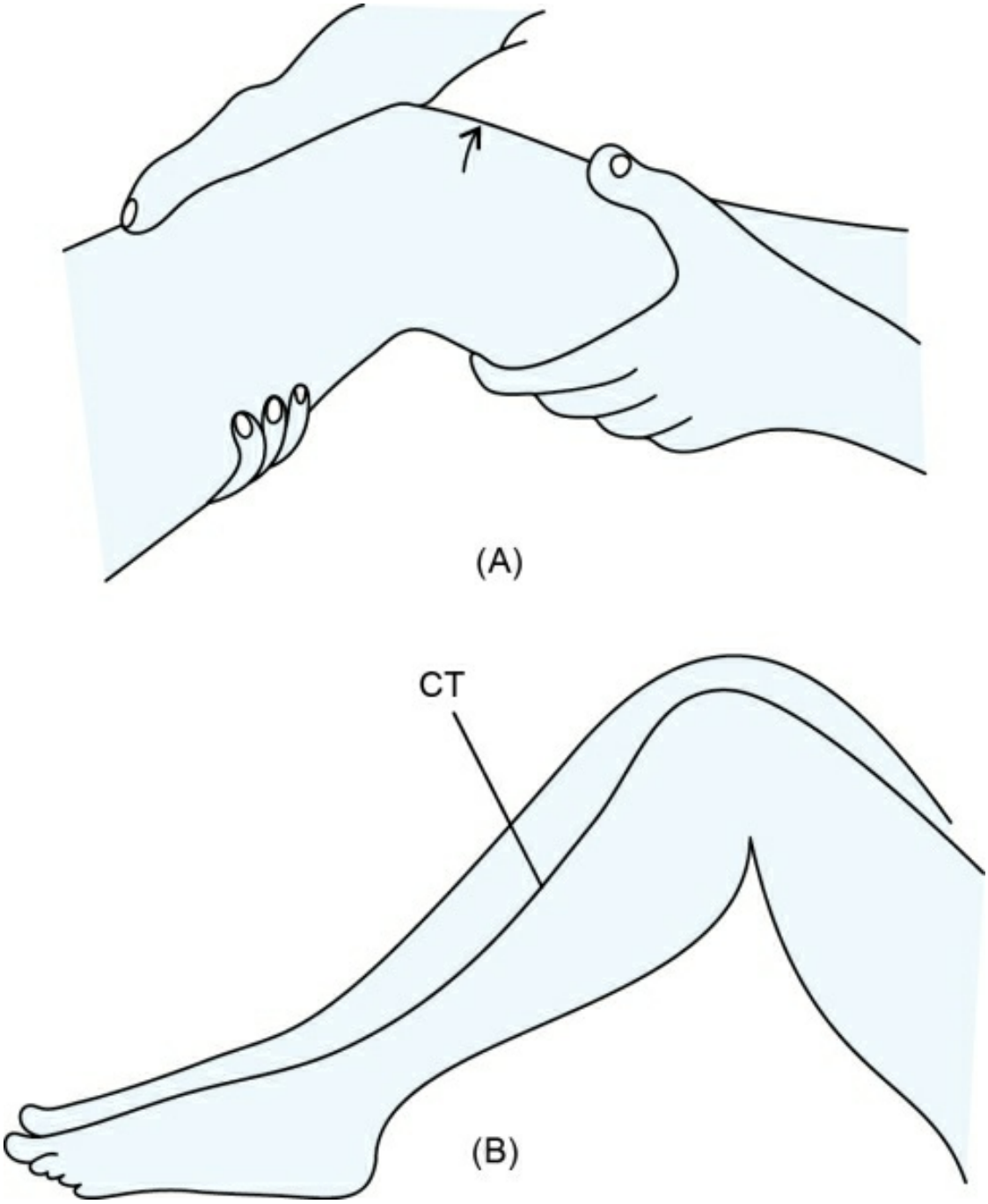

FIG. 36-8 (A) Lachman's test to assess integrity of anterior cruciate ligament: The femur is held firm with one hand, the other hand grasps the tibia with knee in 5–10 degrees of flexion and glides the tibia forwards on the femur. Excessive anterior gliding indicates rupture of the anterior cruciate. (B) Positive posterior cruciate integrity test: at 90 degrees of knee flexon in supine position with foot resting on table: the contour of tibia (CT) appears concave due to posterior subluxation of the left tibia, due to the rupture of posterior cruciate.

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The test is performed in the same position by stabilizing the foot. The examiner grips the proximal end of the tibia (leg) with both hands and glides it backwards over the femoral condyles (posterior drawer test), and forwards (anterior drawer test). Excessive gliding backwards is positive in posterior cruciate ligament tear while anterior gliding of 6–8 mm indicates an anterior cruciate ligament tear. Posterior subluxation or instability is the diagnostic sign for tear of the posterior cruciate ligament.

Lachman test

This is a more specific test especially in an acute state, where the knee cannot to be flexed to 90 degrees. The knee is held in 5–10 degrees of flexion. The examiner, with one hand, stabilizes the femur firmly while with the other he grasps the tibia and attempts to glide it forward (anteriorly) on the femur. The tibia glides forwards abnormally in cases of rupture of the anterior cruciate ligament (Fig. 36-8A). Excessive posterior subluxation of the tibia occurs in a case of injury to the posterior cruciate ligament (Fig. 36-8B).

Stabilized lachman test (wroble & lindenfeld, 1988)

It is a modification of the original Lachman test. This test has the ability to quantitate the amount of anterior translation of the tibia.

The patient is supine and the examiner stands on the side of the knee to be tested. The examiner places his thigh with knee bent beneath the patient's thigh, just proximal to the metaphysis. Hand is placed firmly so that the examiner's thumb and the index fingers are placed on the patient's lateral and medial joint lines, respectively. Using the other hand the examiner sequentially applies anterior and posterior forces to the proximal tibia as is done in the regular Lachman test.

When the posterior cruciate ligament is torn in association with the medial or lateral ligaments, medial or lateral instability results with a positive valgus or varus stress test, respectively, with the knee in full extension.

In isolated medial or lateral collateral ligament tears, the medial or

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lateral stress test will be positive in knee flexion and not in knee extension. Forced hyper-extension of the knee may result in tear of the posterior capsule followed by anterior and posterior cruciate ligament tears (Kennedy et al., 1974).

Combined anterior cruciate and medial collateral ligament tears

Combined anterior cruciate and medial collateral ligament tears will result in positive anterior drawer sign. The application of valgus stress will produce much more opening on the medial side than when the medial collateral ligament alone is torn.

Rotatory instability

Rotatory instability resulting in excessive external or internal rotation of tibia may follow an injury. It could be:

- Anteromedial
- Anterolateral
- Posterolateral

Anteromedial instability

The tibia rotates and pops out anteriorly from the medial side. The medial tibial condyle subluxates anteriorly. This type of injury is precipitated by sudden external rotation of the tibia with the fixed foot over the flexed knee and abducted thigh. The injury usually involves the ACL, middle third of medial capsular ligament and medial collateral ligament.

Anterolateral instability

A common athletic injury occurs when femur rotates laterally while the tibia slides anteriorly and inside. The lateral condyle subluxates anteriorly. The middle third of the lateral capsular ligament, the arcuate complex and the posterolateral capsule may be involved. Sudden internal rotation of tibia by a valgus force to the flexed knee with fixed foot with femoral lateral rotation causes this injury.

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Posterolateral instability

A sudden blow against the anterior tibia with leg externally rotated and foot planted in a varus position causes this instability. The lateral tibial condyle subluxates posteriorly. The posterior third of the lateral capsule, the arcuate complex and the posterior cruciate ligament may also be involved.

These rotatory instabilities can occur independently or in combination.

Rotatory laxity causes marked instability in the knee joint severely blocking functional activities and needing early surgical intervention.

Injuries to the menisci (semilunar cartilages)

Tear of the medial meniscus is the commonest injury (nine times out of ten) due to its relative lack of mobility. The ratio of the anteroposterior displacement of medial and lateral meniscus is 1 : 2 (Kapandji, 1970). It is produced by (a) sudden rotational force with the knee in semiflexed weight-bearing position, (b) sudden twisting injury to the knee while the foot is in contact with the ground, (c) a blow to the flexed and rotated extremity or (d) sudden movement from the hyperflexed to erect posture. The tear of the medial meniscus could be of four types (Fig. 36-9). Injury to the medial meniscus may cause concomitant injury to the medial collateral ligament and anterior cruciate ligament (O'Donoghue, 1970).

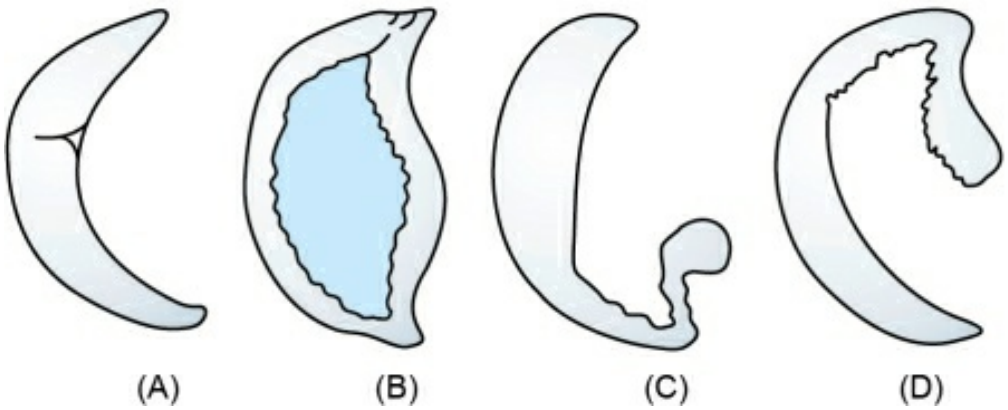

FIG. 36-9 Meniscal tears. (A) Horizontal tear. (B) Bucket handle tear. (C)

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Posterior horn tear. (D) Anterior horn tear.

Horizontal tear

Commonly occurs in patients over 50 years of age. It is produced as a result of degenerative processes in both the menisci (Smillie, 1970); with further degeneration, the peripheral border becomes adherent. Therefore, the movement instead of occurring between the femur and the meniscus or between the tibia and the meniscus, occurs in the substance of the meniscus resulting in a horizontal tear (Fig. 36-9A).

Longitudinal tear (fig. 36-9b–d)

All the meniscal tears begin as a natural longitudinal tear. Depending upon the site, it could be a 'bucket handle' tear, posterior horn tear or anterior horn tear.

In the 'bucket handle' type of tear which is common, the tear extends along the whole length of the meniscus but remains attached at both ends. The centrally displaced fragment blocks the normal play of the femoral condyle during the extreme range of extension, when it needs maximum space. This produces apparent 'locking' in extension.

The posterior horn tear starts at the concave central border, but the tag displaced centrally remains attached to the posterior horn.

The anterior horn tear appears at the anterior end of the concave central border. Here also the tag produced remains attached.

Tear of lateral meniscus

The overall symptoms are similar to the medial meniscus tear. But the pain and tenderness are felt over the antero-lateral aspect. McMurray's test confirms the site of lesion.

1. *'Bounce home' test for bucket handle type tear*: The examiner holds the patient's heel cupping around it and passively extends the knee from a fully flexed position of hip and knee in supine position. If the extension is not complete or has a rubbery end feel with elastic resistance to blocking full extension; it indicates bucket handle type of meniscal tear (Figs 36-9B and 36.10).

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2. *McMurray's test for pedunculated tag of meniscus*: The test is performed by producing internal rotation of the tibia and varus force to the upper part of the leg while the knee is gradually extended for lateral meniscus, and external rotation and valgus for the medial meniscus. The patient lies in supine position with knee completely flexed. Place the thumb and index finger along the joint line to detect the 'click'. The examiner medially rotates the tibia with a grasp at the heel, and extends the knee from full flexion to extension maintaining rotation. Loose (torn) fragment of the lateral meniscus will snap or click with pain as the leg gets disengaged during extension. For medial meniscus, perform the same test (Fig. 36-11) with the tibia rotated laterally. Pain appearing during the first 30 degrees of extension indicates the tear of the posterior horn whereas at 90 degrees or more indicates tear of the medial meniscus.

3. *Apley's grinding test*: With the patient in prone position lying with knee in 90 degree of flexion, vertical compression is applied to the knee joint by pressing the foot downwards. The tibia is then rotated either ways; pain with click localized to the joint line is elicited indicating posterior horn meniscal lesions (Fig. 36-12A). The pain and/or click is felt on the side of the torn meniscus. The same test is performed with knee joint distraction (Fig. 36-12B), eliciting pain in a ligament injury.

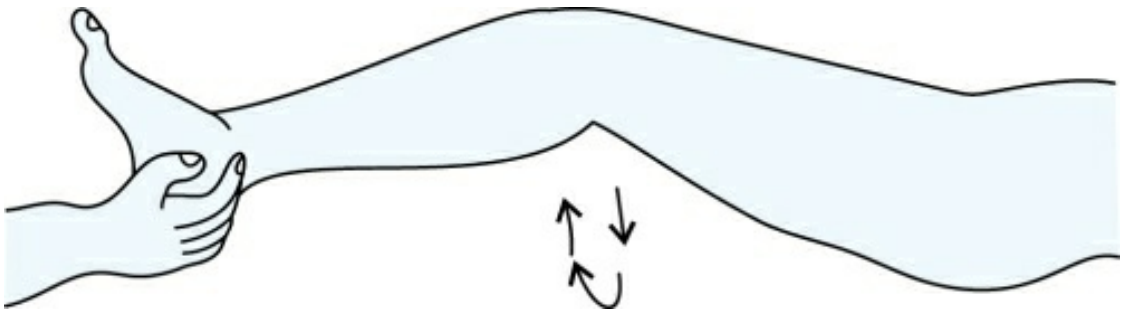

FIG. 36-10 Bounce home test or springy block: on passive extension of knee from fully flexed hip and knee, a rubbery end-feel, blocking full extension indicates bucket handle type of meniscal tear.

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FIG. 36-11 McMurray's test: Flex the hip and knee fully in supine position; place the thumb and index finger on the medial and lateral joint lines. grasping heel with the other hand, knee is gradually extended with (A) external rotation of the tibia and valgus for medial meniscus and (B) internal rotation and varus for the lateral meniscus. Pain and 'click' over the medial or lateral joint line indicate medial or lateral meniscal tear, respectively.

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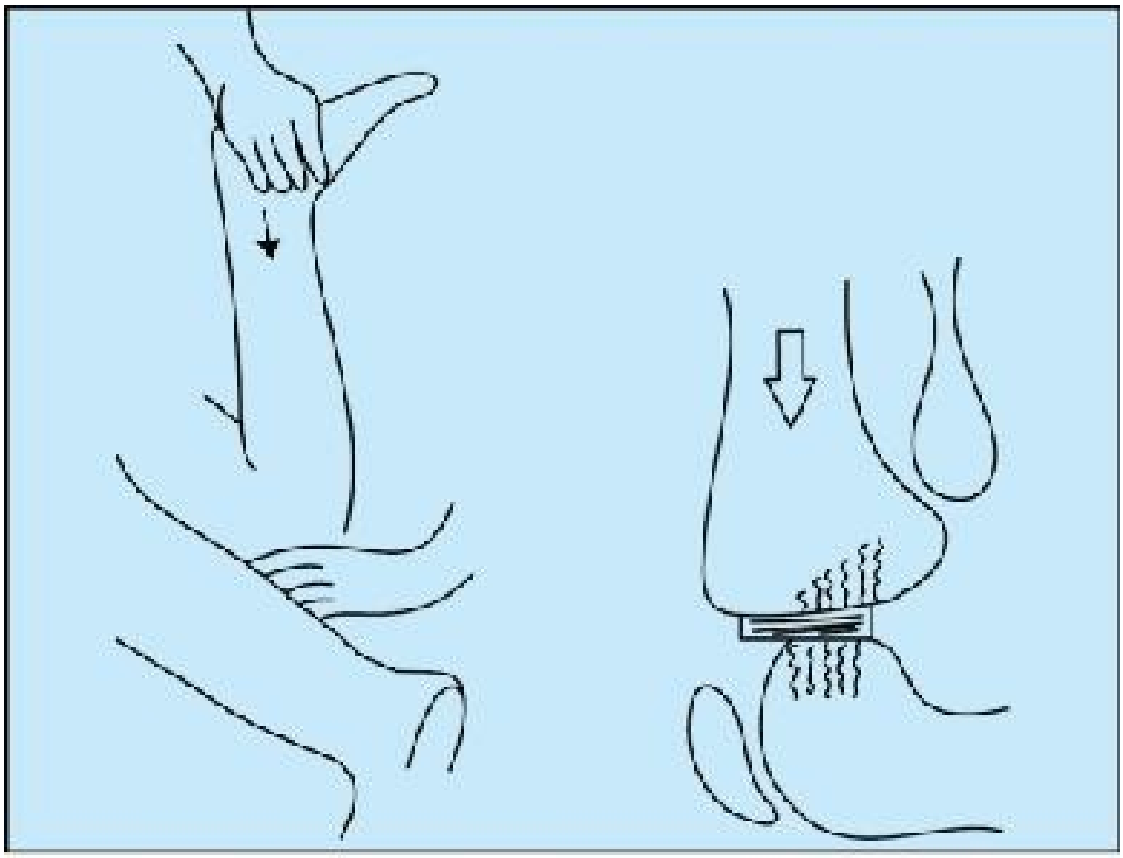
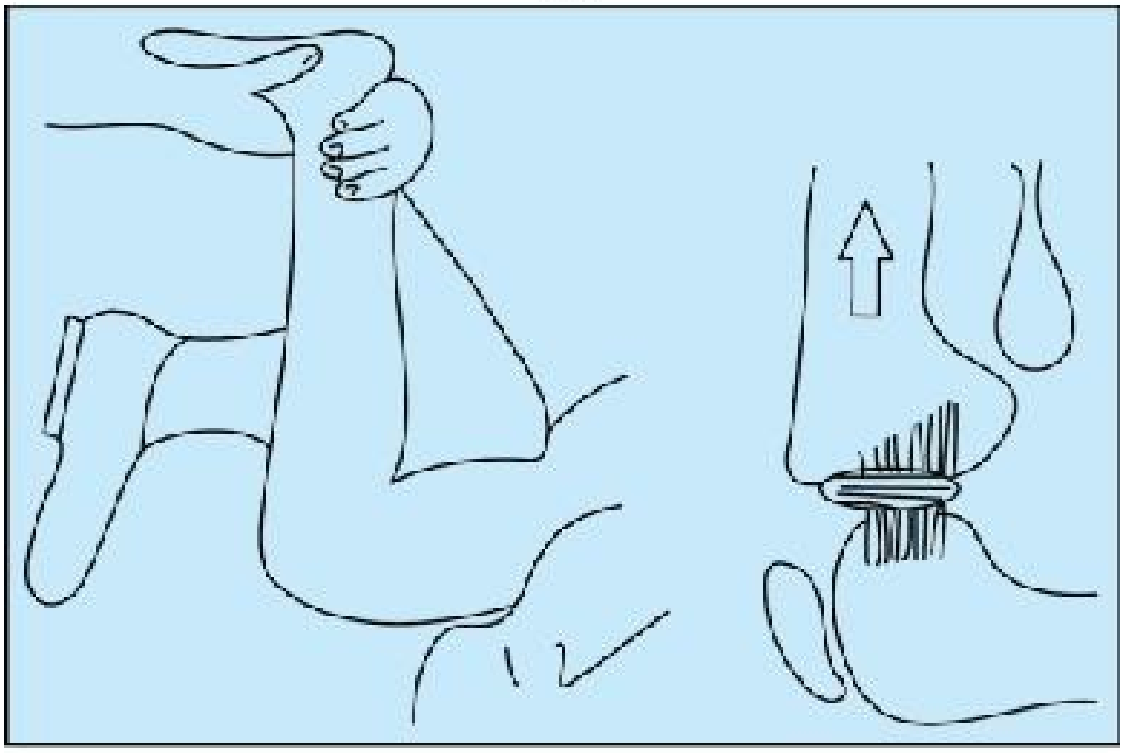


(A)



(B)

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FIG. 36-12 Apley's grinding or compression, and distraction test. (A) Compression or grinding test: on rotation of the tibia with vertical downwards compression at the foot, pain is elicited to the side of the torn meniscus due to compression. (B) Distraction test: same manoeuvre done with vertical upward pull releases the meniscus but stretches the ligaments, causing pain in a ligament injury.

When these tests are positive, the site and nature of the tear can be confirmed by arthroscopy.

Other injuries

Traumatic effusion of the knee

In traumatic effusion, the patellar fossae on either side of the knee are filled up. When swelling extends to the suprapatellar area, it assumes the shape of an inverted horse shoe. The patella gets pushed away from the articular surface of the femur because of this effusion.

Fibrosis of quadriceps femoris muscle

Fibrosis of the quadriceps femoris muscle may occur following an intramuscular injection or may be congenital. There is limitation of flexion at the knee as the fibrosed quadriceps muscle pulls the patella upwards and locks the movement. This necessitates surgical release.

Overuse injuries

Activities repetitive in nature may produce injuries like 'jumpers knee' or patellar tendinitis, iliotibial band friction syndrome, popliteus tendinitis and pes anserinus bursitis.

In jumpers knee, the pain is situated at the patellar tendon which increases with activities which load the quadriceps mechanism.

Iliotibial band crosses the lateral aspect of the knee to be inserted into the Gerdy's tubercle. Mechanical irritation occurs with repeated flexion–extension movements. Tight iliotibial band or stress on the lateral aspect may predispose this injury. Positioning the knee to 40 degrees of flexion in standing on the affected extremity produces pain. Snapping at the iliotibial band may be noticed on flexion–extension of

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the knee.

Popliteus tendinitis

The popliteus muscle prevents excessive internal rotation of the femur as well as anterior displacement of the tibia. Injury to this muscle results in pain on the lateral aspect of knee which is aggravated by squatting or walking down the slope. The pain is usually felt by internally rotating the femur on the weight-bearing leg. There may be increased range of internal rotation with prolonged pronation of the subtalar joint. The pes anserinus bursa prevents friction between the tibia and pes anserinus tendons. Bursitis may occur as a result of excessive knee flexion or extension. Resisted knee flexion with tibia internally rotated causes pain on the medial aspect of the proximal tibia.

Physiotherapeutic management

Acute stage of injury

The main aim of physiotherapy in the acute stage is reduction of inflammation and pain.

1. Cryotherapy – Ice packs for 15 min every hour.

2. Modalities like diapulse, ultrasound therapy, interferential therapy and TENS can be used.

3. Compressive or pressure bandage with limb in elevation.

4. Protection of knee from the position of stress.

5. Early initiation of isometrics for the quadriceps. They should be done at least for 5 min every hour. Prevention of quadriceps wasting and reflex inhibition is important. The isometrics, progressed slowly to the maximum and sustained for 10–15 s, assist in strengthening the quadriceps; whereas speedy isometrics help in resolution of oedema and effusion.

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6. When the leg is immobilized in a POP cast, vigorous movements to the ankle and toes are important to prevent venous thrombosis and to augment circulation. Static contractions to hamstrings and quadriceps in the cast are encouraged. Attempt may be made to perform assisted SLR, abduction of the hip and strong hip extension against the resistance of the mattress.

7. If cast is not advised, a small range of self-assisted relaxed gentle knee swinging could be initiated.

Subacute stage of injury

When the symptoms of the acute stage are reduced, mobilization is initiated and progressed gradually along with strengthening exercises.

1. Initiate mobilization with the patient sitting at the edge of the bed or table, injured limb fully supported by the sound limb. The patient is guided to perform relaxed self-assisted small range of slow rhythmic knee flexion and extension (Fig. 36-13). CPM is an ideal mode of mobilization at this stage.

2. The range and power of quadriceps and hamstrings should be recorded.

3. Passive exercise to be progressed to assisted active or active as early as possible. Self-assisted relaxed passive stretching of knee flexion is excellent for improving the ROM of flexion. Patient in supine or sitting position slides the foot as far back as possible. Then the patient plants the foot on the plinth and slowly moves forward over the planted foot; the maximally achieved flexion is maintained. This can be more effective if it succeeds the relaxed free heel-drag session.

4. Isometrics can be made self-resistive by the patient applying graded resistance with hand. A soft roll is placed under the knee. The patient carries out isometric quadriceps setting while resistance is applied by hand, exerting pressure by the web between the thumb and the index finger 5–7 cm proximal to the superior border of the patella. With

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isometric contraction, the patella moves upwards. The patient resists this movement with hand and then sustains the isometric hold by continuously resisting upward pressure exerted by quadriceps with the hand for 10–15 s. This can be made more effective by adding ankle dorsiflexion with toes stretched in extension. We have found this to be a very effective self-controlled isolated quadriceps exercise. It is also well acceptable to the patient.

5. Relaxed knee swinging should be made speedy with increased arc of movement to attain free mobility.

6. SLR – straight leg raising: It should be initiated as an assisted movement. It could be made more effective by: (i) Slow repetitions with self-generated intramuscular tension without the heel making contact with bed. (ii) By adding weight: the weight or resistance should be gradually progressive. Upper limit of resistance for the SLR should be kept at 10–15 lb (4.5–6.8 kg) (Malone et al., 1980). SLR can be modified to SLA or straight leg abduction. The advantages of these two movements are that all the important muscle groups of the lower limb are exercised at the same time. Due to sustained contractions in all muscle groups, strength as well as endurance improves to a great extent. This can be made objective by the patient keeping a record of (the number of repetitions at a time) his active performance and progress.

7. *Knee flexion*: Knee flexion exercises should be practised in prone position as well as on a static bicycle. Speed, resistance and seat height of the static bicycle should be properly adjusted so as not to overstrain the knee. Begin with half circle of the pedal. The session should be for 15 min initially, increasing gradually to an hour.

8. *Progressive resistive exercise* (PRE): Gradual self-resistive exercise with self-generated tension or graded resistance exercise with De'lorme shoe or weight belts to be initiated.

9. *Flexibility exercises*: Flexibility exercises of static stretching using a

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30-s hold, relaxing and performing five repetitions to hamstrings, iliotibial band and gastrosoleus are important.

10. *Vigorous programme*: When the pain is minimal, ROM and swelling are near normal. The endurance strengthening flexibility exercises are made progressive by suitable techniques. Progress to guided prone-kneeling, assisted squatting, stair climbing and descending and cross-leg sitting.

- Graduated spot running and jogging to be initiated as soon as the pain permits.

- Patients should be encouraged to begin aerobics and go back to work with well learnt precautionary measures. Advice on regular sessions of continuous halfway floor squatting to be emphasized to keep fit and to prevent recurrence of sprain (Fig. 36-14).

11. *Isokinetic exercises*: Isokinetic mode of exercise is effective in improving strength, endurance and functional capacity of the quadriceps and hamstrings. It assists in improving ROM due to the physiological overflow. As the resistance is adjusted in relation to the muscle force through ROM, it prevents excessive compression of the joint. As the isokinetic provides fast contractile velocity, it improves the control and coordination needed for smooth and speedy movements in sports (Davies, 1988).

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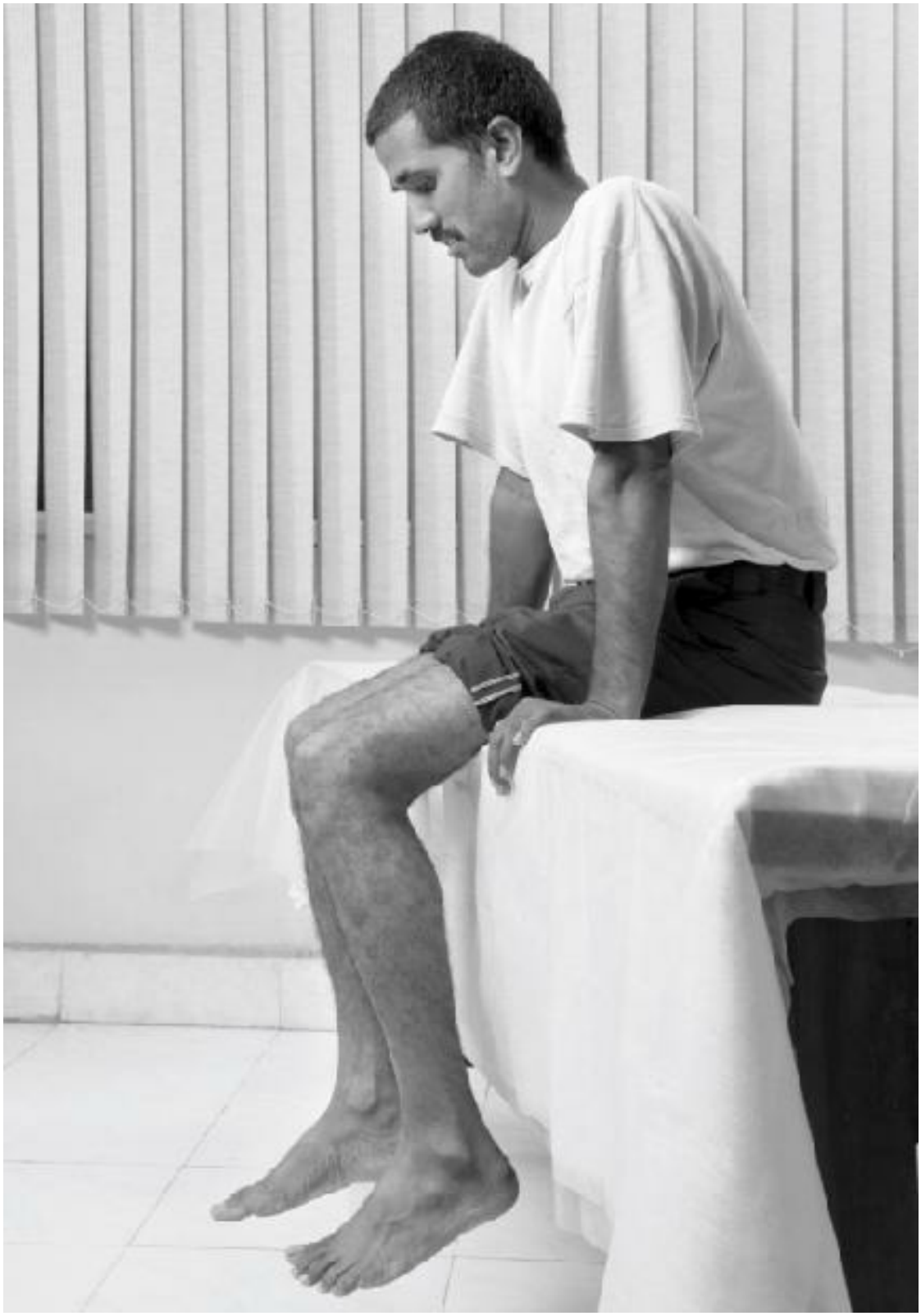

FIG. 36-13 Self-assisted rhythmic relaxed knee swinging, initiated in a small ROM, progressed on achieving further relaxation. The affected knee

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is relaxed and is rhythmically moved passively by the normal leg.

FIG. 36-14 Continuous halfway floor squatting provides an excellent means of body weight resistive quadriceps exercise.

Specific programmes: Emphasizing specific areas in the schedule of therapy is essential as per the diagnosis.

1. ***Extensor mechanism injury***

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(a) Heavy resistance quadriceps exercise should be done in graduated steps to avoid irritation of the involved tissues.

(b) Hamstrings stretching is necessary to prevent patellar compression against the underlying bone.

(c) Resistance to SLR should be applied in the range of 10–15 lbs.

(d) Activities like running, jogging and spot running should be avoided (Malone et al., 1980).

2. ***Injuries to the menisci:*** Extra emphasis is necessary on:

(a) Terminal knee extension – progress from assisted to resisted SLR is important.

(b) Gluteal muscles should be checked for weakness.

(c) Hamstrings stretching, repeated isometrics to the quadriceps and free mobility are also important.

3. ***Injuries to the ligaments***: Anterior subluxation of the tibia may be noticed when there is combined anteromedial and anterolateral instability on full ROM exercise. Similarly, posterolateral instability may result in external rotation of the tibia. This can be avoided by limiting the exercise to a safe range.

Caution

In combined anteromedial and anterolateral instability, full range extension may cause anterior subluxation of the tibia. Therefore, full arc of extension should be avoided while exercising. Posterolateral instability will give rise to external rotation of the tibia against

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posterolateral part of the capsule. Therefore, when there is posterolateral instability, the knee should be exercised in an arc up to 170 degrees or 10 degrees short of full extension.

Hamstrings and gluteal weakness may be present due to chronic ligament instability. They need to be assessed and emphasized.

Chronic stage of injury

Even chronic ligament injuries respond favourably to the regime of knee strengthening and hamstrings stretching exercises. However, the knee should be well protected with a knee brace during strenuous activities.

Patients with chronic ligament instability may show weakness of hip muscles and hamstrings. This has to be tested and strengthening exercises to these muscle groups are included in the therapy whenever necessary.

Surgical treatment

Tears of the menisci: Torn meniscus is better excised. The operation of meniscectomy can be performed by an arthrotomy of the knee or by arthroscopic surgery.

Open meniscectomy: It is performed by doing an arthrotomy of the knee joint. A compression bandage is given to the knee joint, after operation. The bandage is removed after 2 weeks and the knee is mobilized. Weight bearing, however, is started after 3–4 weeks, after building up tone in the quadriceps muscle.

Arthroscopic meniscectomy: It is discussed elsewhere.

Treatment of ligament injuries

In partial rupture, when tense and painful haemarthrosis occurs, aspiration of the fluid may be done. The knee is immobilized in a long leg walking plaster for 4–6 weeks.

Static quadriceps setting and SLR are important during

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immobilization.

Complete rupture of the collateral or cruciate ligaments requires surgical repair or reconstruction. Acute injuries can be repaired whereas chronic (old) injuries need surgical reconstruction using a strip from fascia lata or ligamentum patellae. An above- knee plaster cast is maintained for 4–6 weeks after which the knee is mobilized.

Postoperative regime

1. **Postoperative programme for plica excision**

1st day – Ankle circumduction.

2nd day –

(a) Simultaneous quadriceps and hamstrings isometrics are very important and should be endured.

(b) Walking, gradual weight bearing with crutches.

5th day –

(a) Assisted SLR could be begun if not too painful.

(b) Hamstrings stretching sessions should be started.

2nd week –

(a) Active and active assisted flexion–extension exercises.

(b) Resistive hamstrings exercise to inhibit quadriceps thereby allowing more flexion.

(c) Passive patellar mobilization.

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Progress to resisted techniques.

2. **Postoperative programme for proximal or distal extensor reconstruction**: Knee flexion exercise is very painful and should be begun gradually with maximum relaxation.

Initiate flexion–extension (assisted) in cases of extensor reconstruction. By 6 weeks, the patient should attain 90 degrees of knee flexion.

3. **Postoperative programme for meniscectomies**

(a) Same as 1., only straight leg raising should be started right from day one.

(b) Hamstrings stretching to be begun a week or 10 days following surgery.

(c) Bicycling, running by 1 month.

4. **Postoperative programme following ligament repair**: There is usually a prolonged period of immobilization (about 6 weeks), hence:

(a) Ankle movements, quadriceps and hamstrings isometrics should be started in the cast.

(b) Non–weight-bearing crutch walking should be initiated immediately.

(c) Assisted SLR may be begun after a week.

(d) Knee hinge cast (functional cast bracing) may be

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applied after 10 days to allow small range of knee flexion–extension.

(e) By 6 to 8 weeks, the cast is removed. Knee flexion–extension exercises are made vigorous.

For posterolateral repairs, exercises are concentrated for terminal extension, flexion to extension and SLR.

For anteromedial instabilities, knee extension exercises are started.

Progress to graduated resistance for both the muscle groups. For the first month, the resistance for quadriceps should not be more than 5 lbs.

Passive extension should not be done as it may over-stretch the surgical reconstruction.

Proper instructions and assistance are given for weight bearing and gait training.

Caution

Isometric quadriceps contractions alone may produce a force which draws out the tibia anteriorly in relation to the femur (develop anterior drawer force). This is not advisable till the reconstructed ligament is matured. Therefore, during the early stage following ligamentous reconstruction, isometrics should be performed simultaneously to the quadriceps as well as hamstrings and not to the quadriceps alone (Yasuda & Saraki, 1987). This has to be done with the knee held in 5 degrees of flexion. This procedure is important, especially in anterior cruciate ligament reconstruction. After ACL reconstruction surgery, there is disproportionate loss of strength of the quadriceps. However, routine exercises for

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quadriceps strengthening are contraindicated. They put excessive stress on the reconstructed ACL. If at all, isolated quadriceps isometrics is a must, they should be performed with the knee in 70 degrees of flexion, when the anterior drawer force on the tibia is totally eliminated (Levy & Goldstein, 1987; Yasuda & Sasaki, 1987). The knee ROM is therefore restricted to 30–90 degrees up to 4 weeks after reconstruction.

Since the process of ligament reorganization is very slow, these patients should be put on vigorous activities only after a year. They may require 4–6 months to regain full extension.

Utmost care is needed while teaching floor squatting and cross-leg sitting.

All these patients should be warned to watch for a limp or an increase in swelling. These signs indicate excessive strain and should be avoided.

The hamstrings regain normal muscle power and endurance sooner than the quadriceps mechanism. Therefore, resistive quadriceps exercises (body resistive) need to be continued for a long period (Fig. 36-14).

5. **Postoperative programme for capsular repairs:** Severe sprain to the tibial collateral ligament may result in disorganization of the medial meniscus, ACL and posterior medial capsule.

Immobilization is given for 3–4 weeks with the knee in 60 degrees of flexion and foot in internal rotation. Cast bracing with de-rotation brace follows.

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The most important aspect besides regular routine measures is to regain terminal active extension of the knee (with brace) through slow and controlled exercise. This is to avoid knee instability at a later stage (Malone, 1988).

Weight bearing should be initiated only after regaining full active knee extension.

Exercise programme should be submaximal to begin with, progressing gradually to the maximum. The sequence will be multiple angle isometrics, partial range isotonics and isokinetics.

Adductor and internal rotation strengthening is important.

Maintaining foot with intoeing position is to be guarded carefully.

Monitor correct proprioceptive activities to revitalize mechanoreceptor unit.

The isokinetic protocol should be of gradually progressing velocity spectrum from 30 to 300 degrees/s.

Following reconstruction or repair of the posterior cruciate ligament, isometrics to the quadriceps need to be carefully controlled. The usual tendency of pushing the knee posteriorly with isometric efforts should be discouraged.

Arthroscopy and arthroscopic surgery

Arthroscope is a tubular endoscope through which the inside of a joint can be visualized (Fig. 36-15). It is most commonly performed on the knee joint. However, other joints like shoulder, elbow, wrist and ankle

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can also be visualized with an arthroscope.

FIG. 36-15 Arthroscope.

Indications for arthroscopy

1. Recurrence of symptoms

2. Locked knee joint

3. In the diagnosis of internal derangements of the knee joint and loose bodies, etc.

Arthroscopy is very useful in the diagnosis and assessment of various knee disorders and internal derangements like tears of menisci and cruciate ligaments. Apart from diagnosis, the arthroscope is used for therapeutic purposes also. Nowadays, the various structures in a joint can be operated upon without performing a formal arthrotomy by inserting athroscopic fine instruments through a second puncture in the joint. This arthroscopic surgery helps in removal of torn or degenerated menisci and loose bodies from the knee joint and even helps in the reconstruction of torn cruciate ligaments.

Arthroscopic surgery (diagnostic as well as therapeutic) is performed through one or two small puncture wounds in the skin. Postoperatively, generally, a compression bandage is given for about a week. The period of hospitalization is only a day or two. Therefore, the greatest advantage of arthroscopy is rapid rehabilitation.

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Mobilization and non–weight-bearing can be started within a week, and full weight bearing in the second week.

Physiotherapy

The physiotherapeutic management depends upon the type of lesion and the arthroscopic procedure which could be diagnostic or therapeutic.

In a diagnostic arthroscopy, the programme of physiotherapy is short and simple. It is basically directed to maintain and improve the knee function. The basic principles of physical therapy are as follows:

1. Reduction of effusion

2. Quadriceps isometric contractions

3. Maintenance of full ROM

4. Relaxed knee swinging

5. Proper weight bearing and walking

Physiotherapy for arthroscopic surgery: As for any other surgical procedures, the management falls into the following two distinct phases.

Preoperative training

This has a conditioning effect on the patients and shortens the period of recovery. It consists of:

1. Teaching the exact technique of isolated, sustained isometric submaximal contractions of the quadriceps to avoid atrophy and reflex inhibition.

2. Relaxed speedy quadriceps settings to reduce effusion and oedema.

3. SLR to stabilize the knee.

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4. Resistive exercise for hamstrings and gastrosoleus to increase the posterior stability of the knee.

5. Relaxed coordinated knee swinging for the early return of knee flexion ROM.

6. Single leg standing, balancing, weight transfers and gait training.

Postoperative physiotherapy regime

Zarins et al. (1985) divided the total period of recovery into the following phases:

Phase I: Immediate postoperative period (3–5 days).

Phase II: Phase of early healing (5–15 days).

Phase III: Phase of late healing (15–21 days).

Phase IV: Phase of conditioning (3–5 weeks).

Phase V: Functional progression (6 weeks onwards).

Physiotherapeutic regime is elaborated in Table 36-6.

Table 36-6
Physiotherapeutic Programme (Phasewise) for Arthroscopy and Arthroscopic Surgery

Phase	Physiotherapy Regimen
Preoperative (training)	1. Explain and teach postoperative regime on the sound contralateral limb 2. Isolated quadriceps setting – speedy as well as sustained 3. Straight leg raising 4. Resistive hamstrings and gastrosoleus exercise 5. Relaxed and coordinated knee swinging 6. Instructions in balancing, weight transfer, supported weight bearing and gait cycle (normal)
Phase I	
Immediate postoperative (3–5 days)	1. To reduce pain – Electrotherapeutic modality + Relaxation training 2. To reduce effusion – Speedy quadriceps settings or electrical stimulation under pressure bandage with the limb in elevation; resistive ankle, foot movements and SLR 3. To prevent reflex inhibition – Sustained frequent isolated quadriceps setting with hold for 6–10 s

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	4. Supported relaxed knee passive swinging in small range with normal contralateral leg
Phase II	
Early healing (5–15 days)	Gradual but definite progression of earlier measures in Phase I + Add: 1. Knee rachet, pedocycle or static exercise regime 2. Weight transfers 3. Supported or full weight-bearing ambulation 4. Knee ROM should be 90 degrees at least
Phase III	
Late healing (15–21 days)	1. Vigorous progressive resistive quadriceps exercise, supported and guided functional positions 2. Floor squatting, cross leg-sitting and prone heel sitting (kneeling) 3. Standing on the affected leg alone, ambulation unsupported or with minimal support, but no limp 4. Knee ROM should be around 120 degrees
Phase IV	
Conditioning (3–5 weeks)	1. High sitting speedy isotonic full ROM, relaxed knee swinging 2. Progressive resistive quadriceps exercises 3. Balance activities – proprioception 4. Gait training 5. Return to work
Phase V	
Functional progression(6 weeks onwards)	1. Spot running – by holding wall bars 2. Straight jogging 3. Straight running 4. Jumping, hopping 5. Agility drills (e.g., figure-of-eight running) 6. Gradual return to sports

The modalities like cryotherapy, pulsed electromagnetic energy (PEME), ultrasonics and TENS are valuable in reducing pain and effusion.

Osteotomy around the knee

Osteotomy around the knee joint is done basically to correct acquired genu valgum, varum or recurvatum deformities the causes of which may be varied. Genu valgum may be congenital, due to rickets, quadriceps insufficiency, idiopathic or degenerative arthritis. Genu varum may be caused by rickets, Blount disease (an osteochondritis of the upper tibial epiphysis) or osteoarthritis of the knee joint. Genu recurvatum results from paralytic conditions such as poliomyelitis or excessive spasticity of gastrosoleus.

In genu varum and valgum, the defect may be either in the femur, tibia or both. Corrective osteotomy is, therefore, required in the distal femur, or proximal tibia (Fig. 36-16) or at both these sites, as the case

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may be.

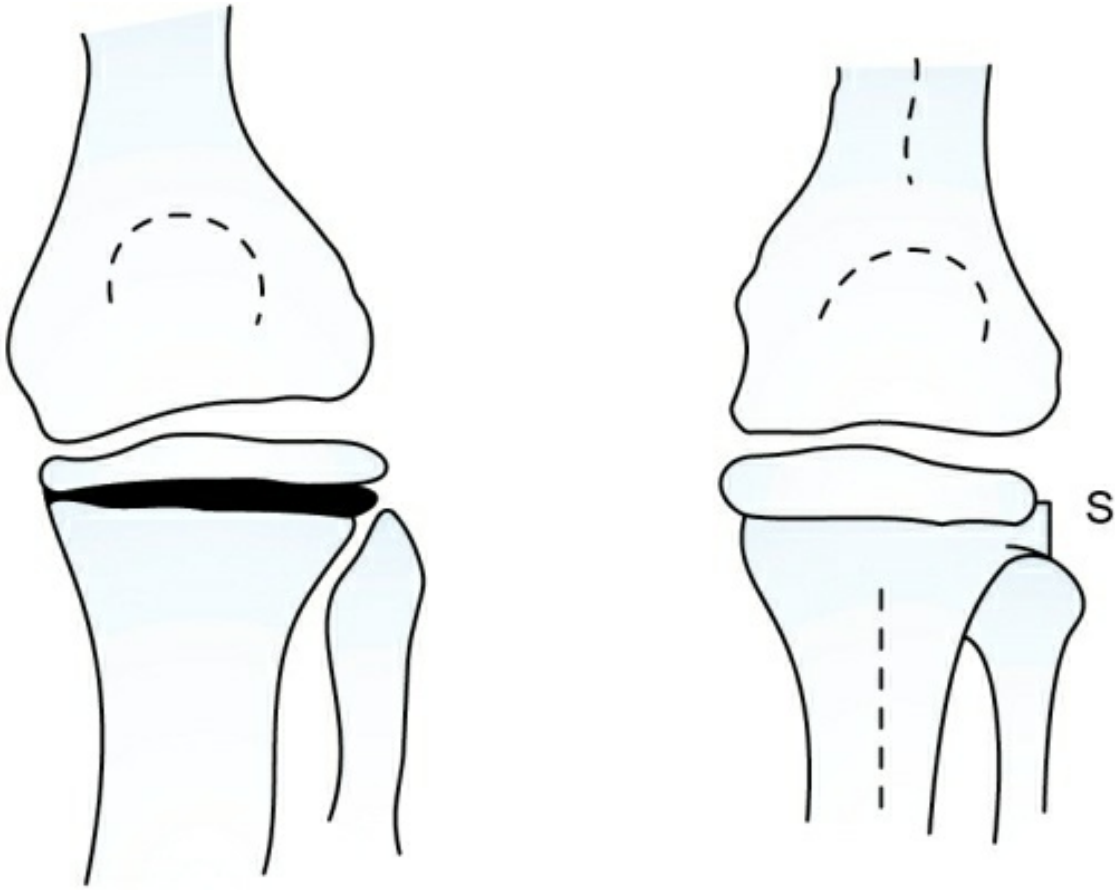

FIG. 36-16 Corrective osteotomy at the proximal end of the tibia fixed by staple (S).

Wedge osteotomy

1. *Distal femoral osteotomy*: It is also called supracondylar osteotomy since it is done in the supracondylar region of the distal femur.

In children, the osteotomy is generally not fixed internally and hence plaster cast immobilization is maintained postoperatively for 6–8 weeks. In adults the osteotomy is fixed internally with special plates and therefore, the

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postoperative immobilization is for 8–10 days only after which knee mobilization is started.

2. *Proximal tibial osteotomy*: As stated earlier, it is performed for correction of genu recurvatum as well as for valgum/varum. Of these, it is most commonly performed in osteoarthritis of the knee joint. It is also termed as high tibial osteotomy (Fig. 36-16).

In osteoarthritis of the knee, varus or less commonly valgus deformity causes abnormal distribution of body weight stress within the joint. In genu varum, these stresses are concentrated medially and vice versa. This leads to degenerative changes in that part of the joint or it could be vice versa.

In osteoarthritis of knee, genu varum deformity is more common with resultant degenerative changes in the medial compartment of the knee joint. A valgus osteotomy is, therefore, a commonly performed operation. In this operation, a wedge of bone is taken out from the lateral cortex of tibia and the gap thus created is closed. The osteotomy may be treated in a POP cylinder cast alone or fixed internally with staples. After osteotomy, the weight-bearing axis shifts laterally from the medial compartment of the knee joint and thus helps in relief of pain.

The prerequisites of this operation (i.e., high tibial osteotomy):

1. Radiographically, only the medial (or less commonly, the lateral) compartment of the knee joint should be involved. In other words, it should not be a generalized (multicompartmental) osteoarthritis.

2. The patient should have at least 90 degrees of flexion at the knee joint without any flexion deformity.

3. The patient should not preferably be obese.

Postoperative regime

The patient is given a POP cylinder cast or an above-knee plaster cast

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after operation. The cast is maintained for a period of 6–8 weeks. However, weight bearing causes compression at the osteotomy site and helps in union of the osteotomy. Physiotherapy is started after removal of the plaster. In cases where the osteotomy has been fixed internally with staples, the POP can be removed after 4 weeks and mobilization started.

Physiotherapeutic management

This is a common procedure in osteoarthritic knee joints having severe genu varum or genu valgum deformities with intense pain.

Preoperative phase

1. Accurate assessment of the degree of deformity, muscle strength, endurance and ROM and functional status is done.

2. Anticipating the postoperative weakness and wasting, the quadriceps should be trained for repeated isometric and resisted exercises.

3. If genu valgum or varum is associated with flexion deformity at the knee, long sessions of sustained low intensity stretching of the knee with small weight are necessary.

4. If there is limitation of knee flexion, various mobilizing techniques may be necessary to attain maximum range of knee flexion.

This programme of improving ROM and strength is especially important where Benjamin's procedure (1969) is to be performed as this procedure involves simultaneous resection of the distal femur and proximal tibia.

Postoperative phase

During immobilization: The leg is put in a posterior splint with pressure bandage. Limb elevation with isometrics (speedy as well as

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slow) should be initiated at the earliest. Strong resisted movements are also given to the ankle, toes and hip. By 3–4 days, feeble isometric contractions of the quadriceps should progress to strong static contractions.

Standing on the normal leg can be initiated by the end of first week.

In the second week, assisted straight leg raising (SLR) exercise can be started safely and progressed to full range active as well as resistive movement of SLR.

Partial weight bearing should be initiated first on double axillary or elbow crutches. Axis of load-bearing should be checked precisely during weight bearing. Appropriate wedge in the shoe may be necessary to correct alignment of the weight-bearing axis in the presence of ankle and foot deformity.

During mobilization: Vigorous relaxed and graduated programme of knee mobilization and strengthening is started after removal of POP cast. Posterior half of the cast is applied during walking. Alternatively, cast brace with mechanical joint may be applied. This helps to initiate knee mobility and muscle strengthening procedures. However, alignment of the axis of the orthotic knee joint to that of the anatomical knee joint should be accurately checked before initiating exercises and ambulation. In cases where some sort of internal fixation has been used, the knee mobilization can be started early. Mobilization can be started by CPM (continuous passive motion) from the second postoperative day.

Optimal range of knee movements and quadriceps strength should be attained by 6 weeks. Full weight bearing may be initiated if the osteotomy has united by this time.

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Vigorous training in functional activities should be initiated. Correct knee sequence in gait training to be concentrated to attain near normal gait pattern.

The patient should have strong and full range of knee movements with total functional independence by 12 weeks.

Caution

Active isotonic exercises are not to be included during early postoperative stage. When the cast is temporarily removed for exercises, there is a danger of reaction to the arthritic changes within the knee (Slocum et al., 1974). Relaxed passive movements are employed as a procedure of mobilization of the knee.

Quadricepsplasty

In this procedure, the quadriceps muscle is lengthened by V–Y plasty to achieve a functional range of knee flexion in a stiff knee. Stiffness of knee is common after injuries, which are either close to the knee joint or need prolonged immobilization, such as:

1. Fracture at the lower third of the femur.

2. Fracture of the femur associated with comminuted fracture of patella.

3. Compound fracture of the femur with delayed union.

4. Infected wound around the knee joint, with skin loss.

It is also indicated in congenital contracture of the quadriceps.

Prerequisites for quadricepsplasty

1. Sound union of the fracture of the shaft of the femur.

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2. Good power and endurance in the quadriceps mechanism.

3. The joint and articular surfaces must be in an ideal condition to permit free movement after surgery.

4. The patient must be young and well prepared to take up the long and painful exercise regimes.

The surgical procedure depends upon the causative factor of the stiff knee.

If the cause of stiffness is intra-articular, then the following operations are indicated:

- *Bennett's procedure*: The tendinous rectus femoris insertion to the upper border of the patella is divided by an inverted 'V' incision. The limbs of the 'V' are extended to the lateral quadriceps expansion. Intra-articular adhesions are divided by reflecting the patella downwards. The quadriceps insertion is sutured with the knee flexed to 90 degrees. The inverted 'V' incision is now converted to an inverted 'Y' (Fig. 36-17). After wound closure, the knee is bandaged in 90 degrees of flexion.

- *Thompson's operation*: This is indicated when the knee ROM is restricted due to adhesions both at the fracture site and the knee joint.

A long anterolateral incision is made exposing the lower two-thirds of the quadriceps and knee joint. The rectus femoris is separated from the vastus mediu, intermedius and lateralis, and the underlying adhesions are removed from all these muscles and the patella. The knee joint is opened and the lateral portions of capsule are separated from the femoral condyles. The knee is manipulated to attain maximum flexion. The muscles are loosely approximated by intermittent sutures.

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A pressure bandage is applied with the knee in flexion or traction may be applied in a Thomas splint with Pearson knee-piece for 3 weeks.

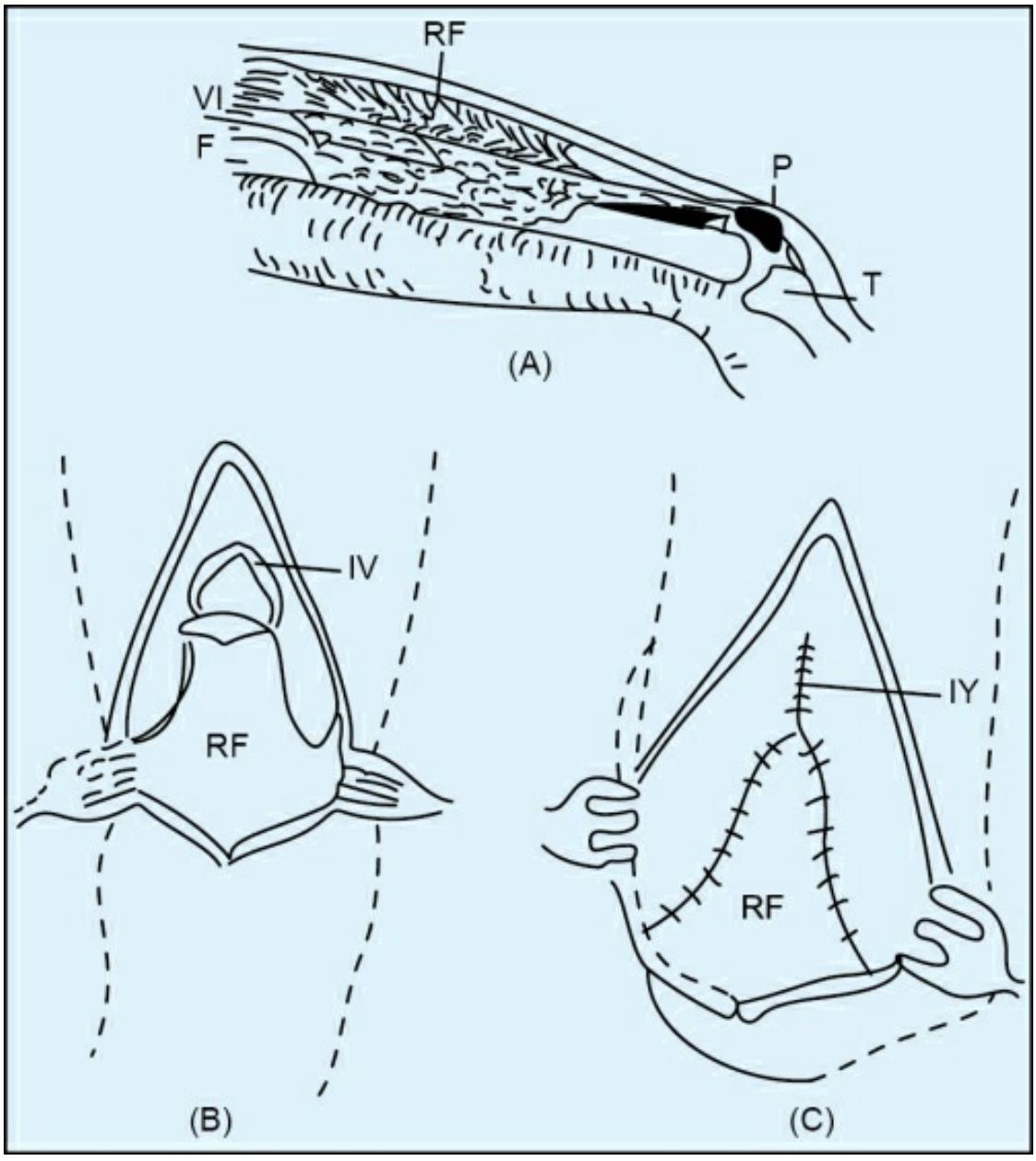

FIG. 36-17 Bennett's procedure: quadriceps lengthening by 'V-Y' plasty: conversion of inverted 'V' incision of rectus femoris (IV) tendon to inverted 'Y' (IY). (A) F, femur; P, patella; T, tibia; RF, rectus femoris; VI, vastus intermedius with adhesions to the callus on femur, restricting the movement of knee flexion. (B) Retraction of rectus femoris muscle by inverted 'V'

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incision (IV) to clear adhesions in the vastus intermedius, with knee in extension. (C) Knee is flexed to the maximum and rectus femoris is stitched as inverted 'Y' (IY).

Physiotherapeutic management

Early mobilization to maintain the ROM achieved by surgery is the most important aspect of physiotherapy.

1. Use of CPM (continuous passive motion) immediately after surgery is ideal.

2. Self-assisted relaxed passive movements by using the contralateral normal limb by the patient himself are initiated at the earliest.

3. TENS may be used along with exercises to reduce pain.

4. After removal of stitches, vigorous exercises are given at frequent intervals to maintain or improve the ROM further.

Caution

The reflex inhibition of quadriceps, resulting in an extensor lag needs to be taken care of from the early stage.

The ROM achieved following surgery should be maintained and improved by repeated relaxed movements or else adhesions have a tendency to reform.

5. Early institution and careful monitoring of isometrics to the quadriceps are very important. Speedy as well as slow sustained isometrics need to be emphasised to re-educate and strengthen the quadriceps.

The rest of the regime follows on the same lines as described for recurrent dislocation of the patella.

Chondromalacia patellae

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It is a degenerative condition of the knee affecting the cartilage of the patella in an otherwise fit person. There occurs fibrillation, fissuring, erosion and softening of the articular cartilage of the patella (Fig. 36-18). It gives rise to the following symptoms:

1. Pain arising from the posterior aspect of the patella.

2. The pain worsens with strong quadriceps contractions in actions like descending stairs or getting up from squatting or from chair.

3. There is an associated symptom of the knee 'giving way' or 'locking'.

4. The ROM at the knee is usually full.

5. There may be slight effusion and quadriceps atrophy.

6. Compression of the patella against femoral condyles causes pain.

7. Radiographs show osteoporosis. Anteroposterior striping is visible on 'skyline view'.

FIG. 36-18 Chondromalacia patellae: Skyline view of patella indicating erosion of the articular cartilage of the patella.

The aetiology is unknown; however, mild repeated trauma, inflammatory or metabolic joint disease may precipitate the condition.

Adolescents and young adults (age group 17–35 years) are commonly affected, the incidence is however more common in females.

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Treatment

Conservative

It is effective in mild cases.

1. Initially, if too painful, the knee is immobilized in a POP cylinder cast.

2. The exercise programme, then, includes:

(a) Gentle isometric quadriceps contractions.

(b) Assisted SLR.

(c) Strong hip, ankle and foot movements.

(d) Ambulation with shoe raise on the normal side, so as to facilitate movement of the affected leg encased in a cast.

When treated without a plaster cast:

1. Avoid strenuous activities.

2. Isometrics to quadriceps with the knee in slight flexion to avoid patellar movement, within the limits of pain.

3. Assisted SLR without hyperextension at the knee.

4. Relaxed passive or active knee swinging to maintain full ROM of both flexion and extension.

5. Deep thermotherapy modality like pulsed short-wave diathermy or ultrasonics may be given as an adjunct for pain relief.

6. Ambulation has to be properly controlled to avoid excessive hyperextension of the knee; genu recurvatum has been reported as

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one of the common features following chondromalacia patellae.

7. Exercise programme to be progressed to PRE as pain is reduced, encouraging functional activities except squatting.

Injection therapy

Corticosteroid injections could be tried.

Surgery

Surgery is indicated only when the conservative treatment fails to provide relief.

1. *Arthrotomy*: The affected area of articular cartilage is removed by shaving and smoothening. This procedure has been reported to be effective in very early cases of chondromalacia patellae.

2. *Patellectomy*: It is indicated when fragmentation and fissuring affects an area of more than 1.3 cm in diameter, or erosion of the articular cartilage and subchondral bone occurs.

Physiotherapy following surgery

A POP cylinder cast is applied after shaving of the articular surface.

The physiotherapy regime is the same as described for conservative management with plaster cast. The only difference being that vigorous exercises are delayed till soft tissue healing occurs.

For patellectomy, the physiotherapeutic management is the same as described under the heading of patellectomy.

Caution

Keeping in view the common occurrence of genu recurvatum, exercises putting extra strain on the posterior aspect of the knee should be deferred, e.g.,

1. Single leg standing,

2. SLR in long sitting and

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3. Excessive knee extension or heel strike stress at an early stance.

Osteochondritis dissecans

In osteochondritis dissecans, there is localized avascular necrosis of a segment of the articular surface of the medial condyle of the femur.

It occurs usually in males during the second decade of life. The predisposing factor may be an injury or impingement against the tibial spine, resulting in thrombosis of the end artery leading to necrosis. One segment of the subchondral bone becomes necrotic with softening of the overlying cartilage. At a later stage, the fragment separates as a loose body. This leaves a shallow cavity in the articular surface which eventually is occupied by fibrocartilage (Fig. 36-19). The precise cause is unknown.

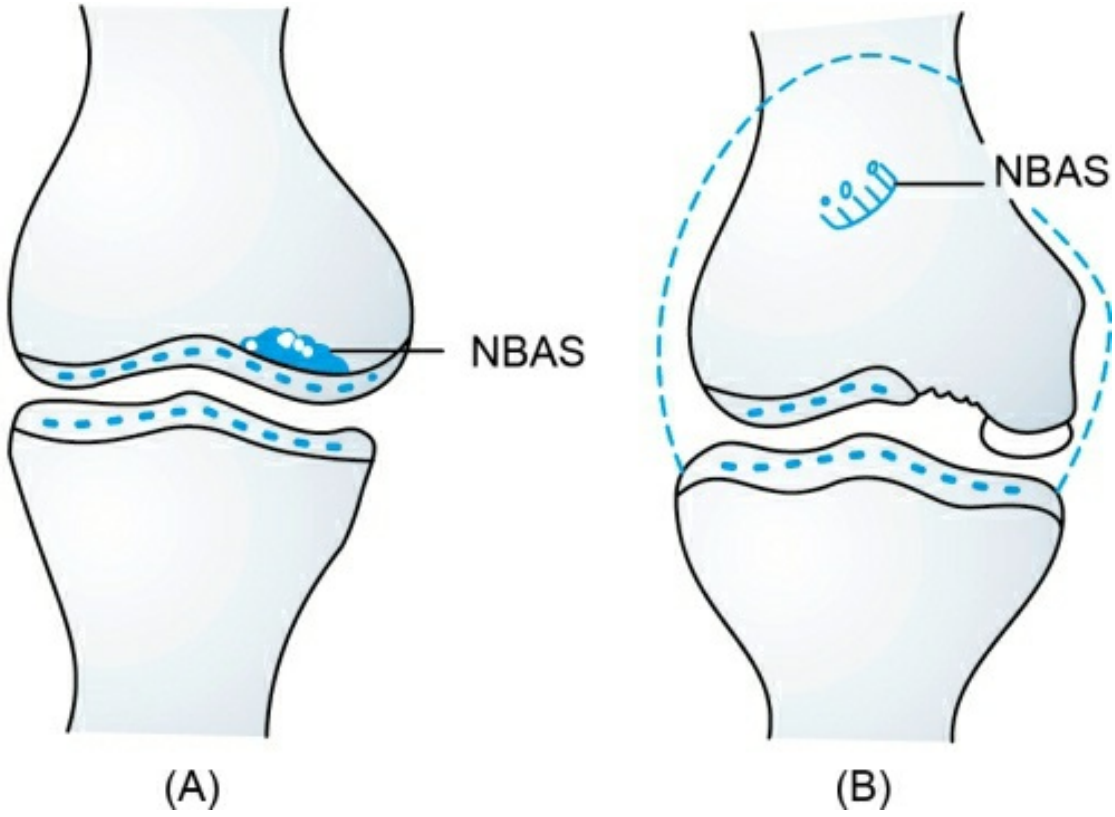

FIG. 36-19 Osteochondritis dissecans: (A) NBAS: formation of necrotic

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bony articular segment. (B) NBAS: separation of the bony fragment as a loose body.

Initially, pain appears after exertion, with occasional effusion. The range of motion at the knee joint is usually not affected. However, sudden locking with sharp pain may occur if the loose body gets lodged into the joint.

Treatment

Rest is given to the knee joint using a POP cast or a crepe bandage. The patient is encouraged to do static quadriceps contractions, limb elevation, and vigorous ankle and foot movements.

Before separation of the fragment, attempts may be made to revascularize the interface by drilling into the underlying healthy bone. When separation of the fragment occurs, the small fragment may be removed by surgery or replaced in its position and fixed by a steel pin or wire.

Rarely, it may affect the elbow joint (capitulum), the hip joint (femoral head) or the ankle joint (talus).

Besides joint mobilization and improving the endurance of the muscles around the knee, prevention of compressive forces on the joint are of primary importance. Therefore, the patient must be guided against undue weight bearing – postures and activities like stair climbing and descending.

Complications: Osteoarthritis of the knee.

Popliteal cysts

Semimembranosus bursitis

The semimembranosus bursa which lies between the medial head of the gastrocnemius and the semimembranosus may become a seat of irritative bursitis. The bursa gets distended with fluid which develops into an elongated fluctuant bursal swelling posteriorly between the planes of these two muscles. A soft cystic swelling close to the medial femoral condyle is formed.

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Treatment

It usually does not require any specific treatment. However, if the swelling becomes large and uncomfortable, excision of the sac becomes necessary.

Baker's cyst

Sometimes, herniation of the synovial cavity of the knee with a fluid-filled sac may occur in the popliteal space. This sac extends backwards and downwards at the posterior border of the popliteal space. A soft palpable bulge is present which becomes more obvious on extending the knee joint (Fig. 36-20). In rare cases, it may be situated at the upper portion of the calf.

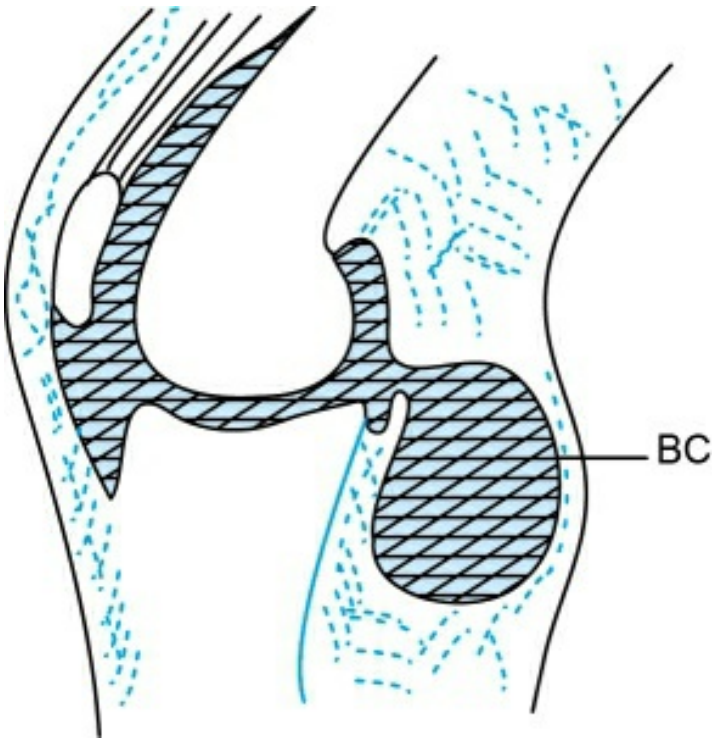

FIG. 36-20 Baker's cyst (BC). Herniation of synovial cavity with a fluid-filled sac in the popliteal space.

The precipitative factor is persistent synovial irritation and effusion as occurs in osteoarthritis.

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Treatment

The treatment is directed towards the underlying causative factor responsible for the repetitive synovial irritation. However, an excessively large Baker's cyst may need excision.

The main principle of physiotherapy is directed towards the reduction of excessive compressive or stretching forces over the popliteal space.

The knee movements are guided without extreme flexion or extension stretches.

Quadriceps strain

Rectus femoris is the commonest seat of strain in the quadriceps muscle. The strain to this muscle results from a miskick, a sudden forceful take off in sprint-start. Direct blow over the muscle belly may also result in a strain.

As this muscle acts on both the hip and knee joints, the diagnostic sign of strain is pain during the combination of hip flexion and knee extension. In grades I and II strains, this combination of movement is painful; however, weight bearing or level ambulation is not much affected. In severe strain of grades III and IV, a gap is felt over the muscle belly at about mid-thigh region and weight-bearing and ambulation become impossible.

In rare cases, vastus medialis, vastus lateralis and vastus intermedius may develop strain. Site of resistive extension provides clues to the involvement of a particular muscle. Resisted knee extension is extremely painful. Similarly, terminal range of knee flexion is also painful due to stretching elongation of the strained muscle.

Besides these sites, the quadriceps apparatus itself may be injured at various sites by sudden knee flexion resisted by reflex quadriceps contractions (e.g., when a person stumbles while going down in steps).

The injury may occur at the upper pole of patella, through the patella or at the attachment to the tibial tubercle.

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Treatment

A complete rupture usually needs surgical intervention in the form of suturing the avulsed quadriceps tendon. Milder varieties of strain may be treated by a supportive bandage.

Following surgery, a POP cylinder is applied for 3 weeks followed by posterior knee slab till the knee regains good range of flexion (around 90 degrees).

Physiotherapeutic management

1. **Patients treated by conservative methods:** Measures to reduce inflammation and pain like ice massage, ice packs, limb elevation and optimal resting position with suitable drug therapy are initiated.

Mild but frequent isometrics to the quadriceps are begun as early as the pain permits.

Relaxed passive knee movements are begun by removing bandage temporarily.

Properly controlled graded active-assisted, active free exercises to improve the strength and endurance of the quadriceps and hamstrings are of primary importance. Terminal range of extension at the knee needs extra attention to avoid extensor lag.

Graded weight bearing and gait training may be necessary to avoid limp.

Exercises should be made vigorous to achieve full function by 5–6 weeks.

2. **Patients treated by surgery:** It follows the same pattern as for conservative treatment. Static quadriceps contractions should be

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started at the earliest (5–6 days) inside the plaster cast. Self-assisted SLR with limb in plaster cylinder should be initiated early.

Non–weight-bearing crutch walking without much jerk should be initiated on the 2nd or 3rd day following surgery and progressed to partial weight bearing by 3 weeks. Full weight bearing can be started safely by 5–6 weeks.

On removal of the plaster cylinder, graded knee flexion–extension exercises beginning with relaxed passive movement should be started. As soon as knee flexion of around 90 degrees is attained, knee-slab can be discarded.

If extensor lag is present, electrical stimulation synchronized with voluntary quadriceps contractions may be needed besides repeated isometrics to the quadriceps.

Progressive resistive exercises, guided squatting, cross-leg sitting and gait training may be necessary.

Adequate knee function is achieved by 6–8 weeks. However, sports should not be resumed before total conditioning is achieved.

Hamstrings strain

The common site of hamstrings strain is at the fibular insertion of the biceps femoris muscle. There is localized tenderness at this site; resisted flexion and active full extension at the knee are extremely painful. Knee may remain locked in slight flexion due to spasm in the strained hamstrings. Many a times, there may be an associated injury to the common peroneal nerve which should be examined carefully. Weight bearing is uncomfortable in grades I and II strains, and is impossible in grades III and IV strains. Ice massage or ice pack, rest in

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optimal position, compression bandage and anti-inflammatory and analgesic drugs constitute the treatment.

Well-controlled isometrics, though painful, should be started early to both quadriceps and the hamstrings.

Self-assisted relaxed knee swinging should be initiated as early as possible. However, weight bearing and strengthening exercise should be progressed in grades to avoid excessive strain. PNF techniques are ideal which should be done with controlled resistance without causing pain in the hamstrings. In some patients, gait training may become necessary.

Full function usually returns within 3 to 4 weeks.

Strained calf muscle

Strain in the calf muscle frequently occurs in athletes due to sudden overstretching of the calf muscle. Pain and tenderness are present in the calf rather than achilles tendon. Also, there is absence of a gap which is the diagnostic feature of rupture of the tendoachilles. Resisted plantar flexion is painful with loss of toe push off while walking. Though painful, it is possible for the patient to stand on the toes, raising heel from the ground.

Spontaneous relief occurs with local ice application, compression bandage and avoiding overstretching activities along with medication.

Adequate functional recovery occurs within a week. However, sportsmen should keep away from vigorous manoeuvres for at least 3 weeks.

Patellar tendinitis (jumper's knee)

Repetitive microtrauma to the tendon-bone interface as in jumpers, is the causative factor for patellar tendinitis. There is pain over the inferior pole of patella.

On examination, tenderness is felt over bone – tendon interface without swelling or instability.

During the acute phase, medication, rest, cryotherapy, diapulse or ultrasonics is applied. Gentle isometrics to quadriceps are initiated.

Gradual mobilization of the knee is begun, when the pain and

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tenderness are reduced.

Curwin and Stanish (1984) advocated the use of graduated eccentric exercise to strengthen the quadriceps muscle – patellar tendon unit. This is done to prepare the tendon for stresses. Improvement in the eccentric work capacity has been found to be greatly rewarding in the early resolution of pain and achieve full function (Jensen & Di Fabio, 1989). Passive stretching of the quadriceps and hamstrings muscles is taught to the patients, along with other mobilizing and strengthening procedures.

Prepatellar bursitis

The prepatellar bursa, which occupies a position just over the patella, may get inflamed (Fig. 36-21). Occasionally, the bursa between the ligamentum patellae and the upper part of the tubercle of tibia may be the site of inflammation. The former is more common. Sustained pressure of body weight due to frequent kneeling (occupational or in handicapped persons who depend on knee walking) can also result in prepatellar bursitis. Alternatively, a direct blow on the knee may precipitate bursitis of these types.

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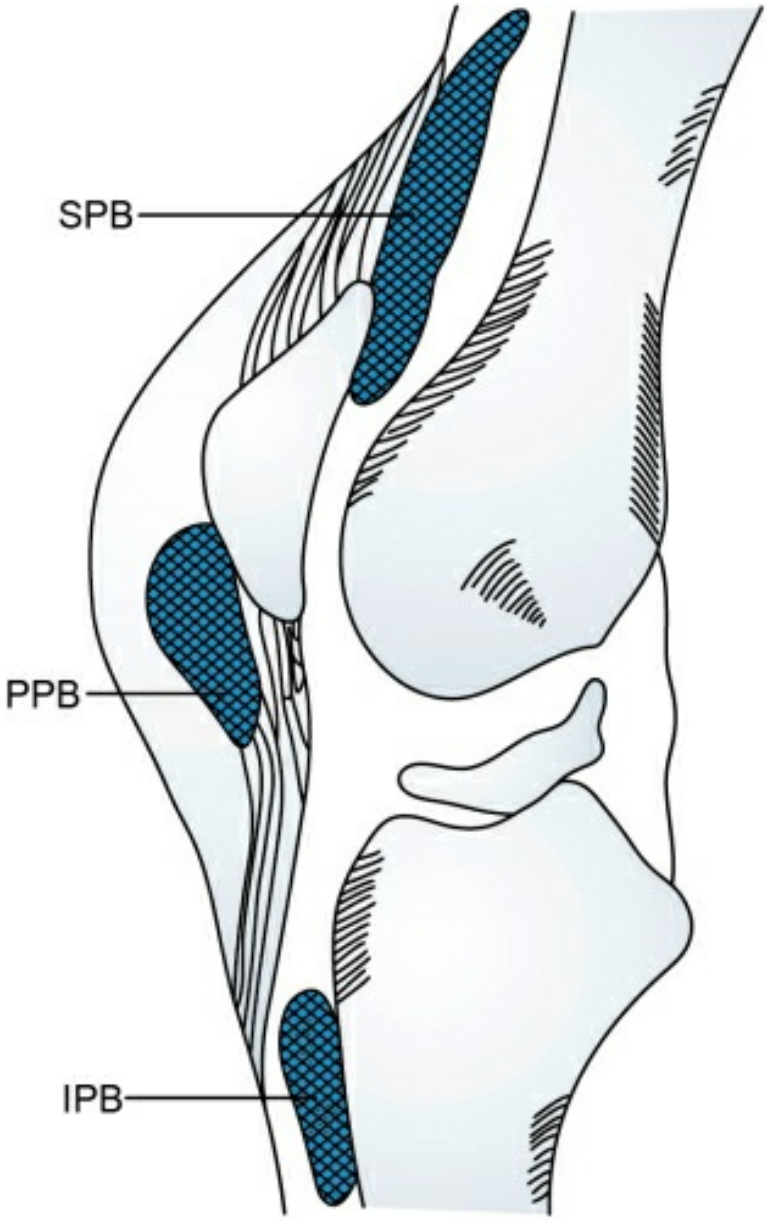

FIG. 36-21 Bursae at the knee. SPB, suprapatellar bursa; PPB, prepatellar bursa; IPB, infrapatellar bursa.

The patient presents with large rounded swelling over the patella. The skin over the swelling may be red, stretched with rise in local temperature. The swelling is tender and quadriceps activity may be painful.

Treatment

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1. ***Conservative***

(a) Analgesic anti-inflammatory drugs.

(b) Rest in the crepe or pressure bandage.

(c) Avoiding kneeling, pressure positions and movements at the knee.

(d) Limb elevation with sustained as well as speedy static contraction of the quadriceps, within the limit of pain.

(e) Relaxed knee swinging in an available pain-free range of flexion and extension.

(f) Electrical stimulation of quadriceps to avoid disuse atrophy.

(g) Assisted SLR.

2. ***Surgery***

Surgery may be necessary in patients nonresponsive to the conservative treatment and with the bursa becoming chronic and painful. The bursa is excised surgically. Postoperatively, a pressure bandage is given for a period of 2–3 weeks.

Postoperative management

1. Limb elevation, strong movements to the toes, ankle and hip.

2. By the end of 1 week when the soft tissues have healed, small range isometrics to quadriceps within the painless range can be initiated.

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3. Self-assisted relaxed passive knee swinging (flexion – extension) is safe.

4. Gentle passive manoeuvres should be initiated to improve patellar mobility.

5. Friction massage may be given around the patella.

6. Relaxed passive movements should be progressed gradually to active-assisted, active and then to active-resistive movements.

7. Re-education in walking is essential to discourage the usual tendency of walking with knee in flexion.

8. Body resistive quadriceps exercises (self-resistive) provide an excellent means of strengthening quadriceps and mobilizing knee.

9. Guided functional positions could be initiated with least pain. The patient should be back to normal activities by 4–6 weeks.

Plica syndrome

A fold in the synovial lining which arises from the undersurface of vastus lateralis passes transversely to the medial wall of the medial condyle of the femur and obliquely gets attached near the infra-patellar fat pad. When it is injured (indirectly), it gets inflamed and painful over an area medial to the patella. Pain is elicited after long sitting or knee flexion movements as the plica is compressed between the patella and the femoral condyle. At a later stage, plica becomes a tough inelastic fibrotic band. The presence of this syndrome can be confirmed by pain on medially displacing the patella with knee flexed to 30 degrees. While performing active extension of the knee from flexion, the patella skips or seems to jump between the range 60–45 degrees, as it passes over the plica. A false positive McMurray's sign may also be present.

Treatment

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Conservative management includes routine knee rehabilitation programme. Transverse friction massage over plica and sessions of hamstrings stretching are important. In nonresponding cases, arthrotomy or orthroscopic surgery to excise plica may be necessary. The management will be on the same lines as described for arthroscopy. Friction massage and hamstrings stretching are important.

Physiotherapeutic management

Arthroscopic surgery is minimally invasive. The patient is sent back home the same day after surgery. There is generally no external immobilization. Therefore, aggressive procedures in physiotherapy can be initiated early. Thus, the return of function is much more rapid.

The improvement in strength and the adaptibility of the repaired tissue to perform functional activities are the important aspects of the therapy.

All the routine procedures of therapy can be included with emphasis to regain terminal extension early.

Full weight can safely be started by 2 weeks following cast removal (8 weeks since surgery). Light activities to be resumed by 3 months.

Genu valgum (knock knee)

Inward or medial angulation of leg over thigh at the knee joint is termed as genu valgum or knock knee (Fig. 36-22A). In this condition, a line drawn from the head of the femur to the middle of the ankle joint passes lateral to the knee joint instead of passing through the centre of the knee.

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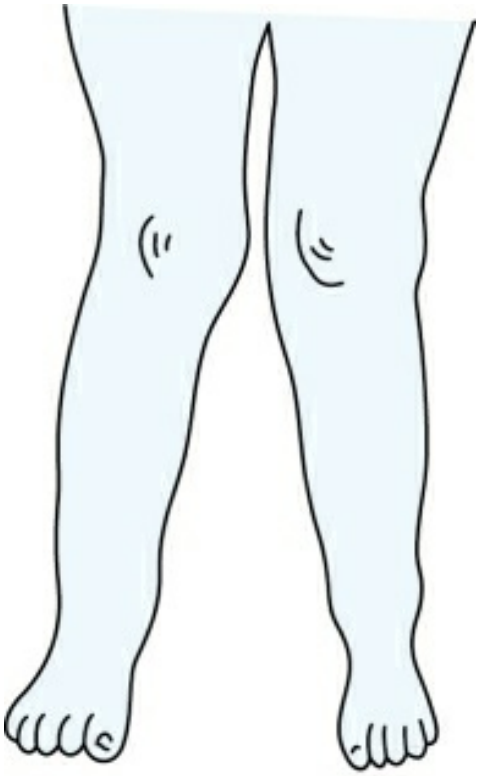

(A)

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(B)

FIG. 36-22 **(A)** Genu valgum. **(B)** Genu varum.

It could be because of:

1. Rickets, producing curvatures in the femur or tibia.

2. Growth imbalance between the medial and lateral femoral condyles. Rapid overgrowth of the medial condyle leads to knock knee.

3. Muscular or ligamentous weakness at adolescent stage.

4. Muscular paralysis of semimembranosus, semitendinosus.

5. Fractures and injuries involving the knee joint.

6. Secondary to coxa vara, flat foot, OA knees or spinal curvatures.

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As a consequence to the deformity, there is increased rotational or posterior mobility at the knee.

Treatment

The knee is evaluated for the degree of deformity in the weight-bearing position. Intermalleolar distance is noted which could vary from 2 inches to 20 inches. The angle of genu valgum is measured with a goniometer or using weight-bearing X-rays.

Any associated deformity is also evaluated.

Proper muscle chart and ROM measurements are recorded along with the effect of the deformity on the overall functional status.

The cases are divided into two groups for the purposes of treatment:

1. Those with negligible bony changes and

2. Those with marked bony changes.

The treatment is directed towards the causative factor. Specially designed orthosis with lateral uprights and a broad knee strap to pull the knee joint laterally is given. The patients are treated by corrective osteotomy.

Physiotherapeutic management

Cases treated conservatively: Correct method of applying orthosis, weight transfers and proper ambulation is taught.

Following surgery:

1. Graded knee mobilization constitutes the major part of physiotherapy. Knee mobilization should be initiated in a small range as relaxed free movement, progressing gradually.

2. Thermotherapy adjunct should be used as a pain controlling measure.

3. Strengthening exercises for the quadriceps, hamstrings and glutei

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should be instituted.

4. When the patient is allowed to walk, weight transfer should be done in stages till independent ambulation is achieved. Any tendency for recurrence should be carefully observed and treated by orthosis.

Genu varum (bow legs)

In this condition, there is lateral angulation of the tibia in relation to the knee. Thus, in standing with the feet together, the knees remain wide apart (Fig. 36-22B).

It is usually bilateral. The main causative factor of this deformity is early weight bearing, especially in children who are fat and heavy. In adults, it could be due to osteoarthritis of the knee joints.

Pathology

In genu varum, there is lateral curvature of the shaft of the femur, tibia as well as fibula, the maximum convexity being at the knee. In bow legs, only the shafts of the tibia and fibula are bent with lateral convexities. Internal rotation may be present at the hip joints with knees in hyperextension. The muscles and ligaments on the lateral aspect of the limb are stretched, whereas those of the medial aspect are shortened. The child adopts waddling pattern of gait with toes turned in and weight being borne on the lateral border of the feet.

Treatment

Mild cases: There occurs spontaneous improvement or full correction as the child grows up to the age of 5 years.

Moderate cases: If the deformity persists, orthosis to pull the knee joints medially (the reverse of the one prescribed for genu valgum) is given.

Severe cases: Nonresponding cases are managed surgically by corrective osteotomy.

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Physiotherapeutic management

It is on the same lines as detailed for the deformity of genu valgum. However, it must be remembered that since this deformity is the reverse of genu valgum, the therapeutic measures should be modified accordingly.

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CHAPTER

37

Regional orthopaedic conditions at the ankle and foot

OUTLINE

- Plantar fasciitis and calcaneal spur
- Metatarsalgia
- Tarsal tunnel syndrome
- Injuries to the tendoachilles
- Tenosynovitis around the ankle
- Pes cavus (contracted foot)
- Hallux valgus
- Hallux rigidus
- Hammer toe

The ankle joint is a complex and fairly unstable joint which derives its stability as well as the functional mobility required in ambulation, sports, etc. from 26 bones (7 tarsals, 5 metatarsals and 14 phalanges (Fig. 37-1)) which are held together by strong ligaments, muscles and the spring-actioned foot arches.

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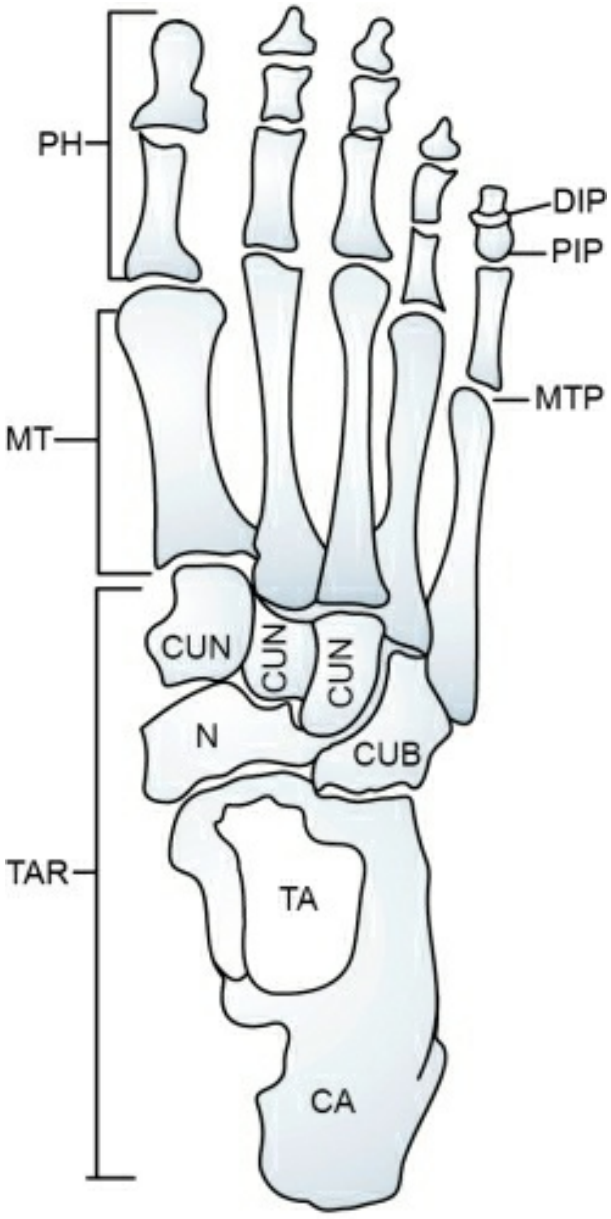

FIG. 37-1 Bones and joints of the foot. CA, calcaneus; TA, talus; CUB, cuboid; N, navicular; CUN, cuneiform; MT, metatarsals; PH, phalanges; MTP, metatarsophalangeal joint; PIP, proximal interphalangeal joint; DIP, distal interphalangeal joint.

Arches of the foot

1. Medial and lateral longitudinal arches extend between the calcaneus and metatarsal heads.

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2. Less defined transverse arch is located just posterior to the metatarsal heads (Fig. 37-2).

These arches are formed by the interlocking of bones and the following ligaments:

(a) Plantar aponeurosis, also known as plantar fascia

(b) Long and short plantar ligaments

(c) Plantar calcaneonavicular ligament

(a) *Plantar aponeurosis*: It is a thick band extending from the calcaneal tuberosity to the toes. It forms a strong intermuscular septum between the lateral, intermediate and medial plantar muscle groups. It has a series of arches for the passage of the flexor digitorium longus and brevis tendons.

(b) *Long and short plantar ligaments:* The long plantar ligament extends from the plantar surface of the calcaneus to the cuboid and the bases of the second to fifth metatarsals.

The short plantar ligament, which is deep to the long plantar ligament, extends from the anterior tubercle of the calcaneus to the plantar aspect of the cuboid.

These ligaments resist the flattening of the lateral longitudinal arch of the foot.

(c) *Plantar calcaneonavicular ligament*: It extends from the sustentaculum tali of the calcaneus to the plantar surface of the navicular bone.

The ligaments are so arranged that they facilitate certain

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movements while at the same time check excessive and harmful joint movements.

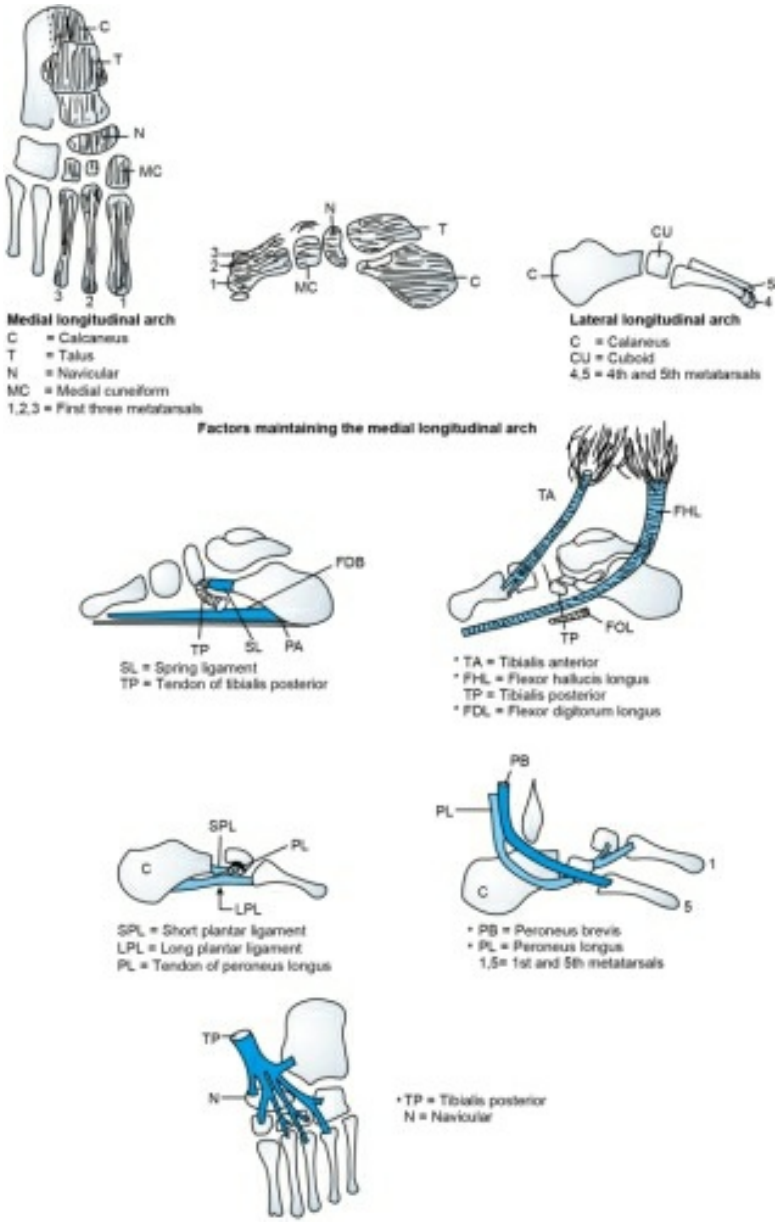

FIG. 37-2 The arches of the foot. **(A)** Factors maintaining lateral longitudinal arch. **(B)** Major gripping force of plantar surface tibialis posterior.

Functions of the arches of the foot

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1. These arches provide stability as well as mobility to body due to their spring action with least expenditure of energy and thereby prevent strain.

2. They also provide protection to the nerves, muscles and vessels of the foot.

3. They protect the foot from sudden injuries or deforming forces.

4. They provide a base for the smoothness of dynamic weight-bearing activities.

Ankle joint

The ankle joint is formed by the tibia, fibula and talus bones. The distal articular surfaces of the malleoli and that of the tibia along with the intervening strong tibiofibular ligament form a compact semicircular bony fit over the dome-shaped superior articular surface of the talus. It is called the ankle mortice (Fig. 37-3). An increase in the distance between the tibia and the fibula in the ankle mortice, called *disruption of the ankle mortice*, indicates a major injury to the ankle joint (Fig. 37-4).

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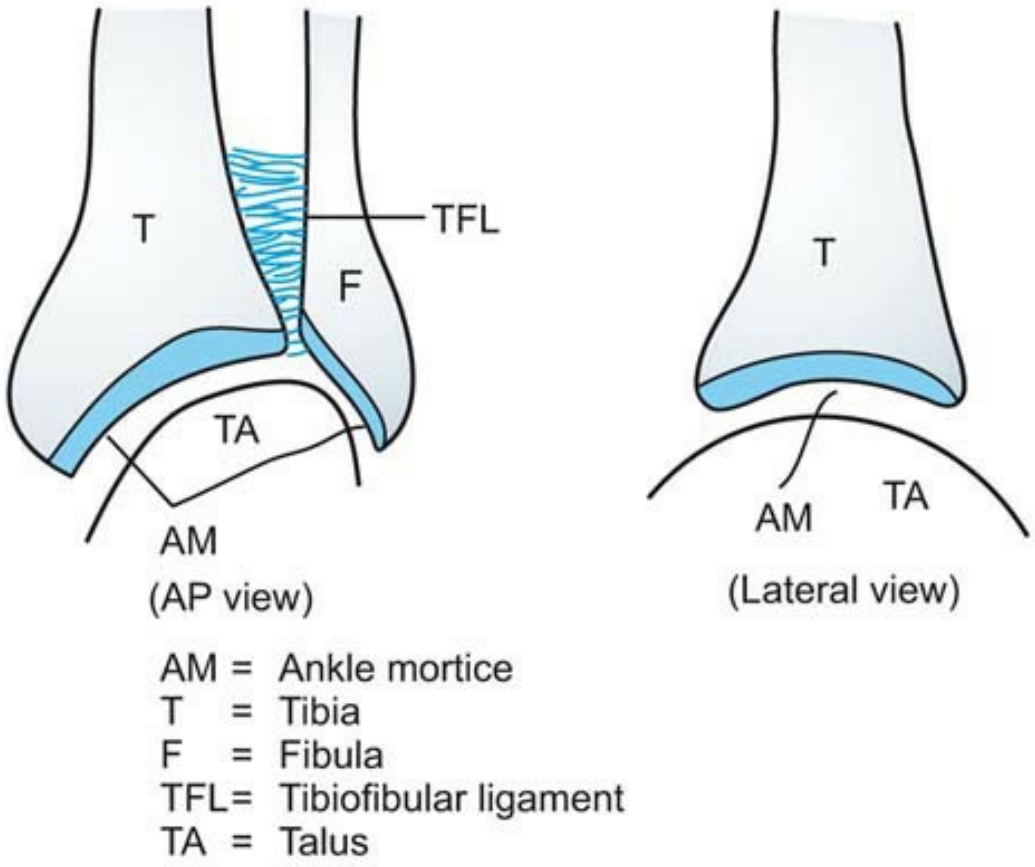

FIG. 37-3 Ankle mortice.

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FIG. 37-4 Bimalleolar fracture of the ankle showing disruption of the ankle mortice.

Structurally, the ankle joint has a strong (but susceptible to injury) deltoid ligament medially and weaker lateral collateral ligament laterally with its well protecting three bands (Fig. 37-5).

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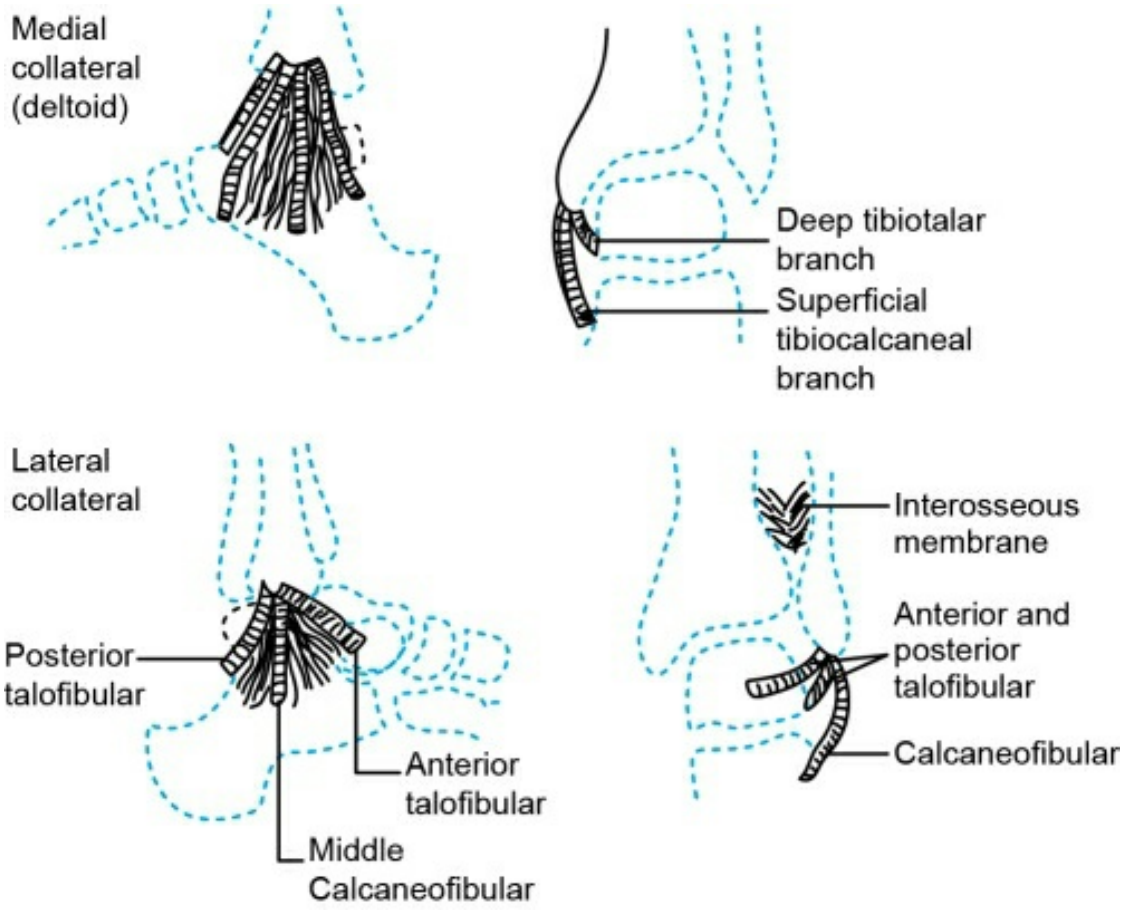

FIG. 37-5 Major ligaments of the ankle.

Muscles of the ankle joint

The muscles acting on the ankle joint are contained in three separate compartments:

1. Anterior compartment

2. Posterior compartment

3. Lateral compartment

The anterior and posterior compartments are separated by an interosseous membrane between the tibia and the fibula. The lateral compartment is separated from the other two by a strong intermuscular septum.

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Anterior compartment muscles cross the ankle joint anteriorly and act as dorsiflexors. The muscles of the anterior compartment (tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneus tertius) enter the foot under cover of the extensor retinaculum and are innervated by the deep peroneal nerve. Since these muscles cross the ankle joint anteriorly, they act as dorsiflexors of the ankle joint.

Posterior compartment muscles consist of a superficial group of gastrocnemius, soleus and plantaris and a deep group of popliteus, flexor digitorum longus and flexor hallucis longus muscles.

Both the superficial and the deep groups of muscles are innervated by the branches of the tibial nerve. The muscles cross the ankle joint posteriorly and become plantar flexors of the ankle.

Lateral compartment muscles are the peroneus longus and peroneus brevis. The peroneus longus traverses the plantar aspect of the foot and is inserted into the base of the first metatarsal, whereas the peroneus brevis takes a direct course to the base of the fifth metatarsal. Both these muscles are innervated by the superficial peroneal nerve.

Joints of the foot

Subtalar joint

This joint is formed by the talus and the calcaneum. The main support of this joint comes from the joint capsule and the strong interosseous ligaments.

Eversion and inversion movements occur at the subtalar joint. Most of the posterior compartment muscles and the tibialis anterior muscle are invertors, whereas the lateral compartment muscles (peroneus tertius and extensor digitorum longus) are evertors. The subtalar

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motion of the extensor hallucis longus muscle, depending upon the angulation of the subtalar axis, can do either inversion or eversion.

Transverse tarsal joint (midtarsal joint)

It is formed by the following two joints:

1. Talonavicular joint

2. Calcaneocuboid joint

Both these joints are supported by several ligaments. The muscles crossing these joints act around a longitudinal as well as an oblique axis. The movements at these joints are plantar flexion, dorsiflexion, inversion, eversion, abduction and adduction. The joints receive a 'shoe-string' support from the crossing of the tendons of the tibialis posterior and peroneus longus. The peroneus longus, with its action of plantar flexion of the first metatarsal, plays an important role during the terminal part of the stance phase of the gait cycle when the body weight is being shifted to the forefoot.

Intertarsal joints

They are formed between the navicular, cuneiform and cuboid bones. These joints allow gliding movement between the tarsal bones.

Tarsometatarsal joints

These joints are formed by all the metatarsal bones, articulating with three cuneiform bones and the cuboid bone. The stability provided by the three cuneiform bones to the second ray is important in the late stance phase of the gait cycle when an increased load is transmitted from the ground through the second metatarsal.

Metatarsophalangeal joints (MTP)

The metatarsal heads and proximal phalangeal bases form the metatarsophalangeal joints. They allow the movements of dorsiflexion, plantar flexion, abduction and adduction.

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There are a number of plantar, dorsal and interosseous ligaments.

The movements of the toes are due to the action of various extrinsic muscles originating proximal to the foot and inserting into the foot; as well as intrinsic muscles originating and inserting within the foot.

Abductor hallucis, flexor digitorum brevis and abductor digiti minimi form the first layer of the plantar intrinsic muscles.

The second layer is composed of the flexor hallucis, flexor digitorum longus muscles, quadratus plantar and four lumbricals.

The third layer consists of the medial and lateral heads of the flexor hallucis brevis muscle, adductor hallucis (oblique head) and flexor digiti minimi brevis muscles.

The fourth layer is formed by the plantar and dorsal interosseous muscles.

Innervation of the plantar intrinsic muscles is from the medial and lateral plantar nerves.

Muscular representation of neurologic levels

The following muscles are recruited to test the integrity of the motor supply at the neurologic level:

1. Tibialis anterior (L4)

2. Extensor hallucis longus and extensor digitorum longus (L5)

3. Gastrosoleus, peroneus longus and peroneus brevis (SI)

The same three levels are used for testing the sensory integrity:

1. Medial dorsal foot (L4)

2. Middorsal foot (L5)

3. Lateral dorsal foot (SI)

Vascular supply

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The main blood supply of the ankle comes from (a) the anterior tibial artery, the main artery of the anterior compartment, and (b) the posterior tibial artery, the main artery of the posterior and lateral compartments. These two arteries are formed by the division of the popliteal artery. It supplies all the three compartments by sending terminal branches to the foot.

Movements of ankle in relation to the movements of the lower limb in gait cycle (mann, 1985)

Stance phase

1. *Heel strike to midstance*

   (a) Lower limb medial rotation; ankle joint plantar flexion.

   (b) Subtalar joint pronation

   (c) Transverse tarsal joint free motion

2. Foot flat, midstance to heel raise

   (a) Lower limb lateral rotation

   (b) Ankle joint dorsiflexion

   (c) Subtalar joint supination

   (d) Transverse tarsal joint increasingly restricted motion

3. *Heel raise to swing*

- Ankle joint plantar flexion

Swing phase

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1. Lower limb medial rotation

2. Ankle joint dorsiflexion

3. Subtalar joint pronation

4. Transverse tarsal joints free motion

Gait terminology

1. *Stride*: complete cycle of locomotory sequence of right (Rt) plus left (Lt) steps.

2. *Step length*: The step length between right and left heel strikes in a normal adult is nearly 80 cm.

3. *Cadence*: Rhythm of locomotion. In a normal adult, it is 101–120 steps per minute.

Range of motion: Average range of ankle movements during normal walking:

1. Dorsiflexion – 9.6 degrees (Winter, 1987)

2. Plantar flexion – 19.8 degrees

3. Foot out toeing of 6.8 degrees (Murray et al., 1970).

Kayano (1986) found that the medial longitudinal arch lengthens from the early stance to foot flat due to the vertical force of the body weight. It then shortens as the body weight is decreased and there is activation of the arch supporting muscles.

Direct loading to the foot during locomotion (gait cycle)

Vertical ground reaction force has been reported to be between 1.1

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and 1.3 times the body weight (Cavangh et al., 1981). It was found to be maximum just before foot flat and immediately following midstance phase.

Pressure distribution studies during walking have shown that the maximum pressure areas are the medial and lateral parts of the heel, lateral border of the foot and the heads of the second to fifth metatarsals (Fig. 37-6).

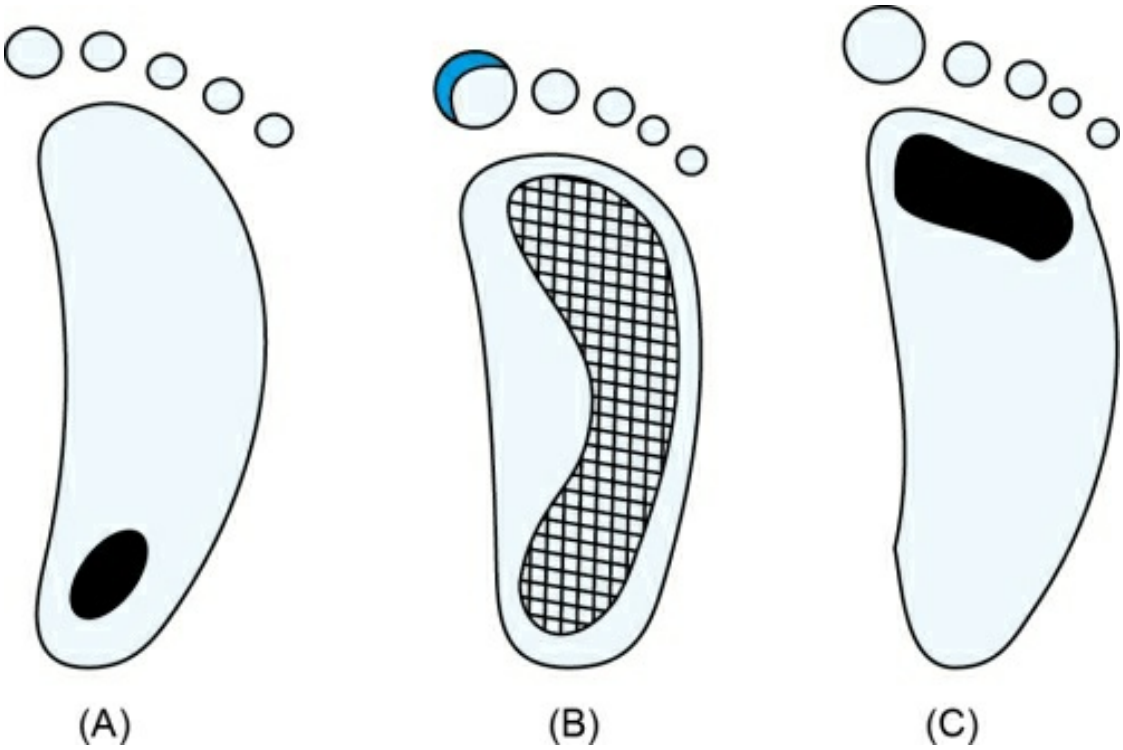

FIG. 37-6 Normal pressure distribution areas during walking cycle. **(A)** At heel strike. **(B)** At midstance. **(C)** At toes off.

Forefoot is exposed to the heaviest mechanical stresses. For nearly 40% of each step, it carries the weight of all other parts of the body. Both the compressive and shearing forces are taken up by the ball of the foot and are transferred to the skeleton (Moller, 1979).

Ankle sprain

The ankle joint is fairly unstable and depends largely on the ligaments

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for its stability. Therefore, it is highly susceptible to sprains.

The ankle sprain is of two types:

1. Pronation or eversion sprain

2. Supination or inversion sprain

Pronation or eversion sprain

It is caused by pronation or eversion of the foot combined with internal rotation of the tibia on the fixed foot. This injury is serious as it may cause a fracture along with tear of the deltoid ligament, tibiofibular ligament and the interosseous membrane (Guise, 1976). Following an injury, there will be swelling and tenderness directly over the ligaments. Tenderness will be present below the medial malleolus when the deltoid ligament is injured and over the anterior aspect of the ankle when the anterior tibiofibular ligament and the interosseous membranes are involved. All weight-bearing activities are extremely painful. Passive movements which exert stress on a particular ligament are painful whereas there will be hypermobility at the joint in case of complete rupture of the ligament.

Treatment

When this injury involves diastasis of the distal tibia and fibula along with complete tear of the deltoid ligament, anterior and posterior tibiofibular ligaments and the interosseous membrane, the choice of treatment is surgery to reduce diastasis and to remove interposed segments of the medial deltoid ligament. Postoperatively, the limb is immobilized in a plaster cast for 6 weeks.

Incomplete rupture of these ligaments can be treated conservatively. The first priority is to reduce swelling and pain. Immediate measures like ice application, limb elevation, compression bandage and repeated toe movements are encouraged. Analgesic and anti-inflammatory drugs are given to reduce pain and inflammation. The limb is then immobilized in a plaster cast for a period of 4–6 weeks.

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Mobilization is begun after removal of the cast and progressed gradually to attain full function. It may take about 3 months to return to normal activities and to sports by another 3 months.

Supination or inversion sprain

It is a common capsuloligamentous injury with a reported incidence of about 85% of all ankle sprains (O'Donoghue, 1958). This injury occurs as a result of sudden adduction–inversion force on the ankle. The tibia rotates externally on the fixed foot with the foot going into sudden inversion, which is compounded by the body weight. It causes injury to the anterolateral part of the joint capsule, and one or all the lateral ligaments (i.e., talofibular, anterior tibiofibular and/or calcaneofibular).

When a sudden inversion force occurs with the ankle in midposition of dorsi and plantar flexion, the injury involves the talofibular ligament. Whereas, when the excessive inversion–adduction movement is associated with forced plantar flexion, the injury commonly involves the calcaneofibular ligament. This can be identified by the site of pain and tenderness. Pain and tenderness over the talus indicates injury to the talofibular ligament while the same over the calcaneus indicates involvement of the calcaneofibular ligament. The pain will increase with ankle adduction–inversion in neutral in the former and adduction–inversion with plantar flexion in the latter.

Tear or incomplete rupture

When the adduction violence is insufficient to rupture the lateral ligaments, it results in strain or partial ruptures.

Tear of the anterior tibiofibular and talofibular ligaments can be identified by the 'anterior drawer' test. Under local anaesthesia, the heel is supported on a sand bag and downwards stress is applied on the distal part of the tibia for 30 s, while the radiograph is being taken. A gap of more than 6 mm between the talus and the tibia indicates ligamentous instability (Fig. 37-7).

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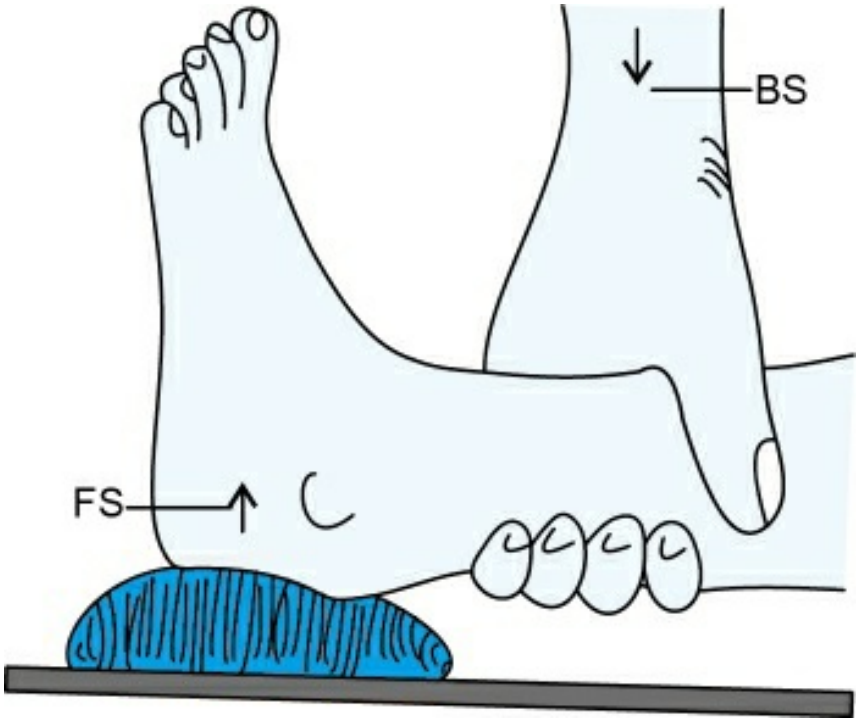

FIG. 37-7 Anterior drawer test for testing the integrity of the anterior tibiofibular ligament. FS, forward stress on the heel; BS, backward stress on the distal tibia.

A good range of passive dorsiflexion and plantar flexion at the ankle joint is possible but attempted adduction in the neutral position of the ankle and foot increases pain in cases of anterior talofibular ligament injury.

The patient is able to take some weight on the affected limb though with difficulty.

Complete rupture

Severe adduction–inversion force causes complete rupture of the lateral ligament. The talus gets tilted medially in the tibiofibular mortice. An anteroposterior radiograph is taken while adduction stress is applied to the heel under local anaesthesia. This manoeuvre causes medial tilt of the talus in the ankle mortice which if more than 20 degrees, confirms the diagnosis of a complete rupture.

The passive ROM of ankle dorsiflexion and plantar flexion is relatively good and less painful but severe pain occurs when the ankle is adducted with the foot in plantar flexion in cases of complete

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rupture of the calcaneofibular ligament.

The patient is unable to take the body weight on the affected leg and prefers to walk by hopping only on the sound limb.

Treatment

Cases of partial rupture are treated conservatively with immobilization by strapping, daily open taping (Fig. 37-8) or by cast brace. Those with complete rupture are treated with POP cast with or without surgery. The surgery consists of repair or reconstruction of the ruptured ligament.

1. *Strapping*: Strapping immobilization is given for 3 weeks. Partial weight bearing is permitted after 3 days with crutches. But full weight bearing is deferred till pain or limp disappears.

2. *Daily open tapping*: In this method, hydrotherapy in ice whirlpool is given for 20–30 min followed by open taping for 4 days. Later on, contrast hydrotherapy followed by closed taping is done. Closed taping is done with the foot in maximum dorsiflexion and eversion with knee flexed to 90 degrees to achieve maximum relaxation of the gastrosoleus.

3. *Cast brace technique:* Cast brace allows early mobilization and weight bearing. The brace is fabricated using synthetic materials.

The methods of daily taping and cast bracing allow early mobilization and thus prevents disuse atrophy and formation of adhesions. It has been reported that early mobilization stimulates healing of the torn ligaments and also improves strength of the ligaments, thus promoting the strength and stability of the ankle joint (Clayton et al., 1968; Tipton et al., 1965, 1970).

Strong toe movements, limb elevation, diapulse, pulsed ultrasonics, cryotherapy by ice packs, ice massage or ice

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immersion are effective in reducing pain, oedema and inflammation. Immersion in ice cold water for 20 min at 50–60°F has been found to be more effective than heat or contrast bath in reducing oedema (Barnes, 1979; Knight, 1978;Moore, 1977). Alternating cryotherapy (ice immersion) with exercise is more effective. It consists of numbing the ankle with cold immersion followed by exercise.

4. *Cases treated by plaster cast (with or without surgery)*: Cases with complete rupture of the ligaments are treated by immobilization for 3–4 weeks in a plaster cast or surgical repair of the torn ligaments.

FIG. 37-8 Open taping of the ankle.

The supportive treatment includes limb elevation, strong toe movements, application of diapulse along with anti-inflammatory and

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analgesic drugs. In cases treated conservatively, walking heel is provided which facilitates early weight bearing with walking aid. However, walking should not cause pain. Cases treated by surgery need to continue non–weight bearing up to the time the operated ankle is painful.

Mobilization

Early mobilization by relaxed passive movements in the maximum, but pain-free range is ideal (Cyriax, 1978). The patient is taught the correct technique of performing relaxed passive movements. The movements should not be forcible to overstretch the fibrils that are gaining longitudinal attachment within the healing breach; nor should they be too gentle as to fail to disengage those fibrils that are gaining abnormal transverse adherence.

Deep friction massage is also one of the effective procedures to prevent or reduce adhesions.

Thermotherapy can be applied if there is no evidence of oedema. It is helpful in increasing capillary permeability, promoting reabsorption of the extravasated fluid and dissolution of the organized haematoma, thus, helping early healing (Griffin & Karselis, 1978). However, heat should not be used in the presence of haemorrhage.

Ultrasonics is especially beneficial in improving extensibility of the reconstructed or injured ligaments.

Active and graduated resistive exercises should be started as early as possible with emphasis on the muscle groups of the anterior and lateral compartments. Intrinsics also need to be strengthened with active slow circumduction and maximum isometric toe flexion. This technique provides strong isometric contractions to the intrinsics along with resistance to the other muscle groups of the ankle and foot.

Full weight bearing should be started after 6 weeks.

Re-education in foot placement, weight transfer and normal pattern of gait can be assured by adequate aid and gait training.

On achieving proficiency in gait, vigorous regime of toe standing, heel standing and walking, and speedy coordinated exercises like spot jogging, running should be gradually initiated. This prepares the

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patient to resume sports by 8–12 weeks.

Conditioning exercises are initiated so as to improve strength and endurance of the peronei to prevent recurrence of the sprain.

Heel pain

Heel is the most common site of pain. Although it may also occur as a result of subtalar joint disease, tendinitis, disease of the calcaneum, retro-calcaneal bursitis or the inflammation of a fat pad, it commonly occurs either due to plantar fasciitis or calcaneal spur (Fig. 37-9).

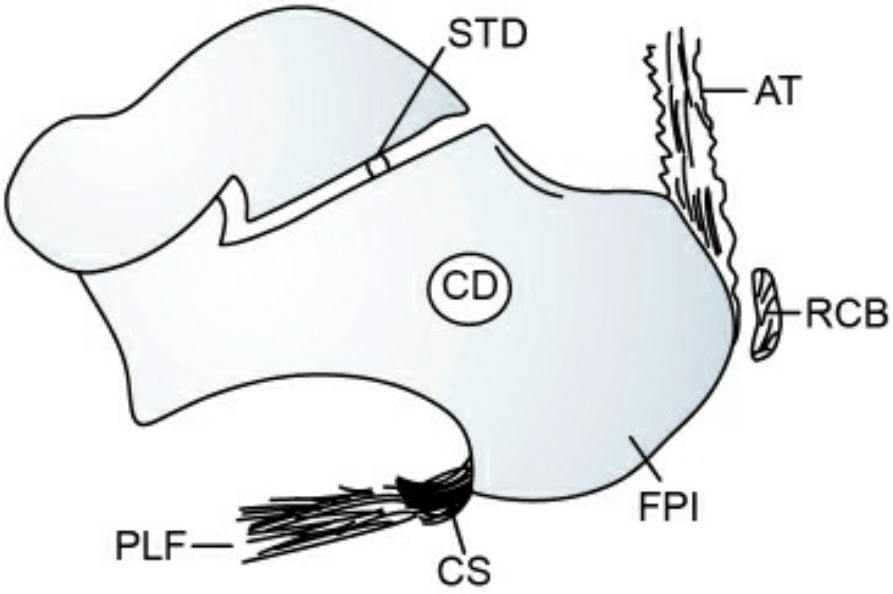

FIG. 37-9 Common causes of heel pain: STD, subtalar joint diseases; AT, Achilles tendinitis; CD, diseases of calcaneum; RCB, retrocalcaneal bursitis; FPI, fat pad inflammation; CS, calcaneal spur; PLF, plantar fasciitis.

Plantar fasciitis and calcaneal spur

Heel pain, a common complaint, may arise from seven different conditions. However, plantar fasciitis and development of a calcaneal spur are common causes of heel pain (Fig. 37-9).

Plantar fasciitis

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Plantar fascia extends from the plantar surface of the calcaneum (Fig. 37-9) to the metatarsal heads and supports the medial arch of the foot.

Summation of a series of microtrauma to the plantar fascia due to sustained stress of weight-bearing hopping, jumping or running results in plantar fasciitis.

During the first 15% of the gait cycle, the foot is subjected to pressure as much as 120% of the body weight (Canningham, 1950). This load on the foot is supported by the passive structures (bones and ligaments) alone as the intrinsic muscles come into action only around 30% of the gait cycle. Therefore, the maximum stress of the body weight falls on the ligaments and plantar fascia. Significant stress falls on the plantar fascia in stabilizing the foot from the heel raise to the toe-off phase of gait again when the metatarsophalangeal joints are extended (Hicks, 1954). Repeated stress of this nature causes plantar fasciitis.

Pain is felt over the inner aspect of the sole or heel in all weight-bearing situations. The pain is usually worst in the morning when the patient steps down from the bed for the first time. On examination, tenderness at the inner part of the calcaneus, the site of origin of the plantar fascia, is seen. Pain is relieved as soon as weight bearing is discontinued.

X-ray of the heel shows a bony spur in the calcaneum (Fig. 37-10), which may not be of much significance.

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FIG. 37-10 Calcaneal spur. Note the bony spur on the plantar surface of the calcaneum.

Treatment

Soft cushion heel or silicon heel pads can be used inside the shoes

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along with nonsteroidal anti-inflammatory drugs (NSAIDs). A local steroid infection into the plantar fascia, at the tender sport can also give relief from pain. However, the result may be unpredictable. It is tempting to excise the body spur on the plantar aspect of the calcaneum, as seen on the X-ray; however, it is generally not required.

Calcaneal spur

Continued overstrain of the plantar fascia results in stripping of the periosteum from its origin at the calcaneus. The gap thus formed is filled up by proliferation of bone, resulting in formation of a bony spur to secure the detached attachment. Occasionally a bursa forms over the bony spur which may get inflamed resulting in pain. Thus, calcaneal spur is a late sequelae of plantar fasciitis. The calcaneal spur may not always be painful. Once formed, this spur is permanent; and attempts to remove it result in its recurrence.

Treatment

Analgesics and anti-inflammatory drugs are prescribed to reduce pain and inflammation. Locally, heat modality may be used for relief of pain. Local steroid injection may also be given but in rare instances, it may cause degeneration tear/rupture of the tendoachilles.

The basic aim of treatment is to:

1. Reduce pain and inflammation by taking off the irritating focus of the strain of weight bearing (e.g., heel raised walking while getting down from bed in the morning or after long sitting).

2. Relieving strain from the fascia by providing an appropriate wedge in the shoe. This helps in lessening the angle between the hindfoot and the forefoot, and relaxes the fascia. It is done by adjusting the height of the heel to a minimal level at which the pain disappears. The UC-BL shoe insert has proved very effective. This shoe insert reduces tension and constant irritation of the inflamed fascia and also provides an alternative to elevate the foot arch (Campbell & Inman, 1974) (Fig. 37-11).

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Elongated soft heel pad or well-padded medial arch support covering the longitudinal arch is occasionally effective.

3. Faradism can be an effective measure to induce contractions in the intrinsic muscles; improving their tone, power and circulation. Hard shoes should be avoided. Small heel shoes help in transferring the weight on toes, and can be used while the treatment is going on. After that, the patient may return back to normal shoes.

4. Exercises to the intrinsic muscles in warm water in the morning before initiating weight bearing are useful in lessening the morning pain.

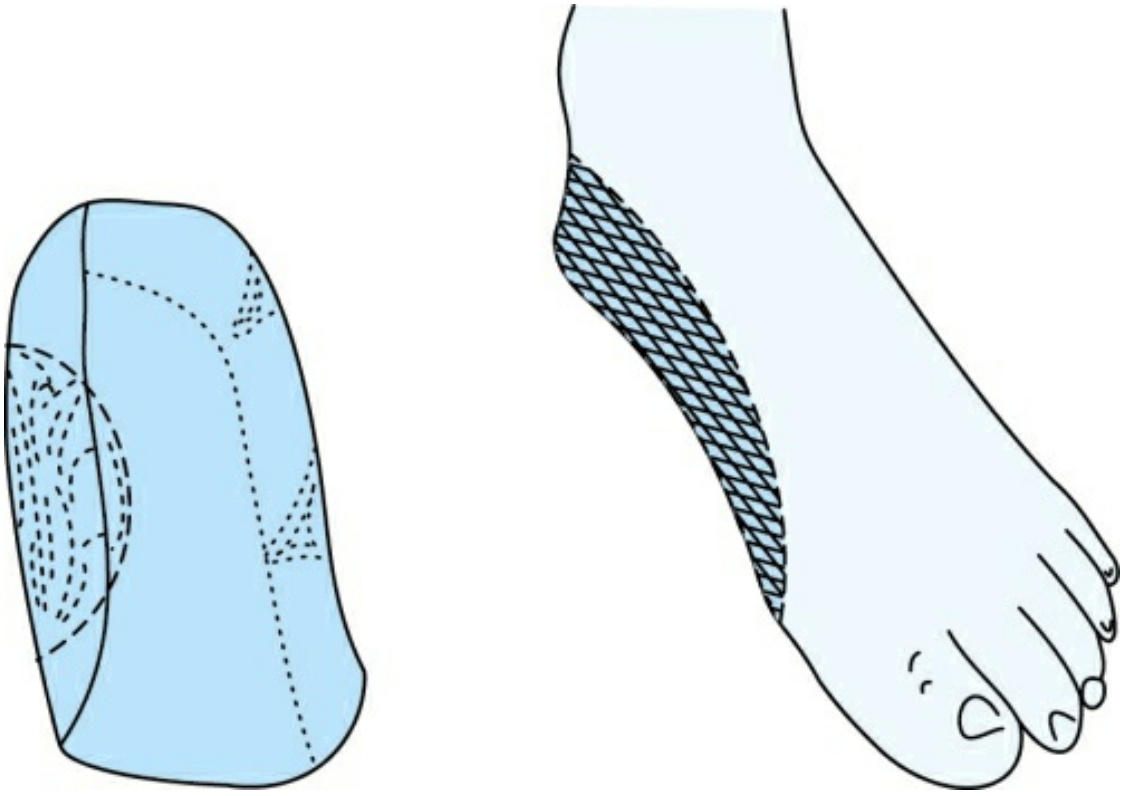

FIG. 37-11 'UC-BL' shoe insert.

It must be emphasized that the patient performs these exercises for several short sessions during the day.

Strengthening exercises to the intrinsic muscles, like sustained toe

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curling, performed even with shoes on, provide an excellent technique of resistive exercise. Sessions of holding the contracted position inside the shoe several times a day are very effective, provided they are done at frequent intervals within the level of discomfort.

Slow barefoot walking on the lateral border of the foot with cupping of the foot by curling of toes is effective in moulding longitudinal foot arch. It can be made effective by repeatedly doing this exercise with the shoes on in standing, walking as well as sitting.

Sorbo rubber heel pad provides better relief in patients with calcaneal spur.

Metatarsalgia

Normally only about one-third of the body weight falls on the forefoot and that is distributed between the pads of the toes and metatarsophalangeal joints. In metatarsalgia, pain occurs over the plantar aspect of the foot when an excessive proportion of body weight is taken up by the forefoot. The pain is felt under the metatarsal heads and is relieved by resting the foot. Tenderness is felt over the plantar aspect of the capsules of the metatarsophalangeal joints.

It is common in the presence of the following factors:

1. Pesplantaris

2. Pescavus

3. Muscular weakness: Weakness in the short toe flexors due to inactivity or immobilization can also give rise to metatarsalgia on the initiation of sudden weight bearing.

4. Wearing high heels: This may also cause constant strain over the forefoot giving rise to metatarsalgia. Therefore, while using high heels, the surface where the heel rests should be horizontal so that the major weight is transferred to the stable horizontal heel rather than to the metatarsal heads (Fig. 37-12).

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5. Tightness of plantar aponeurosis: Occasionally the digitation of plantar aponeurosis gets shortened, pulling the metatarsal head downwards. It causes curling of the toes. If not attended to, this may cause shortening of the extensor tendons of the toes resulting in loss of passive range of flexion at the metatarso-phalangeal joints. This gradually results in hyperextension at the metatarso-phalangeal joint with flexion at the interphalangeal joints (a deformity corresponding to Volkmann's ischaemic contracture of the hand). This is commonly seen in rheumatoid arthritis. Correction of this deformity is possible only with surgical release of the tight plantar aponeurosis and the tendons of the extensor digitorum.

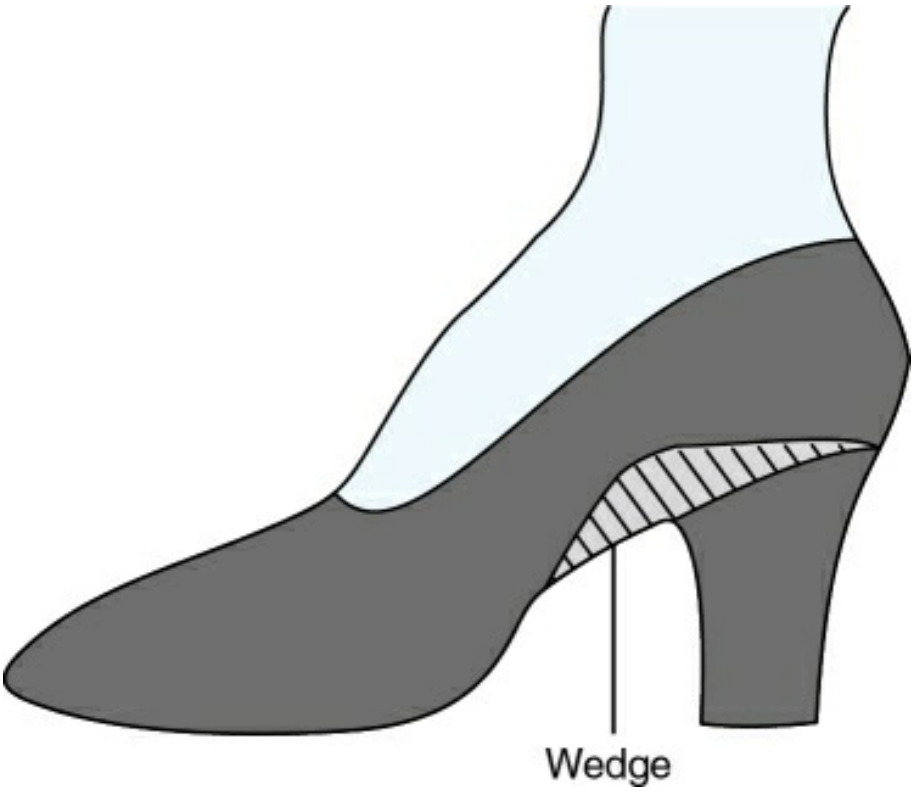

FIG. 37-12 Wedge to render heel horizontal to accept more pressure, reducing tension on the metatarsal heads.

Treatment

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1. Painful stage: Warm water bath, contrast bath, transcutaneous electrical nerve stimulation (TENS), ultrasonics, diapulse or hot packs.

2. When associated with swelling: Suitable cryotherapy with leg in elevation.

3. Speedy ankle and toe movements to reduce oedema and to improve circulation.

4. Faradism under pressure (elastic bandage) with leg in elevation.

5. Faradic foot bath synchronized with voluntary intrinsic exercise.

6. Gradual re-education of walking with appropriate shoe wedge, pad or metatarsal bar (Fig. 37-13).

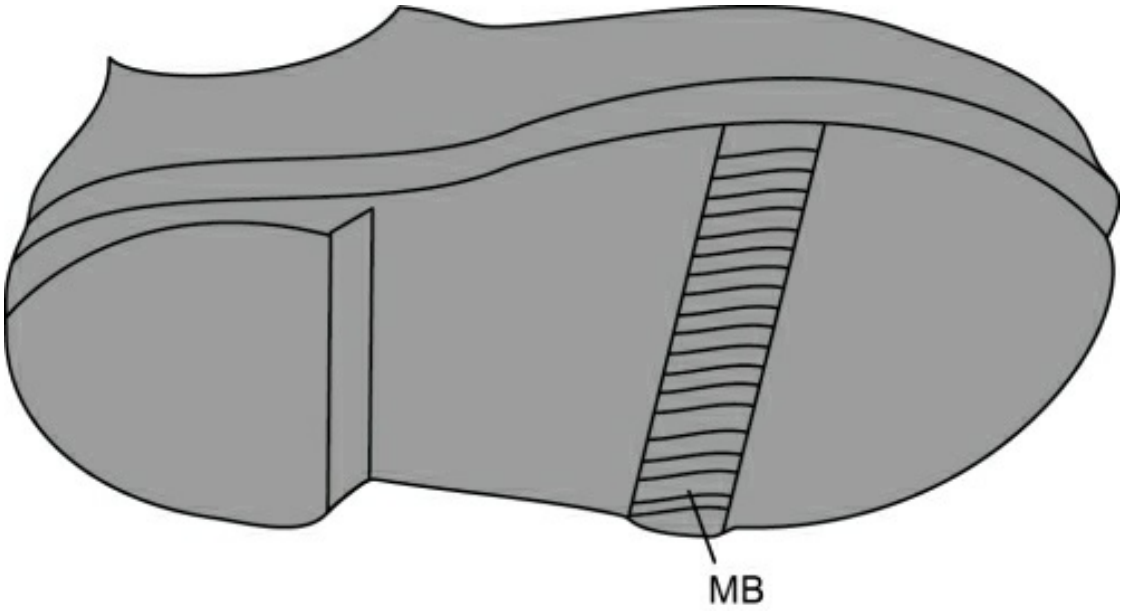

FIG. 37-13 Metatarsal bar (MB).

Vigorous stress of weight bearing to be avoided but strengthening exercises to intrinsics should be stepped up to avoid recurrence.

Morton's metatarsalgia

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In Morton's metatarsalgia, there is sudden onset of pain with burning sensation over the outer border of the forefoot and between the third and fourth toes while walking. Pain subsides after rest and massage. The causative factor is a thickened digital nerve (often a neuroma) between the third and fourth metatarsal bones (Fig. 37-14). It is now believed to be an entrapment neuropathy of the digital nerve associated with thickened intermetatarsal bursa.

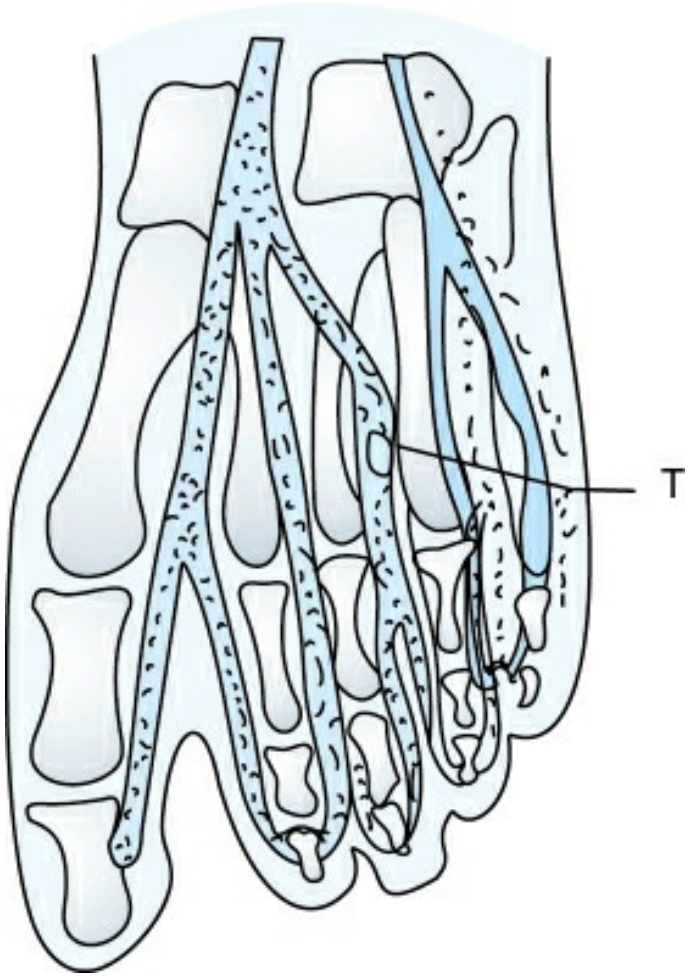

FIG. 37-14 Morton's metatarsalgia. T, thickening of interdigital nerve between the third and fourth metatarsal.

Treatment

Conservative treatment consists of altering the alignment of the

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metatarsal heads by providing a small pad which elevates the heads of the metatarsals. This prevents painful nipping of the digital nerve.

If conservative method fails to relieve pain, resection of the nerve and/or neuroma offers total relief.

Tarsal tunnel syndrome

In this condition, pain, burning sensation or paraesthesia may occur in the toes and sole of the foot in the distribution of the medial plantar nerve. This occurs as a result of compression neuropathy of the medial plantar nerve in the tarsal tunnel under the flexor retinaculum on the medial aspect of the heel (Fig. 37-15). This situation is analogous to the compression of the median nerve in the carpal tunnel at the wrist.

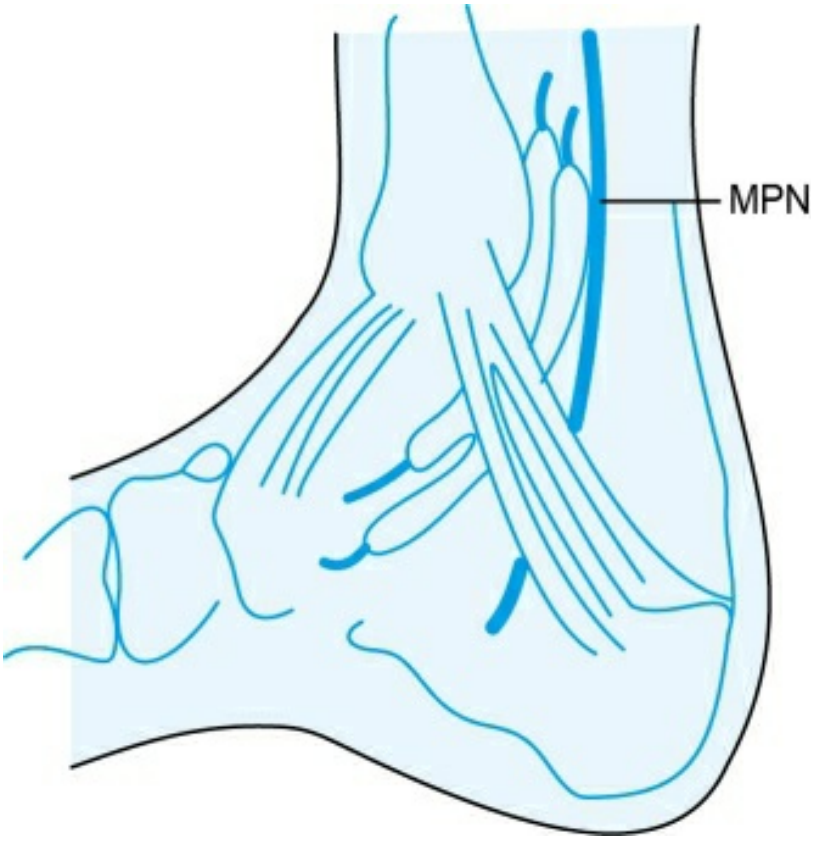

FIG. 37-15 Tarsal tunnel syndrome: Compression of the medial plantar nerve (MPN) in the tarsal tunnel.

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This compression neuropathy may be precipitated by previous sprains, fracture, tenosynovitis of the tibialis posterior or flexor hallucis longus tendons or exaggerated medial or lateral deviation of the calcaneum.

Treatment

Surgical decompression of the tarsal tunnel by excising the flexor retinaculum relieves the symptoms.

Nonoperative treatment includes steroid infiltrations at the compression site, corrective orthosis, thermotherapy, ultrasonics and TENS.

Injuries to the tendoachilles

The Achilles tendon is the strongest and thickest tendon in the body. It is a fast-twitch and slow-twitch muscle and needs a correct balance between the gastrocnemius and soleus for an individual to stand and hop on the tip toe. In spite of being strong, the Achilles tendon is susceptible to injury, especially at a site which is about 4–5 cm proximal to the calcaneus. This is because of two factors. First, it narrows considerably near its attachment to the calcaneus. Secondly, it is a site of poor blood supply.

The common injuries to the Achilles tendon are as follows:

1. Tendinitis

2. Rupture

Tendinitis

The cause of tendinitis is usually a friction syndrome. The tendon is constantly irritated due to the friction caused by the posterior shoe tab in modern design shoes. It may also result from undue strain due to overexertion.

There is localized tenderness, swelling or a nodule. Pain is present on resisted plantar–flexion or tip-toe standing.

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Treatment

Acute phase

1. Ice massage or ice pack.

2. Deep transverse friction massage, if not painful (Cyriax, 1978).

3. Pulsed ultrasonics (Dyson, 1989; Williams, 1976).

4. Diapulse.

5. Shock absorbing heel cushion or appropriate heel raise.

6. Gentle full range relaxed passive movements to the ankle and foot. Resisted toe movements with the foot in neutral position.

7. Avoidance of weight-bearing or straining activities.

8. Non–weight-bearing exercises.

Subacute phase

1. Passive full range stretching to avoid adhesions.

2. Pulsed ultrasound (Dyson, 1989; Williams, 1976) to resolve adhesions and to improve the tendon extensibility.

3. Gradual single-leg weight bearing to be initiated against wall bars with knee in flexion to avoid undue stretching.

4. To be progressed to bilateral toe standing, jogging and spot running.

5. Proper gait training.

Rupture of tendoachilles

It is a common injury in sports. It occurs as a result of sudden and

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forceful dorsiflexion of the foot when the gastrocnemius is contracting strongly. The rupture may also occur in the middle aged, about 4–5 cm proximal to its insertion. This area has decreased vascularity. The rupture usually occurs in a degenerated tendon, with ragged margins of ruptured ends. Walking is extremely painful with local swelling and marked tenderness over the site of rupture.

Diagnosis

The diagnosis of rupture is ascertained by two tests.

Simmonds–thompson test (fig. 37-16)

The patient lies prone and the foot is supported in plantar–flexion; it is then allowed to relax in dorsiflexion. The foot in the relaxed position remains in a greater degree of dorsiflexion as compared to the contralateral normal foot. The calf muscle is then squeezed, which causes reflex contraction of the gastrocnemius producing plantar–flexion on the normal side. However, the test is positive when the foot instead of going in to plantar–flexion remains limp.

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FIG. 37-16 Tendoachilles rupture: Simmonds–Thompson test: Squeezing of both the calf muscles, the foot on the ruptured side (right) does not go into plantar–flexion as the left.

Heel raise test

The patient fails to raise the heel from the ground in standing on the affected leg alone.

Treatment

Conservative

The complete rupture of the Achilles tendon can be treated conservatively. It needs above-knee plaster immobilization for a period of 8 weeks with the knee in 30 degrees of flexion and in equinus to allow close approximity of the ruptured tendon for healing. After 8 weeks a high-heeled shoe is given for another 8

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weeks.

Immobilization in equinus produces wasting of the soleus (Haggmark & Eriksson, 1979) and long toe flexor muscles. Therefore, the cast needs to be changed to gradually accommodate more and more of dorsiflexion to avoid contracture and equinus deformity.

Alternatively, close POP can be avoided by taping the foot in plantar–flexion and equinus by 30 mm (1.5 inch) heel raise or removable cast.

Physiotherapy is limited to:

1. Strong toe movements, in elevation and resisted movements to the muscles and joints free from casts

2. Diapulse over POP or cryotherapy in taping

Surgical treatment

Surgery can be done in fresh as well as old ruptures. A rupture with clean edges may be sutured, whereas in a rupture with ragged ends, accurate repair is not possible. In such cases, the tendon is repaired using a strip from the proximal part of the tendon itself (Fig. 37-17). Alternatively a strip from the fascia lata may be used. Postoperatively, an above-knee plaster cast is given for a period of 6–8 weeks with the foot in full equinus. Subsequently, a short-leg cast is given for 2–3 weeks with slight equinus.

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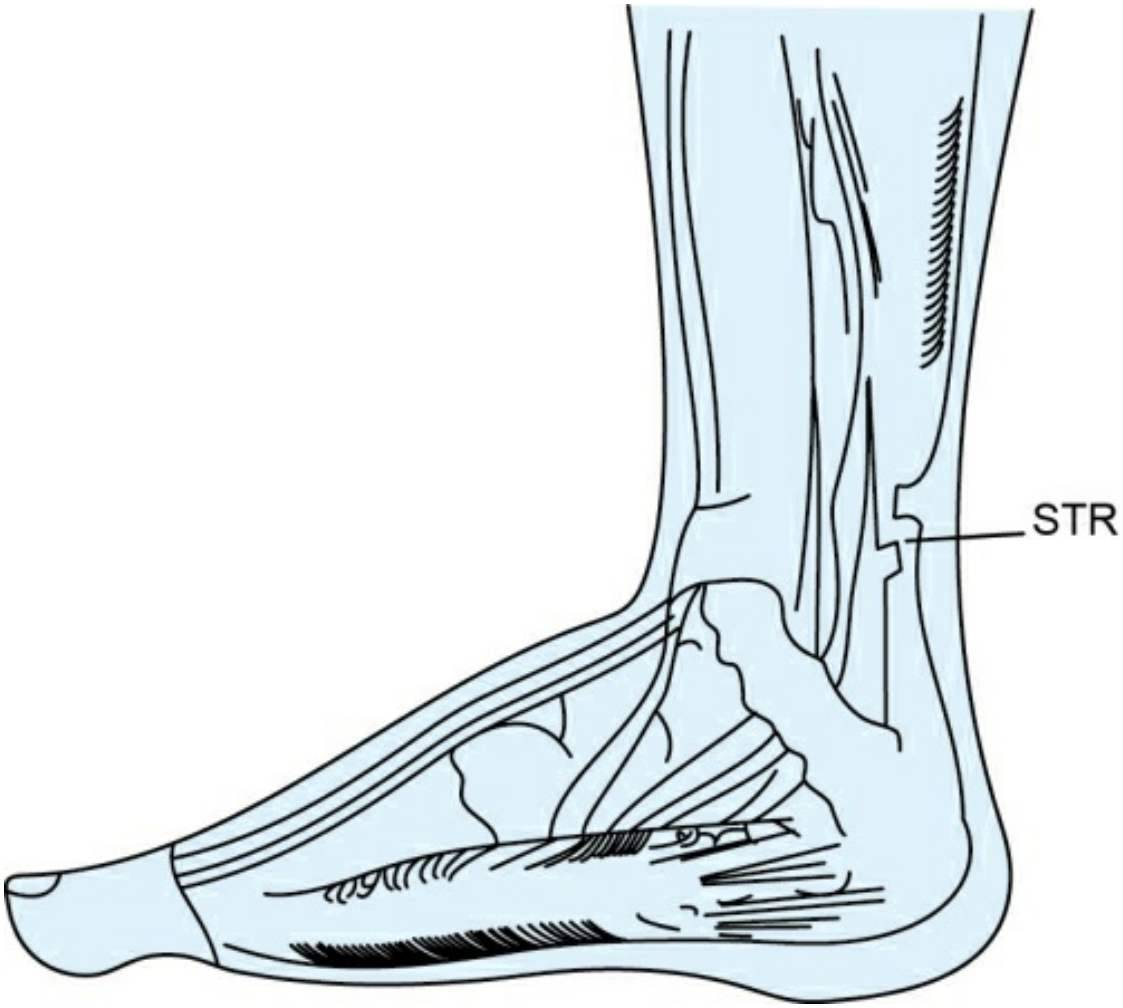

FIG. 37-17 Tendoachilles rupture: tendon repair by using a strip from the proximal part. STR, site of tendon repair.

Following surgery: Following surgery the leg is immobilized in an above-knee light non–weight bearing cast for a period of 6–8 weeks. Non–weight bearing ambulation with strong toe movements is given. Diapulse may be useful when a short leg cast is given and vigorous knee movements are begun.

Mobilization (after removal of the plaster)

1. Graduated, relaxed passive dorsiflexion is to be emphasized. Mobilization of foot is initiated with strong toe flexion and stabilization at the calcaneus.

2. Gradual partial weight bearing is begun with a heel raise of 15 mm

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(3/4 inches) to avoid stress on the repaired tendon.

3. Whirlpool or warm bath provides an ideal medium for exercises at this stage.

4. Ultrasonic and friction massage may be necessary when the repaired tendon is shortened and surgical scar is adherent.

Rest of the therapeutic programme should be progressed as described for tendinitis.

Tenosynovitis around the ankle

Occasionally, tenosynovitis may occur in the tendon sheaths of the tibialis posterior, peroneus longus and long toe flexors. It is often precipitated by the presence of degenerative changes, flat foot or rheumatoid arthritis. The patient presents with pain, tenderness and swelling along the affected tendons. Pain becomes severe when these muscles are stretched by forced movements such as inversion or eversion with foot plantar flexed. Excess of synovial fluid may be demonstrated by milking the tendon sheaths proximally. Tenderness is maximal behind the malleoli (Fig. 37-18).

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FIG. 37-18 Tenosynovitis: maximal tenderness is felt behind the malleoli.

Treatment

- Symptoms are resolved with rest and immobilization in a below-knee walking plaster.
- If symptoms persist on removal of the plaster, elastocrepe bandage and ultrasonic therapy are effective.
- Some patients may need medial or lateral wedge in their footwear to avoid excessive strain during weight bearing.

Talipes equinus

It is the commonest type of acquired foot deformity following muscular imbalance. It is produced either due to the weakness or

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paralysis of the dorsiflexors or spasticity in the plantar flexors. It may occur as a result of improper foot positioning in bed-ridden patients. It may be present in a case of unilateral limb length disparity where the equinus is used as a compensatory mechanism to equalize the limb length.

The deformity is at the ankle joint while the midtarsal joint is normal. There is exaggeration of the longitudinal arch and broadening of the heads of the matatarsals due to the constant pressure of body weight on the forefoot as the heel is off the ground.

Pathology

There is stretching of the ligaments on the dorsum of the foot; with shortening of the inferior-calcaneo-navicular or 'spring' ligament, plantar fascia and other plantar ligaments. There is lengthening of the anterior tibial group of muscles with shortening of the long toe flexors, peroneus longus and especially tendoachilles.

Treatment

Conservative treatment

In early cases, the deformity can be corrected by manipulation. After the manipulation, aluminium splint, Denis Browne splint, POP splint or toe-pickup orthosis may be given.

Physiotherapeutic management after conservative treatment

1. Relaxed full range passive movement worked up to get maximum dorsiflexion and its passive maintenance is important.

2. Whenever possible efforts should be made to get active contractions in the anterior tibial group of muscles to strengthen them.

3. Gait training should be initiated with toe-pickup orthosis or BK orthosis. Posterior splint should be applied during night and while resting to avoid recurrence.

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4. Assisted standing on the affected foot stretches the tight plantar flexors with body weight.

Surgical treatment

Severe cases of fixed equinus deformity need surgical intervention. The surgical procedures performed are as follows:

1. *Tendon release*: The plantar fascia and the tendoachilles are divided and the foot is brought to the correct position. Following this, immobilization in the posterior splint is done in paralytic cases, whereas BK POP cast is applied in cases where spasticity of the gastrocsoleus is the cause.

If equinus is associated with claw toes, division of flexors and extensor tendons of toes may be necessary.

2. *Triple arthrodesis*: The principles of this operation as well as the physiotherapy programme have been discussed elsewhere.

Physiotherapeutic management after surgery

1. *During immobilization.* The joints free from immobilization are exercised vigorously.

2. Toe movements are encouraged with the operated leg in elevation.

3. Non–weight-bearing crutch walking could be begun immediately.

4. After removal of the plaster, maximum emphasis has to be placed on controlled passive, active assisted and eventually active dorsiflexion of the foot with toe extension.

5. When weight bearing is allowed, weight transfers, balance and gait training (as described earlier) and other modes of ambulation are taught. Initially the patient may need orthosis which, if possible, should be gradually discarded when the active dorsiflexion control is

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restored.

Pes cavus (contracted foot)

There is marked exaggeration of the longitudinal arch of the foot with dropping of the tarsus. It may be associated with equinovarus or calcaneal deformities (Fig. 37-19).

FIG. 37-19 **(A)** Pes planus (dropped medial longitudinal arch). **(B)** Pes cavus (abnormally high longitudinal arch). **(C)** Pedoscopic prints: 1. Normal foot, 2. Pes cavus, 3. Pes planus.

Paralysis of plantar flexors resulting in unopposed action of the dorsiflexors gradually sets pes cavus. Weakness of the intrinsic foot muscles, lumbricals and interossei could be the cause.

There is dropping of the anterior transverse arch. In case of paralysis of intrinsic muscles, their stabilizing action is lost resulting in uncontrolled action of the long toe flexors, which cause clawing of the toes.

When the long toe flexors are paralysed, the anterior tibial muscles exert excessive pull, resulting in raising of the anterior part of the calcaneus and depression of the anterior transverse arch along with hyperextension at the MTP and flexion at the IP joints (clawing) – Fig. 37-19B.

Treatment

Physiotherapy and special shoes can control the deformity in the early stage. Neglected and severe cases need surgical intervention.

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Surgical treatment

1. *Steindler's operation*: All the muscles on the under surface of the calcaneum along with the plantar fascia are divided. The divided muscles slide forward and get attached to the bone distally. The cavus position is thus corrected. A below-knee POP cast is applied in the corrected position for 3–4 weeks.

2. *Lambrinudi's operation*: This consists of the arthrodesis of the interphalangeal joints to correct the clawing; the long toe flexors also act at the metatarsophalangeal joints supporting the metatarsal heads. Thus, the muscle power is redistributed in the foot. It is not done when there is paralysis of the long toe flexors or when the metatarsophalangeal joints are dislocated.

3. *Fasciotomy*: Plantar fascia is divided along with the tendons of the extensor digitorum longus (when contracted). The foot is then stretched, the deformity is corrected and immobilized in a plaster cast for 3–4 weeks.

Physiotherapeutic management

For conservatively managed cases

1. Pain to be controlled by a suitable pain-relieving modality. Faradic foot bath and exercises under warm water can be given.

2. A small sand bag is placed over the dorsum of the foot in contact with the ground or by offering self-stretching by placing the heel of the normal foot over the dorsum of the deformed one. The weight of the sand bag or the pressure of the normal foot offers relaxed passive stretch to the contracted plantar fascia.

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3. Movements of dorsiflexion combined with toe extension have a stretching effect on the longitudinal arch. Resisted toe extension is useful in preventing clawing of the toes.

4. Corrective shoes with soft padding are given to encourage weight bearing over the arch.

For surgically managed cases

1. Exercises to the joints free from immobilization

2. On removal of the plaster: active exercises to the metacarpophalangeal joints, ankle and foot.

3. Stretching sessions to flatten the longitudinal arch by weight bearing and weight transfers to it.

4. If the surgical scar is painful, friction massage can be helpful.

5. Re-education in ambulation.

Pes plannus (flat foot)

A foot deformity opposite to pes cavus. Here, the medial longitudinal arch of the foot is dropped downward; thereby, there is a loss of the spring action causing excessive stress over the whole foot during every step.

Causes

Pott's fracture, crushed injury to the calcaneum, laxity of ligaments (deformity appear only on bearing weight), bony ankylosis (talocalcaneal bar) result in a rigid flat foot remaining flat even during non–weight bearing; sometimes, there are spasmodic reflex

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contractions of the peronei (e.g., rheumatoid arthritis and tuberculosis). This is known as a spasmodic flat foot.

It may be associated with valgus heel with partial subluxation and eversion of a subtalar joint.

Symptoms

Except for the spasmodic variety, it is usually pain free. Later on weight bearing becomes painful.

Treatment

For children younger than 3 years, initial stage C and E heel shoes with medial arch support, and arch support in the footwear should be used at home. Custom prothesis for age group between 3 and 10 years. At late stage, they will need well-moulded orthosis.

Physiotherapy

- Strengthening and endurances exercises to the intrinsics (in warm water).
- Corrective gait training with orthoses and bearing weight on the lateral border of the foot without orthoses.
- Repetitive toe curling even with shoes on (it provides resistance).

Surgery

Rarely performed procedures:

- Modified Hook–Miller's procedure
- Durban's flat foot plasty
- Triple arthrodesis

Hallux valgus

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This deformity is characterized by abnormal abduction of the first metatarsal with adduction of the phalanges. It is usually present during early life but gets aggravated in later age (Fig. 37-20). Injury or diseases like gout, arthritis or even bad footwear can precipitate this condition.

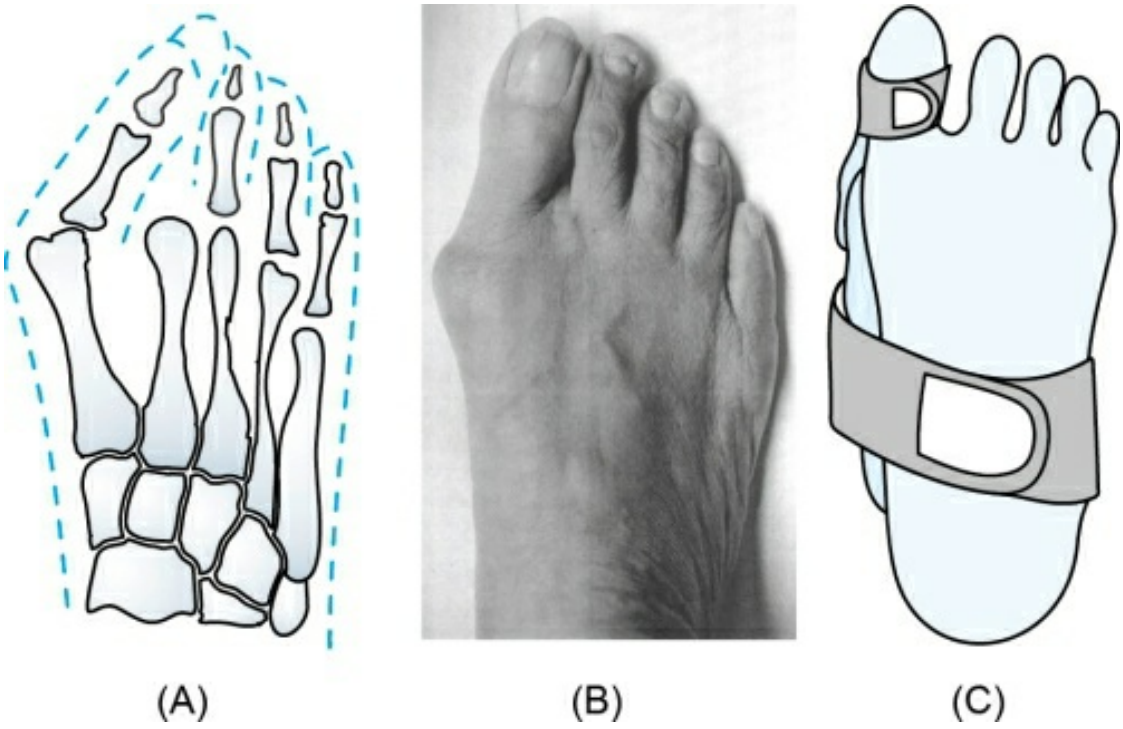

FIG. 37-20 Hallux valgus. **(A)** Abnormal abduction of the first metatarsal. **(B)** Hallux valgus deformity. **(C)** Corrective orthosis.

A false bursa may form over the first metatarsal head, which may get thickened and enlarged. This is known as 'bunion'. The articular cartilage may get inflamed, eroded and atrophied. New bone formation may take place on the medial side of the metatarsal head (exostosis or spur). Tendon of the extensor hallucis longus is shortened and displaced laterally. It acts with a mechanical disadvantage, increasing the deformity. Intrinsic muscles, too, cannot act effectively. These inadequacies result in dropping of the arch and eversion of the foot.

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Treatment

Mild cases are to be managed by physiotherapy and proper footwear.

Surgical treatment

Severe cases do not respond to conservative treatment and need surgery.

1. Arthroplasty: The bunion and the exostoses are removed, shortened and the soft tissues are divided. The joint is aligned in the maximally corrected position.

2. Keller's operation: Proximal two-thirds of the proximal phalanx are removed with the bunion and the medial portion of the head of the metatarsal (Fig. 37-21A).

3. Mayo's operation: The head of the metatarsal is excised. Firm dressings or plaster cast are given for 2–3 weeks following surgery. Occasionally, traction may be applied through the pulp of the toe.

4. Arthrodesis: Arthrodesis of the metatarsophalangeal joint of the big toe (Fig. 37-21B)

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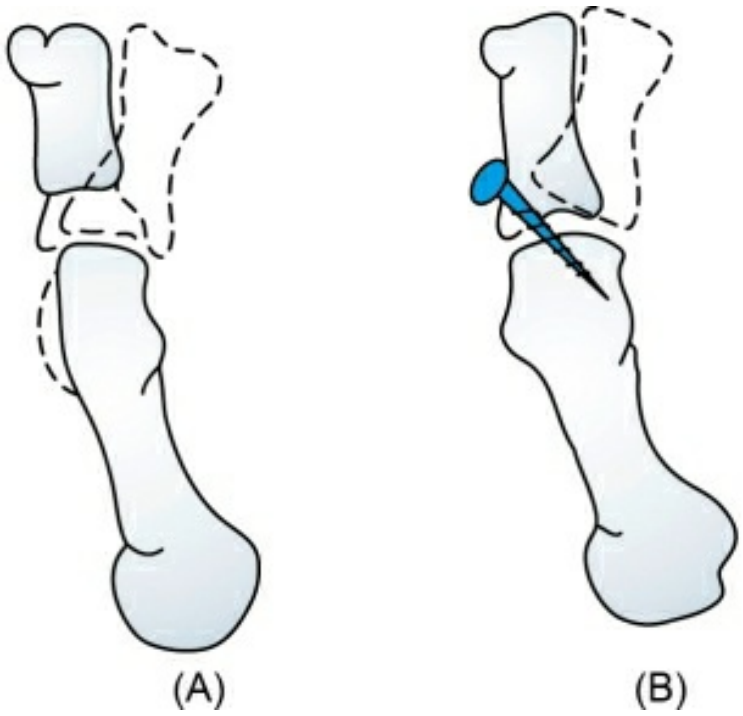

FIG. 37-21 Surgical procedures for hallux valgus. **(A)** Keller's arthroplasty. **(B)** Arthrodesis.

Physiotherapeutic management

1. The patient is taught to carry out relaxed passive stretching of abduction of the toe many times a day.

2. Straight inner border footwear with wedge in between the great toe and the second toe greatly helps in maintaining constant abduction stretch on the great toe. Night splint may be given.

The most important factor to be remembered with the splint or the corrective shoe is that it must not exert any pressure or friction over the medial aspect of the head of the first metatarsal.

3. Strong active exercises are given for strengthening the lumbricals and interossei.

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4. Proper weight bearing: Weight bearing, which tends to be more on the lateral aspect of the foot to avoid pressure and pain, should be discouraged.

5. Faradic foot bath may be necessary to relieve pain, improve circulation and induce contractions of the intrinsic muscles.

Physiotherapy following surgery: It follows the same course as described earlier during immobilization. After the removal of stitches:

1. The patient is trained in relaxed passive stretching of the toe. It is advisable to put a soft cotton or foam wedge between the great toe and the second toe.

2. Strong exercises are given to the intrinsic muscles of the foot.

3. Active fanning of the toes in warm water with assisted abduction of great toe is to be emphasized.

4. Faradic foot bath is useful in assisting active efforts.

5. Weight transfers, gait training and ambulatory activities to be gradually added avoiding the limp.

Hallux rigidus

This deformity results in stiffness of the great toe at the metatarsophalangeal joint.

Focal sepsis, direct injury to the great toe or tight footwear precipitates rigidity. There is erosion of the cartilage with inflammation of the synovial membrane. Spasm in the extensor hallucis longus leads to shortening of the soft tissues leading to bony

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ankylosis.

Stiffness of varying degrees with pain is the conspicuous feature. The first phalanx may even be fixed in flexion (hallux flexus). However, interphalangeal movement is not affected.

Treatment

Conservative

1. Thermotherapy modality with other measures should be used to relieve inflammation.

2. Pressure relieving measures like metatarsal bar, soft sole and modified footwear should be used.

3. Stress on the toe to be reduced by guiding modified gait with minimum toe extension during the push off phase of gait. POP cast may sometimes be necessary.

Surgical

- Excision arthroplasty of the proximal half of the first phalanx.
- Arthrodesis of first MTP joint.

Postoperative management

1. Besides other routine postoperative measures, the metatarsophalangeal joint of the great toe should be mobilized early.

2. Repeated active flexion–extension exercise in warm water restores ROM early.

3. Exercising intrinsic muscles is important.

4. Proper gait training.

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Hammer toe

In this condition, there is contracture in the second toe which could be congenital or familial in origin. Tight shoes can also produce hammer toe. It results in flexion deformity at the proximal interphalangeal joint and flexion or extension at the distal interphalangeal joint. The long extensor tendons are contracted along with the overlying skin (Fig. 37-22).

FIG. 37-22 Hammer toe. Flexion deformity of the proximal interphalangeal joint with compensatory hyperextension at the metatarsophalangeal and distal interphalangeal joints.

Treatment

The toe is strapped to the neighbouring toes in the corrected position with an adhesive plaster. Corrective splint during rest is necessary to maintain small constant stretch. Relaxed passive stretching with axial

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traction and its retention stretches the short muscles.

Surgical

Excision of the proximal interphalangeal joint corrects the deformity. In severe cases, arthrodesis of the first interphalangeal joint is also one of the surgical procedures adopted to manage severe cases of hammer toe.

After the operation, immobilization is maintained for 4–6 weeks after which weight bearing is permitted.

Postoperative management

Mobilization and stretching of the metatarsophalangeal and interphalangeal joints are encouraged. Following the procedure of arthrodesis, other relevant joints are mobilized to the maximum.

Following all the procedures, adequate maintenance of correction, along with other routine procedures are adopted till free and correct function is achieved.

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CHAPTER 38

Yoga, yoga *asanas* and physiotherapy

OUTLINE

- Yoga and physiotherapy
- Genuine yoga
- Preventive and promotive aspects of yoga and yoga *asanas*
- Therapeutic benefits of yoga
- Preventive benefits of yoga
- Rationale of yoga and physiotherapy
- Yoga as applied to physiotherapy

Yoga and physiotherapy

Yoga

Yoga is a supreme harmonization of physical, vital, mental, psychological and spiritual aspects of an individual. The basic aim of genuine yoga is to acquire intelligent and absolute control of the mind through self-development of physical and mental faculties. This absolute harmony and coordination of mind and body, though based upon physical exercises, breath and mind control, is primarily a spiritual process. Thus, attainment of physical fitness through yoga *asanas* and *pranayama* is just the initial two steps towards the path of *yoga sadhana.*

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Yoga is very ancient and the time of origin of its practice and doctrine cannot be dated with accuracy. The word 'yoga' is mentioned in the *Rigveda* and some of its methods are found in Vedic literature, which dates back to thousands of years before Christ. One description of yoga and its definition is found in the ancient Hindu epic, *Bhagwat Gita,* which defines yoga as follows:

1. *Samatvam yoga uchhayate* – meaning, yoga is balance and harmony of the mind and body

2. *Yoga karmasu kaushalam* – meaning, yoga is skill in work

Physiotherapy

Physiotherapy is the treatment of disease or its aftereffects by means of various physical modalities like remedial exercises, heat (thermotherapy), cold (cryotherapy), various modes of electrical currents, water (hydrotherapy) and wax (wax therapy). The basic aim of physiotherapy is to provide maximum possible physical independence within the limits of the disease and disability. Of all the modalities at hand, exercise forms the basis of physiotherapy for the relief of symptoms and improvement of functions or functioning capacity of the body.

The word *exercise* originated from the word '*ex'* meaning out and the word '*ere'* derived from '*arcere'* meaning to lock. Thus exercise means to unlock or to free a part to move. The origin of exercise as a therapeutic measure dates back to the prehistoric period. The earliest writing on therapeutic exercises using various postures and movements of the body is traced back to about 1000 years before Christ in Cong Fou of Ancient China (Mac Auliffe, 1904). The fourth volume of *Atharvaveda* of ancient India called *Ayurveda* recommended remedial exercise and massage about 800 years before Christ (Guthrie, 1945).

In ancient Greece, interestingly enough, there existed a class of gymnasts, besides philosophers and priest-physicians, who practised medicine. They also studied the effects of diet and exercises (Littre,

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1839).

The knowledge about the relationship between body movements and muscles is found in a book on articulations by Hippocrates. In his text, he also very often used the word *exercise* (Adams, 1849; Littre, 1839).

The theoretical benefits of yoga have resulted in its tremendous attraction, wide appreciation and universal popularity, so much so that practically every individual, at least *verbally,* praises yoga. Innumerable yoga centres have come up within a short span. It is being taught and practised at numerous yoga centres around the globe. But how much of it is true or genuine?

Genuine yoga

There are four basic forms of yoga: Karma yoga, Jnana yoga, Bhakti yoga and Raja yoga (Table 38.1). The first three forms trace their origin to the *Bhagwat Gita.* The fourth form is the creation of the sage Patanjali, the father of yoga sciences. He mentioned it in his *Yoga Sutras.* Raja yoga has three components: *Hatha* yoga, *mantra* yoga and *laya* yoga (Table 38.2). *Hatha* yoga itself is a scientific integration of eight basic elements or steps, known as the eight limbs of the body of yoga. As it is impossible for the human body to achieve control without acquiring the control of its limbs (arms and legs), the body of yoga also cannot achieve full control without the control of its eight limbs or elements. These eight limbs are called *astangas.* Therefore, genuine yoga is to acquire step-by-step mastery over all the *astangas.* The objectives, requirements and composition of *astangas* are presented in Table 38.3.

Table 38-1

Basic Forms of Yoga

Yoga			
Karma Yoga (right attitude towards work)	Jnana Yoga (pursuing knowledge)	Bhakti Yoga (devotion)	Raja Yoga (mastering the mind)

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Table 38-2

Components of Raja Yoga

Raja Yoga	*Hatha* yoga	Body and mind control
	Mantra yoga	Recitation of *mantras* as an aid to meditation
	Laya yoga	Arousal of *Kundalini* by practice of *hatha* and *mantra* yoga

Table 38-3

Basic Elements of Astangas

1. *Yama*	Disciplinary or moral restraints
2. *Niyama*	Spiritual observances
3. *Asana*	Movement and posture of the body for promotion of perfect health and to bring about harmony in the body
4. *Pranayama*	Rhythmic breathing or regulation of breathing process (control of bioenergy or *prana)*
5. *Pratyahara*	Withdrawal of mind from external objects
6. *Dharana*	Concentration of mind on one object for a brief period (mental control)
7. *Dhyana*	Meditation or concentration of mind on one object for a long period
8. *Samadhi*	Attainment of supreme harmony (between mind and body)

These *astangas,* or eight elements, which are the basic components of complete yoga, are divided into two major stages:

1. *Bahiranga or external yoga*: This includes the first five elements. Regular and disciplined practice of *yama, niyama, asana* and *pranayama* is needed to attain the fifth element of *pratyahara. Pratyahara* or abstraction is a phase of acquiring the highest control of the senses. The void between the senses and the mind leads to the conquest of the senses with total adjustment of one's motivation, value judgement, attitudes and behaviour. This minimizes the objective causes of mental distractions and depravities. By the practice of external yoga, an individual succeeds in freeing himself from the condition of sensate and emotional servitude. The strict observance of these five elements or Bahiranga yoga prepares the individual to be fit to

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practise *antarangas* leading to *samadhi.*

2. *Antaranga* or *internal yoga*: Also known as Raja yoga, it leads towards the achievement of the remaining three elements, namely *dharana, dhyana* and *samadhi.* It represents a state of immaculate consciousness. *Samadhi* is the final stage of supreme harmony, where the individual remains unmoved (or still) by any sort of physical or mental afflictions. Therefore, Patanjali aptly defined genuine yoga as 'stilling of the modifications of consciousness'.

Second classification of yoga

The second classification of yoga is based on the principles of preparing oneself physically and morally for the achievement of supreme harmony.

1. Moral preparation through *yama, niyama* and *pranayama*

2. Physical preparation through *asanas* and *pranayama*

3. Real yoga through *dharana, dhyana* and *samadhi*

Therefore, yoga *asanas* and *pranayama* are two of the eight elements of complete yoga. These two elements assist in acquiring physical control. As these two elements are the important constituents of physical or body control, it is important to know the detailed methodology of *asanas* and *pranayama.*

Methodology of *asanas* (hatha yoga)

The yoga that deals with the physical aspect of the human body is termed as *hatha yoga*. It represents the polarity in which all human beings function. It consists of two basic principles, namely HA and THA.

HA: It is an active or positive principle of existence and is symbolized by sun, heat, light and creativity.

THA: It is an inactive or negative principle and is represented by moon, cold, darkness and receptivity. A human being enjoys perfect

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health only when there is equilibrium or balanced functioning of these two polarities. *Hatha* yoga leads to the achievement of absolute control over the body. *Asanas,* thus, have a dominant role to play in *hatha* yoga.

Yoga asanas

Each *asana* is a series of scientifically developed slow, rhythmic and graceful movements of various joints and muscles of the body aimed at attaining a definite posture as related to that particular *asana. Asanas* aim to acquire optimal physical conditioning with minimum efforts. Smooth, rhythmic body movements are not possible without perfect neuromusculoskeletal coordination and control.

Each *asana* has three stages.

Stage I

During this early stage, a particular *asana* is slowly and gradually initiated from the fundamental starting position (e.g., supine lying, sitting, standing, prone lying). From this fundamental position the body is slowly moved towards the posture of that particular *asana.* It must be progressed in graduated steps and not be proceeded beyond the stage where even the slightest discomfort is felt.

Stage II

This stage represents static holding of the posture assumed during stage I. However, this static brief holding should be a relaxed posture not causing any strain on the body.

Stage III

This is a stage of graduated return of the body to its original starting position. The gentle, rhythmic and dynamic reverse movements of the various components of the body frame during stage I and its reflective holding during stage II promotes harmonious equilibrium of the two basic energies needed for the control of the body. The regular practice of *Hatha* yoga results in a slim body (lissom), joyous face, sonorous voice, sparkling eyes, positive good health, virility, exuberance of

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vitality, radiance and purity of the nervous system (Yogendra, 1978).

Pranayama

Pranayama is based on the methodology of breathing to achieve respiratory control. A single yogic breath has four units:

1. *Puraka*: Related to inhalation of oxygen to the fullest capacity of the lungs

2. *Kumbhaka*: Refers to the steady state of holding air with full distension of the lungs

3. *Rechaka*: Refers to the total exhalation of air emptying both lungs to the maximum

4. *Shunyaka*: Holding the state of void or vacuum when air from the lungs is totally expelled

To achieve effective breathing control, these four stages are sequentially performed in a ratio of 10:20:10:10 s each. The ratio could be 10:40:20 s when *pranayama* is performed with the first three units: *puraka, kumbhaka* and *rechaka* leaving the fourth unit of *shunyaka.* Yogic breathing carried out by this method tones up the intrathoracic and intraabdominal viscera and the total respiratory system. The stage of holding air with full distension of lungs *(kumbhaka)* has been given more importance and its duration is double as compared to that of the other stages.

Preventive and promotive aspects of yoga and yoga *asanas*

Prevention of ill health or a disease is more logical than allowing it to occur and then struggle to cure it. *Yogabhyasa*, that is, scientific knowledge of yoga, *kriyas* and regular practice of *asanas* prepares an individual's body to an ideal state which not only prevents the disease but also tunes the whole body system to a level that it can effectively

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neutralize or fight back to reduce the impact of the disease, thereby promoting its early resolution. Also, in yoga, one finds maximum emphasis on body hygiene through strict body discipline and various purificatory processes. This aspect is contributory in prevention of disease.

The added advantage in the promotion of health through yoga is that besides attaining physical fitness, it offers positive mental health. The basic approach of yoga is through psychosomatics, so much so that the term preferred to the therapeutic approach is *yoga psychosomatics*.

The importance of positive mental health in any circumstances of ill health need not be overstressed. In fact, medical science can never boast of positive physical health without sound mental health. Unfortunately, this important aspect, though accepted theoretically, is generally overlooked in present therapeutic methods.

As yoga includes both these aspects, its integration is important in prevention of the disease and promotion of the positive physical and mental health. It therefore deserves a proud place in any health care programme.

Yoga has a positive influence on both external and internal functions of the body.

Promotion of external functions

For optimal physical functioning, the flexibility of joints, muscular strength and endurance, and neuromusculoskeletal coordination are important. The toning up of these body systems through *yoga asanas* and *pranayama* improves the physiological functions of all the systems and organs of the body.

Promotion of internal functions

Yoga provides efficiency in the functioning of the central nervous system (CNS) and peripheral nervous system (PNS). The optimal functioning of the ANS depends upon the degree of equilibrium of the sympathetic and parasympathetic nervous systems. When there is dominance of the sympathetic nervous system, it results in loss of

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normal homeostatic condition of the body or optimal physiological functioning of the body. Therefore, promotion of the parasympathetic system or its dominance over the sympathetic system is important for health. Influencing the functioning of higher nervous systems also results in improved functions of the internal viscera including the endocrine system. However, achieving such modifications in the nervous system, which holds a master control over the functioning of each and every living cell of the human body, needs genuine practice of *astangas*, especially transcedental meditation (TM) (Anand, 1975). The promotion of cellular health results in adequately meeting the fundamental needs of the body, namely of nutrition and elimination. Besides promotion of the circulatory and respiratory systems, it improves the tone and elasticity of the musculoskeletal system. This provides a higher anabolic ratio while accelerating the interchange of products between blood and muscles.

Emotions, behaviour of the endocrine gland hormones and mental health are deeply correlated with each other. By practising *asanas*, bandhas and mudras regularly, physical and mental health are maintained as the endocrine system is crucial in maintaining all levels at the optimum. Some yogic practices, particularly uddiyan bandha, kapal bhatic, nauli, dhanwasana, halasana and yogamudra, can alter the menstrual cycle in women; therefore, they should practise them on a mild scale and with careful observation.

Thus, these two elements of *asanas* and *pranayama* have a significant role to play in the prevention of disease and promotion of positive health.

Preventive and promotive aspects of physiotherapy

The field of physiotherapy, which was primarily limited to movements of joints following fracture or injury, has developed into a medical speciality with wide horizons of its application. Besides its therapeutic role, it has acquired a significant role in both aspects of prevention, primary and secondary:

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Primary prevention

Just like yoga *asanas* and *pranayama,* physiotherapy has several systematically designed and scientifically proved procedures of exercises which promote optimal physical fitness. Physical fitness tones up all the systems and organs of the body to prevent disease, facilitating the process of recovery.

- Prevention of cardiorespiratory diseases: prevention or control of disease-prone risk factors like obesity, hypertension, diabetes and dyslipidaemia

- Prevention of common musculoskeletal disorders like pain and/or stiffness in the neck, shoulder, back and knees which have been the source of discomfort and loss of productive working hours and work efficiency

- Prevention of common sports injuries by conditioning specific injury-prone areas

Secondary prevention

- Prevention of life-threatening cardiorespiratory and vascular complications following major surgical procedures

- Prevention of secondary musculoskeletal complications following injuries or diseases, burns, amputations, etc.

- Prevention of the recurrence of cardiovascular and cardiorespiratory ailments by cardiopulmonary conditioning (as detailed in Chapter 1) and also prevention of the recurrence of common musculoskeletal disorders like pain and stiffness in the neck, back, shoulder or knees and muscular atrophy and weakness

Therapeutic benefits of yoga

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Hypertension

Reduction of systolic blood pressure from 150 to 140 mm Hg, and reduction of diastolic blood pressure from 94 to 88 mm Hg was reported in 22 hypertensive patients after TM.

The practice of *shavasana* also resulted in a significant reduction of hypertension (Datey & Bhagat, 1975).

Exercise tolerance

Patients of coronary artery disease (CAD) with stable angina showed improvement in exercise tolerance. Increase in the duration of exercise, increase in maximum work load and delay in ST depression in the ECG were reported in 10%, 15% and 15% of patients, respectively.

Bronchial asthma

Spontaneous reduction in the rate of breathing from 13 to 10 and reduction in the airway resistance were found in about 50% of patients with bronchial asthma. The severity of symptoms was reduced in as many as 75% patients (Wallace 1970; Wallace and Benson, 1972).

Swami Anandananda and associates (1975) reported an improvement in the lung function, pattern of breathing and even harmonal homeostasis just by practising simple muscular exercises *(shukshma vyayam)* with certain *asanas* in patients with mild-to-moderate bronchial asthma. However, they concluded that yoga cannot substitute drugs for emergencies like status asthmaticus.

Diabetes

Adult onset type diabetes, of less than 10 years' duration, with a fasting blood sugar of less than 250 mg%, and patients requiring less than 40 units of insulin daily for control of their diabetes responded favourably (Rugmini, 1975).

Low backache

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Practising *Konasana, Supta-vajrasana, Bhujangasana, Shalabhasana* and *Chakrasana* showed favourable response in patients suffering from low back pain with improved functional capacity (Udupa, Singh & Shettiwar, 1975).

Squatting posture gives excellent stretch for lower spine while strengthening the muscles of legs and hips. It helps to open the lower spine. People who squat often get less backache problems. However, squatting should not be done for long periods.

Tachycardia, palpitation, nervousness, insomnia

All these symptoms and signs responded favourably to the regular practice of *asanas* (Udupa, Singh & Shettiwar, 1975).

Preventive benefits of yoga

Physiological, biochemical and various all-round beneficial effects have been reported by a number of studies in normal subjects practising TM as follows:

Oxygen consumption and metabolic rate

Oxygen consumption reduced to the extent of 16–25% by regular practice of TM for 40–60 min. Also the reduction in the metabolic rate achieved after TM was found to be even more than that during the state of deep sleep (Wallace, 1970).

Reduction in heart rate

Reduction in heart rate by 5 beats/min (from 71 to 66) was reported during TM and it remained at that level up to 15 min after TM.

Perceptual motor performance

The speed and accuracy in performing complex perceptual motor test improved in subjects practising TM.

Level of plasma cortisol and plasma prolactin

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Level of plasma cortisol reduced by 25–30% and plasma prolactin level was found to be increased in subjects practising TM (Jeving, Wilson, Venderlaan & Levine, 1975). Blood lactate level dropped from 10 to 6 mg/100 mL (Wallace and Benson, 1972), all indicating a profound state of muscular relaxation.

Besides these, other benefits in normal subjects are as follows:

1. Reversal of biological ageing as proved by the measurement of auditory threshold, near point vision and systolic blood pressure

2. Improved athletic performance with reduction of heart rate

3. Feeling of restful alertness

4. Improved memory, intelligence, academic performance and concentration

Therapeutic benefits of physiotherapy

Modern physiotherapy has a wide variety of specialized exercise techniques, evolved and established through scientific research. The specific technique of therapeutic exercises is planned after a thorough clinical examination and investigations indicating the nature, degree of involvement, and the prognosis of the disorder. It may be directed toward the following:

1. To improve strength, endurance and flexibility of muscles

2. To facilitate neuromuscular coordination

3. To restore function or to provide maximum functional independence within the limits of the disease and disability (rehabilitation of physically handicapped patient)

4. To build up vicarious movements or trick movements to compensate for the permanent loss of movements

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5. To facilitate neuromuscular re-education through biofeedback or synchronization of electrical stimulation with voluntary efforts and specialized exercise techniques

6. To achieve cardiopulmonary conditioning to prevent as well as control risk factors for CAD, hypertension, diabetes, obesity, etc.

7. To improve body balance and gait

8. To promote performance by leading to optimal physical fitness through increase in functional capacity ($VO_{2\ max}$)

9. To prevent common sports injuries by conditioning of an athlete

10. To prepare for and facilitate child birth

11. To relieve pain and inflammation and to augment healing

12. To provide ergonomic advice with specific exercises, to prevent common musculoskeletal ailments

13. To prevent postsurgical complications

14. To promote physical fitness for overall positive health benefits

15. To improve psychological status leading to positive thinking, greater self-confidence, feeling of relaxation and wellness following a session of exercise

Rationale of yoga and physiotherapy

Physiotherapy has its origin in yoga. The basic postures of the body known as fundamental or starting positions for initiating therapeutic exercise are same as the starting postures or *asanas* in yoga, e.g., *tadasana* corresponding to standing or *shavasana* corresponding to supine lying (Figs. 38-1, 38-2).

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FIG. 38-1 Tadasana, corresponds with the fundamental standing position.

FIG. 38-2 Shavasana, corresponds with the fundamental supine lying.

Similarly, many exercises resemble certain *asanas* (Figs. 38-3–38-10).

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(A)

(B)

FIG. 38-3 Pawan muktasana, similar to low back stretch or knee–chest position.

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FIG. 38-4 Bhujangasana, similar to hyperextension stretch to the whole spine.

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FIG. 38-5 Paschimottasana, corresponds to spinal stretch in flexion along with hamstrings stretch.

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FIG. 38-6 Ardha halasana, similar to straight leg raising.

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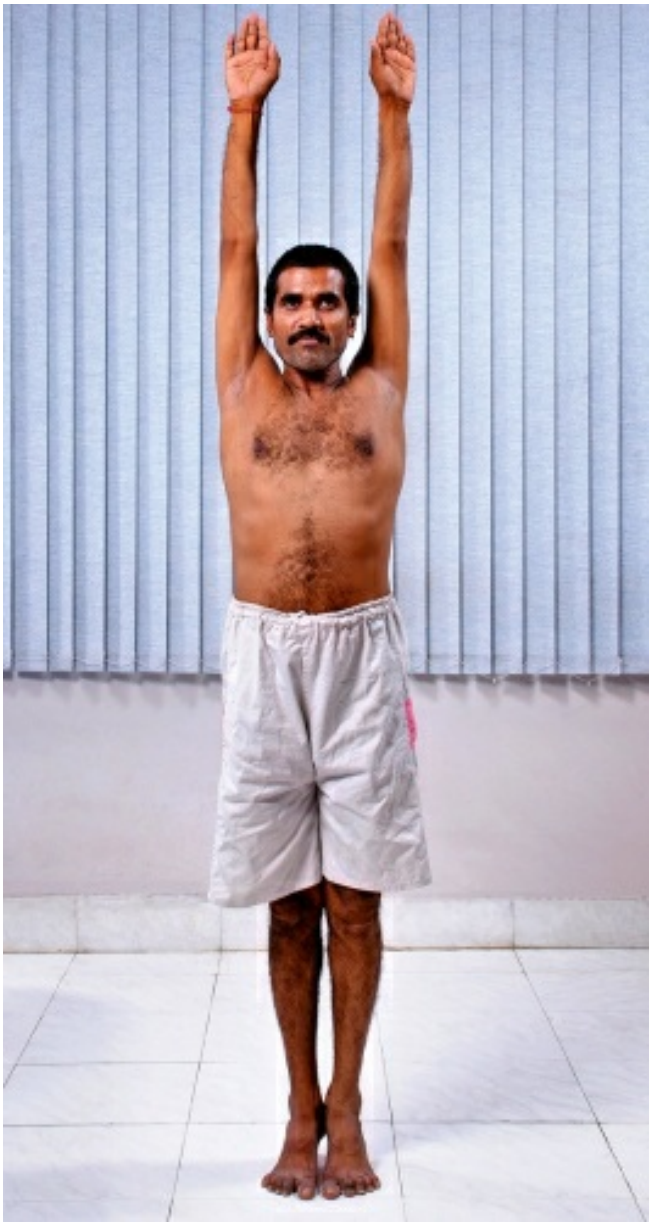

FIG. 38-7 Vrikshasana, similar to whole-body stretch.

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FIG. 38-8 Gomukhasana, similar to shoulder stretch.

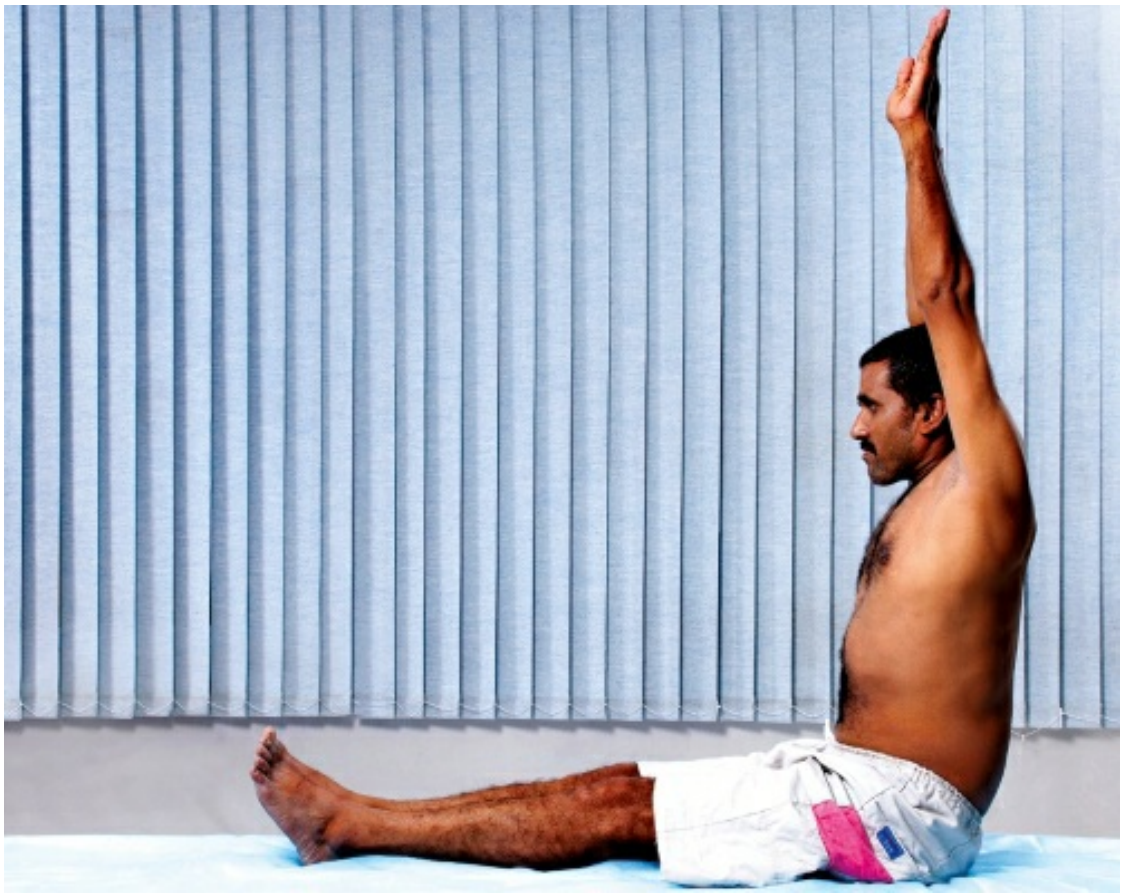

FIG. 38-9 Supta urdhwa hastasana, corresponds to arm stretching over head in long sitting.

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FIG. 38-10 Naukasana, similar to stretching of the whole spine and legs together in hyperextension.

However, the basic difference is obvious when it comes to the methodology of performance of the therapeutic exercise and yoga *asana*.

In yoga *asana,* one assumes a definite posture of a particular *asana* and holds that posture for a brief period and then returns back to the starting position. Thus, the sequence of yoga *asana* is a slow, rhythmic dynamic movement of the body progressing to a static state of holding and again returning to the starting posture (*dynamic-static hold-dynamic*), whereas in therapeutic exercise, the sequence, speed, groove of the movement and arc of joint range vary as per the required effect of exercise. Although the maximum emphasis is on dynamic exercises, static exercises are used in physiotherapy to prevent painful joint compression and disuse atrophy, to improve strength, endurance, posture and to induce relaxation.

Similarly, exercises could be passive, assisted, active or even resistive as against only dynamic and static in yoga. Thus, the mode of therapeutic exercise is extremely variable and as such, there is no

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generalization of exercises, rather the mode of exercise is planned on an individual basis. The exercises are modified or progressed as per the requirements of the patient's condition.

This is not true with *Hatha* yoga. Although the *asanas* are more or less based on scientific experimentation, they are limited to certain body movements, postures and breathing and cleansing techniques *(kriyas).* This has resulted in providing excellent general exercises with flexibility to the whole body.

Yoga *asanas,* without integration of *astangas* or all the eight elements of yoga, are excellent means of promoting flexibility to the joints and soft tissues. They also help improve muscular strength, endurance, controlled muscular actions, controlled breathing and relaxation. This limits their application in patients with spinal cord injuries, polyarthritis, severe physical handicap and neurological disorders.

The efficacy of exercising the whole body through *asanas* in a specific localized disorder or dysfunction is not without doubt, whereas advanced exercise techniques like proprioceptive neuromuscular facilitation (PNF), biofeedback and self-controlled movements in combination with a suitable electrotherapeutic modality help to re-educate neuromusculoskeletal function.

Pranayama and yoga *kriyas* (or *shat karmas),* the procedures for systemic purification, are, no doubt, excellent techniques to promote respiratory and gastrointestinal systems on the whole. But various methods of chest physiotherapy and postural drainage to eliminate secretions from a diseased area of the lung are much more specific.

The slow, smooth and rhythmic movements of yoga *asana* leading to a static relaxed posture aim at conservation of energy *(prana).* As against this, in physiotherapy, the movements, although smooth and rhythmic, are aimed at overloading or excessive expenditure of energy (e.g., cardiorespiratory conditioning). The nature of movements in restorative or re-educative therapies is not so vigorous but is dynamic and repetitive.

Yoga as applied to physiotherapy

Yoga *asanas* can be applied effectively and to a very great advantage

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with some modifications.

1. *Shavasana* is ideal for total relaxation of the body after continuous exercise sessions or in patients where vigorous and strenuous exercises are contraindicated.

2. Intermittent practice of TM is ideal for better concentration of mind for all therapeutic exercise procedures and also in sensory, motor and neuromuscular re-education procedures.

3. Intelligent integration of certain yoga postures and their suitable modifications, like inhibitive procedures, facilitate movement control by reduction of selective postures and postural attitudes. The effect of *asanas* is more on the trunk portion of the body. These bring about changes in the pressure in the internal cavities of the visceral organs, though in physiotherapy, limb movements are also included, which helps in increasing peripheral circulation also.

4. *Pranayama* and other cleansing *kriyas* can be added to chest physiotherapy.

5. Modified *asana* postures can be effective in common musculoskeletal dysfunction.

A number of studies have been reported on the therapeutic aspects of yoga without due consideration in determining the base for autonomic balance. Moreover, these studies have included only a few elements of yoga like *asanas* and *pranayama* or meditation alone.

A study conducted with one or two elements out of eight elements of yoga does not constitute genuine yoga. Therefore, concluding the benefits of this partial yoga is also not justifiable.

Future studies should be conducted by integration of all the eight elements of yoga. Who knows? Inclusion of *astangas* may even promote healing or rejuvenation of the body systems (e.g., nervous system) or the organs which are so far labelled as impossible in the medical sciences.

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Some precautions while doing yoga

- Do not force or strain. Pay special attention to your pain.
- Do not ignore or push through the pain. If pain becomes worse, the muscle is already overstretched; hold the stretch where you are comfortable.
- If pain decreases, you are doing yoga in a beneficial way.
- Pay attention to your breathing.
- Listen to your body. If something does not feel right for your back, take rest.
- Remember to rest periodically in the midst of busy days.
- Try to increase the stretch time slowly.
- Stretch on a daily basis to prevent the muscles from tightening up.
- Deep relaxation in a simple technique but a powerful tool for healing and taking away incapacitating back pain.
- One should take into account his or her limitations due to age, sex, hyper- or hypotonic condition of the musculature rigidity or flexibility of the joints and the purpose of practising *asanas*. Therefore, *asanas* should never be done in a competitive spirit.

Conclusion

The science of yoga, which has a spiritual base, has tremendous potential not only in health but in all spheres of life. It has excellent dimensions as a preventive and promotive science for positive health through *asanas, pranayama* and meditation. Its applicabilities remain obscure due to the practice of only partial yoga.

Yoga teaching needs to be extensive which should include basic and

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applied medical sciences like human anatomy, physiology, kinesiology, biomechanics and pathology.

Intelligent integration of *asanas, pranayama, kriyas* and meditation with physiotherapeutic procedures has a definite role to play in the preventive, promotive and curative aspects of positive health.

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Chapter 39

Sports medicine

Outline

- Incidence and broad classification of sports injuries
- Major causative factors
- Role of physiotherapy
- Prevention of injury
- Treatment of injury
- Training of an athlete
- Grooming of the specific athletic skill

Sports medicine has acquired the status of an independent speciality of medical sciences. Its basic aim is to prepare and educate an athlete to achieve the optimal physical efficiency with safety.

Incidence and broad classification of sports injuries

Rapid increase in the speed and the competitive nature of sports have resulted in an increase in the incidence of sports injuries. Williams reported as far back as 1979 an incidence of sports injuries between 5% and 10% of the attendance at

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the accident and emergency departments (Williams, 1979).

Except for sedentary games, the incidence of sports injuries is predominant in the lower limbs, foot and ankle; injuries alone account for about 80–82%.

Therefore, prevention as well as management of foot and ankle injuries demands optimal care and competent management.

Major causative factors

■ Inadequate conditioning of the body particularly cardiorespiratory and musculoskeletal systems

■ Intermittent periods of lay off

■ Overuse of a particular musculoskeletal complex related to the requirements of individual sports (e.g., overhead shoulder movement of a cricket bowler)

Broadly, sports injuries can be classified into two major categories:

1. Traumatic, extrinsic or external injuries: These occur mainly as a result of direct external trauma (e.g., direct hit from an object used in a sport like cricket ball, or a fall). Traumatic injuries are common in contact sports.

2. Nontraumatic, intrinsic or internal injuries: These occur as a result of indirect internal trauma due to overuse of a particular tissue which is subjected to stereotyped repetitive

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movements in sports. The summation of a series of indirect microtraumas results in internal tissue injury (e.g., tennis elbow, tenosynovitis, stress fracture). Fortunately, the majority of sports injuries are orthopaedic and physiotherapy-related injuries which respond favourably to adequate simple measures. A physiotherapist must be aware of the injuries commonly met with in sports (Table 39-1).

Table 39-1

Regionwise Common Sports Injuries

Region	Specification	Cause	Injury (Mode)
Head	Head injury	Direct violent blast	Fracture/dislocat of the cervical spine
Neck	Whiplash	Direct/indirect violent jerky flexion–extension	Fracture/dislocat of the cervical spine
	Burner and Stringer syndrome	Direct trauma	Forcing neck int flexion and later flexion nerve roc compression, brachial plexus lesion
	Cervical sprains and strains	Indirect trauma following jerky sudden	Posterior longitudinal ligament is commonly

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		neck movement	involved
Shoulder	Fracture/dislocation	Direct hit or violent indirect trauma with violent fall on outstretched hand	Anterior dislocation/fract of the greater tuberosity or nec are common
	Recurrent anterior dislocation	Indirect trauma, fall with arm in abduction and external rotation	History of earlie anterior dislocat or defect in humeral head
	Dislocation of acromioclavicular joint	Direct: impact on the outer side; indirect: fall on outstretched hands	
	Bicipital tendinitis, Supraspinatus tendinitis, rotator cuff syndrome	Indirect due to repetitive movements	Repeated friction causing rupture the tendon or tendinitis

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	Fracture of the clavicle	Direct fall on the shoulder; indirect fall on outstretched hand	Fracture of the clavicle (junctior middle and oute third)
Elbow	Tennis elbow	Indirect trauma due to overuse of stressful extension of elbow	Tendinitis of common elbow extensor origin
	Golfer's elbow	Indirect trauma due to overuse of repetitive stressful flexion of elbow	Tendinitis of common elbow flexor origin
	Fracture/dislocation	Direct trauma, indirect violent fall on the outstretched hand with elbow in slight flexion	Usually posterio dislocation is common, fractu of coronoid proc of ulna may occu

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Wrist	Carpal tunnel syndrome	Indirect injury, due to overuse of wrist joint	
Hand	Tenosynovitis	Indirect, due to overuse of the wrist joint; usually occurs as a result of infection	Inflammation of the synovial lini of flexor tendons the wrist
	Mallet finger	Direct hit on the tip of the finger with hard object	Rupture of the extensor tendon
	Fracture of the MP, PID and DIP joints	Direct hit – violent hit over these joints	Trauma
Trunk	Rib fracture	Direct or indirect trauma	
	Intercostal strain	Indirect injury	Trunk twisting c stationary feet
	Abdominal sprain	Indirect injury	Overuse injury
	Low back pain	Wrong postural mechanism, or postural defect; loss of	Bony or soft tiss strain, sprain

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		joint flexibility, intervertebral instability	
		Muscular weakness, tightness of hamstrings or hip flexors	
		Direct injury to the back	
Hip	Hip joint pain	Overuse, indirect injury	Training on harc surface
	Groin pain	Overuse, indirect injury due to adductor strain	Sudden external rotation with leg abducted positic
	Thigh pain	Direct blow or repeated adductor strain	Quadriceps mus contusion
	Tensor fascia strain	Indirect overuse syndrome or friction syndrome	Repetitive knee flexion–extensio strain
	Pyriformis tightness	Overuse syndrome	

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	Pain – symphysis pubis	Overuse of adductors or loosening of symphysis pubis	Ligamentous str
Knee	Fracture patella	Direct hit or indirect trauma due to excessive quadriceps pull	Fracture of the patella
	Ligamentous injuries	Direct trauma causing overstretching of the ligaments	Incidence of AC injury is more common
	Meniscal injury	Direct twisting injury to the knee joint or indirect trauma	Tears, cysts or discoid menisci
	Chondromalacia patellae	Indirect overuse injury	Irritation of the under surface of patella
	Patellar tendinitis (Jumper's knee)	Indirect repetitive trauma at the tendon bone junction or hamstrings	

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		tightness	
Leg	Calf strain	Overuse strain to calf muscle or violent push off thrust	Bracing lower le against ground reaction forces o landing
	Hamstring sprain	Indirect injury to the hamstrings	Violent contracti of hamstrings during push off
	Shin soreness	Indirect overuse injury	Repetitive shock absorptive stress due to overuse
Ankle and foot	Inversion or evertion strain with or without fracture	Indirect injury due to violent inversion or eversion with ankle joint relaxed in plantar flexion	Fall from height and repetitive overuse
	Stress fracture of tibia	Indirect overuse weight bearing injury	Hairline fracture the upper or low end of the tibia, fibula or metata bones
	Fractures of the fifth metatarsal	Indirect overuse	Weight bearing results in–

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		injury to the fifth metatarsal; sudden twisting of ankle in inversion	Avulsion fractur of the base of the fifth metatarsal – Jones fracture – Dancer's fractu
	March fracture	A fatigue fracture, indirect injury due to sustained standing	Fracture occurs a the second or thi metatarsal bones sustained standi
	Medial tibial stress syndrome	Indirect injury due to periosteal inflammation	Periosteum gets inflamed over th medial border of the distal one-thi of tibia (shin splints) due to overuse
	Anterior impingement syndrome	Overuse syndrome due to repetitive excessive dorsiflexion	Excessive dorsiflexion of th ankle joint result in impingement the anterior tip o the tibia on the neck of the talus
	Posterior impingement syndrome	Overuse indirect injury due to	Posterior tubercl of the OS calcis compresses the

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		repetitive plantar flexion	synovial or capsular tissue against the tibia due to repetitive plantar flexion
	Flexor hallucis longus tendinitis	Indirect overuse, putting extra strain on flexor hallucis longus	Extreme repetiti plantar flexion puts extra stress dynamic stabilization of medial foot and ankle on flexor hallucis longus
	Injury or fracture of sesamoid bone of great toe	Direct impact of the foot or overuse injury	Impact of the foo on a hard surfac with toes in extension or repetitive microtrauma to foot; the fracture may occur when the proximal phalanx of the fi MTP is jammed into the dorsal articular surface the metatarsal head
	Tenosynovitis	Overuse causing inflammation	Deep toe flexors, tibialis posterior peronei are

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		of the synovial lining of the fibrous sheath of deep toe flexors	commonly involved; overus results in synovi inflammation

Note: It must be remembered that every speedy sport is susceptible any type of neuromusculoskeletal injury.

Role of physiotherapy

The well-established role of physiotherapy as 'only after injury' is incorrect. With rapid developments in the art and science of physiotherapy, physiotherapy has great potential to play a multifactorial role in the enhancement of all the four major aspects of sports:

1. Prevention of injury

2. Treatment of injury

3. Training of an athlete

4. Grooming of the specific athletic skill

1. Prevention of injury

Preventing injury or ensuring early recovery is of primary importance to any competitive sport or athletic event.

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To prevent injury during the sport, the most important first step is to conduct extensive physical examination with objective evaluation of the physical adequacies required in competitive sports, such as:

(a) Preexisting pathological deficiencies which are likely to obstruct the efficiency of a sports person are detected (Table 39-2).

(b) The status of conditioning of the musculoskeletal complexes predominantly involved in relation to the chosen sport is examined.

(c) Exercise tolerance: A well-monitored exercise stress test which provides normative data on the physical work capacity (PWC) or aerobic capacity is inescapable.

(d) Before starting training on sport, overall physical fitness of a sports person is assessed by a special fitness test (Table 39-3).

(e) Observation on the field: After selection for a particular sport, the sport person is critically observed in a trial game on the field for any abnormal attitudes and abnormal mechanics, wrong postural attitudes, lack of speedy coordination, etc. are recorded so that specialized training can be given to correct them, especially on the field itself.

Table 39-2

Possible Pathological Deficiencies

Inadequacy of muscle	Lack of strength, endurance

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functions	and flexibility
Limitation of a joint range of motion both active and passive	Due to soft tissue or skeletal pathology
Static as well as dynamic body balance	Stable as well as instant regaining of equilibrium
Lack of movement coordination between the body and the limbs	Controlled – slow as well as speedy coordination of limb movements
Lack of agility and speed	For instantaneous position changes while the body is in motion

Table 39-3

Physical Fitness Test before Exercise Training and at Regular Intervals

Ability to jump from the height of 1 m
Trail test to assess adequacy of strength, endurance, flexibility, agility, neuromuscular coordination and balance by the field test of a chosen sport
Presence of full passive ROM without any discomfort
Pain-free full active ROM against resistance
No limp during brisk walk, jogging or running
Full floor squats on both as well as on a single leg
Complete cross-legged sitting
Test for runners – ability to extend knee fully against the resistance of 20 pounds, 10 times in <45 s
Test for contact sports: The same test as for runners, but

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against the resistance of 45 pounds

On the basis of the data thus collected and the musculoskeletal requirements of a chosen sport, a comprehensive exercise prescription is formulated (e.g., improving the strength, endurance, flexibility and coordination of the evertors of the ankle and foot will be instrumental in preventing or in decreasing the gravity of the commonly occurring inversion strain at the ankle joint).

Specific precautions to prevent injury

■ Use adequate well-fitting protective aids (guards, helmets, etc.).

■ Comfortable light weight flexible footwear as per the requirements of a particular sport (e.g., runner's shoes should have excessive cushioning to absorb the impact of the ground reaction forces), excessive flexibility to toes, heel wedge and 0.5 inch rocker under foot to facilitate toes-off.

■ Do not undertake vigorous outdoor sports in extremely high or low temperature or excessive humidity (e.g., temperature >42°C or 107°F, humidity close to 100% or more).

■ Lower extremity impact exercises should not be performed on hard concrete surfaces or soft glossy surfaces. The floor base should be tough.

■ Initial phase of conditioning must have intermittent breaks to prevent overuse injury.

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■ Appearance of pain or swelling during or following game should not be overlooked. It may be a warning signal for future capsulitis or arthritis.

■ Using chewing gum during sports, a commonly seen attitude which may cause asphyxia, should be stopped.

■ Careful self-monitoring for adverse signs and symptoms like dyspnoea, giddiness, excessive sweating, chest pain, or angina should be taught, gradually tapering down the intensity and never with an abrupt stop.

■ Use protective guards even during the field trials.

2. Treatment of injury

Sports injury could be simple, just a contusion, sprain, strain, open wound or a simple fracture. Although rare, the injury could be cripping or even life-threatening in high-speed and high-power contact sports, e.g., injury to the head, neck or back. The treatment depends upon the gravity of the structural involvement.

Fortunately, majority of sports injuries are simple in nature and, therefore, can be managed effectively with appropriate orthopaedic and physiotherapeutic procedures. As a rule of thumb, the treatment begins by following the principles of rest, ice, compression and elevation (RICE). On the whole, the methods of treatment follow the same lines as described in the chapters under respective headings. However, certain modifications are needed due to the alterations in the demands of an athlete.

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Modifications in therapeutic approach

■ The sports person needs 100% recovery in the shortest possible period as compared to 60–80% recovery which may be acceptable in an average individual, who only needs pain-free activities for daily routine.

■ Personally supervise and ensure that the basic principles of early treatment with the concept of 'RICE' are adequate and correct and are substantiated with anti-inflammatory analgesics.

■ Avoid detoning of the body, which sets in early and progresses rapidly by rest and immobilization. Start early vigorous exercise to the body parts free from immobilization, avoiding stresses over the injured area.

■ Begin early mobilization of the injured area by relaxed passive movements strictly in a pain-free range to avoid developing adhesions.

■ Progress rapidly to the self-assisted active, and active resistive mode with carefully graded resistance, to minimize the loss of muscular strength or endurance.

■ Instead of a regular routine of treatment of once a day or on every alternate day, treat the injured athlete two to three times a day.

■ Maximum emphasis has to be given to improve the psychological trauma of injury through an encouraging psychophysiotherapeutic approach.

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■ Discourage early resumption of sport without physical fitness test to avoid recurrence or breakdown and increased morbidity.

Responsibilities of physiotherapist

The present trend of a physiotherapist accompanying a sports team as a first-contact clinician, following an on-the-field injury, has immensely increased the responsibility of a physiotherapist. Therefore, he must have adequate knowledge, experience and professional expertise of the following:

(a) Emergency life-saving procedures like cardiorespiratory resuscitation

(b) Ability to quickly diagnose the type, the structural involvement and the gravity of injury

(c) Ability to take correct, on-the-spot decision on the immediate management of an injured athlete

(d) Ability to decide whether an athlete urgently needs:

i. Orthopaedic consultation and care

ii. Hospitalization

iii. Investigative procedures like radiograph and blood test

iv. Just a simple conservative care

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Orthopaedic management

Initial diagnosis is made through critical clinical history and physical examination of an injured athlete. If there is any doubt about the diagnosis, a number of diagnostic modalities could be used as and when required (Table 39-4).

Table 39-4

Diagnostic Procedures

1. Conventional or plain radiography	For avulsion injuries or fractures
2. Stress radiography	For ligament injury
3. Arthrography	It consists of injecting radiopaque contrast material into the joint space followed by plane radiography; it is useful in detecting soft tissue injury around the most susceptible areas like knee, ankle, shoulder (e.g., ligament or meniscal injuries)
4. Computerized tomography (CT)	Three-dimensional spiral CT is particularly beneficial in detecting skeletal imaging of areas which are not readily accessible to conventional radiography like cervical spine, pelvic, shoulder girdle.

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5. Radionuclide imaging (bone scan)	It is useful in ruling out bone injury and in detecting stress fractures and chronic ligament injuries
6. Magnetic resonance imaging (MRI)	It has revolutionized the diagnostic procedures; it can give an exact picture of the location and extent of bone injury, bone bruises, all the types of soft tissue injuries like muscle, tendon, ligament as well as cartilage
7. Diagnostic arthroscopy	It is an excellent investigative technique in detecting the exact offending tissue inside the joint and the degree of damage to it

After confirming the diagnosis, if suitable, conservative measures like close reduction, immobilization and traction may be adopted.

Surgical treatment

Arthroscopic surgery: Arthroscopy can be used as a tool to conduct surgical procedures like meniscectomy, ligament reconstruction, removal of osteophytes and biopsy. As it does not involve large incisions, the period of recumbency and the rate of healing are speedy and ideal for sports injuries.

The other surgical procedures commonly used include immediate soft tissue repair, reconstruction or suture.

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Occasionally, fractures or other bone injuries may need surgical interventions like open reduction or even internal fixation.

Before resuming the sports, an athlete must undergo specific fitness test (Table 39-5).

Table 39-5

Fitness Test before Resuming Sports after Injury

No tenderness over the injured site
No discomfort or pain during
• Resistive isometric as well as full-range isotonic movement to the involved musculoskeletal complex
• Full range of passive movement in the event of fracture or joint involvement
• While performing sport-related activities on the field
No limp while jogging or running
No comparable loss of timing of the injured limb when injury involves upper extremity
Does not need any support or strapping except the one needed to secure the dressing (Wright, 1981)

3. Training of an athlete

Remember, for peak performance, an athlete needs 100%

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physical and mental fitness. With a sound background of anatomy, physiology, kinesiology, biomechanics and day-to-day experience in the management of injuries and above all an exercise-oriented approach, the physiotherapist should be able to give optimal performance fitness to the athlete. Moreover, with frequent and longer sessions involved in the therapy, the therapist can contribute significantly to boost the morale of the athlete in terms of improving self-confidence, self-awareness and a feeling of well-being.

Exercise training

Before initiating exercise training, an athlete must undergo a thorough medical screening in and a test for physical fitness (Table 39-5). A thorough medical screening of the athlete is essential to rule out any contraindications for vigorous sports. It consists of an evaluation by the following:

■ Medical examination including history, physical examination, laboratory investigations, radiograph – one should also rule out risk factors for exercise or vigorous sports such as cardiac or metabolic diseases

■ Monitoring graded exercise tolerance (GXT) test or stress test

■ Evaluation of musculoskeletal system to detect any pathological deficiencies by passive and passive accessory joint movements, and strength and endurance tests (e.g., a run of 2.4 km gives a time which correlates very well with the aerobic capacity or endurance fitness)

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■ Sport-specific examination of the major parts of the body involved in a particular sport

After these tests, a specific programme to develop the efficiency of an athlete is formulated to enhance physical fitness.

The physical fitness in an athlete is not limited only to a strong body, it also needs optimal physical functioning of the body. The required physical fitness is possible with the highest degree of synchronized tuning of the neuromusculoskeletal system. This is achieved by attaining the maximal level of the following:

■ Endurance

■ Strength

■ Power

■ Flexibility

■ Agility

■ Coordination

■ Reflex reactions

■ Balance and equilibrium of the body

To improve the afore-mentioned aspects of physical fitness, the exercise modes must be planned to meet adequately the individual demands of each sport.

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The basic components of the exercise training, in general, are:

(a) Endurance training

(b) Strength training

(c) Free weight training

(d) Agility training

(e) Speed, strength or power training

(f) Body stretches and relaxation techniques

(a) **Endurance training:** The performance of an athlete greatly depends upon the maximum level of aerobic capacity, physical work capacity or functional capacity (VO_{2max}) and anaerobic threshold (AT). The functional capacity determines the rate at which oxygen is delivered to the exercising muscles; the demand for which rapidly increases with increase in the vigorousity of the game.

The important determinant of VO_{2max} is the maximal cardiac output (or Q_{max}) which denotes the volume of blood pumped by the heart per minute. This depends upon the maximum stroke volume (SV_{max}), which denotes the volume of blood pumped with each heartbeat. Thus, increased stroke volume results in an increase in cardiac output which, in turn, is reflected by an increase in the functional capacity. Thus, the major contribution to improve functional capacity, physical or performance efficiency comes from cardiac output which, in turn, depends upon the efficiency of the cardiorespiratory

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system. Therefore, improvement of cardiopulmonary conditioning (CPC) is the basic requirement of endurance training. Endurance exercise training works on the principle of overloading the physiologic systems of the body to a definite predetermined range of exercise intensity or target training range.

Besides improving maximum aerobic capacity (VO_{2max}), endurance exercise has the advantage of improving aerobic threshold (AT) and improving the capacity of the athlete to perform intense sport for a longer period. Endurance training also enhances other basic physical requirements of sports like agility, coordination and flexibility along with balance and equilibrium (Fig. 39-1). In general, endurance exercise training improves functions of the body systems and organs besides offering safety from CHD, diabetes, hypertension, hyperlipidaemia and obesity with enhancement of the psychological status.

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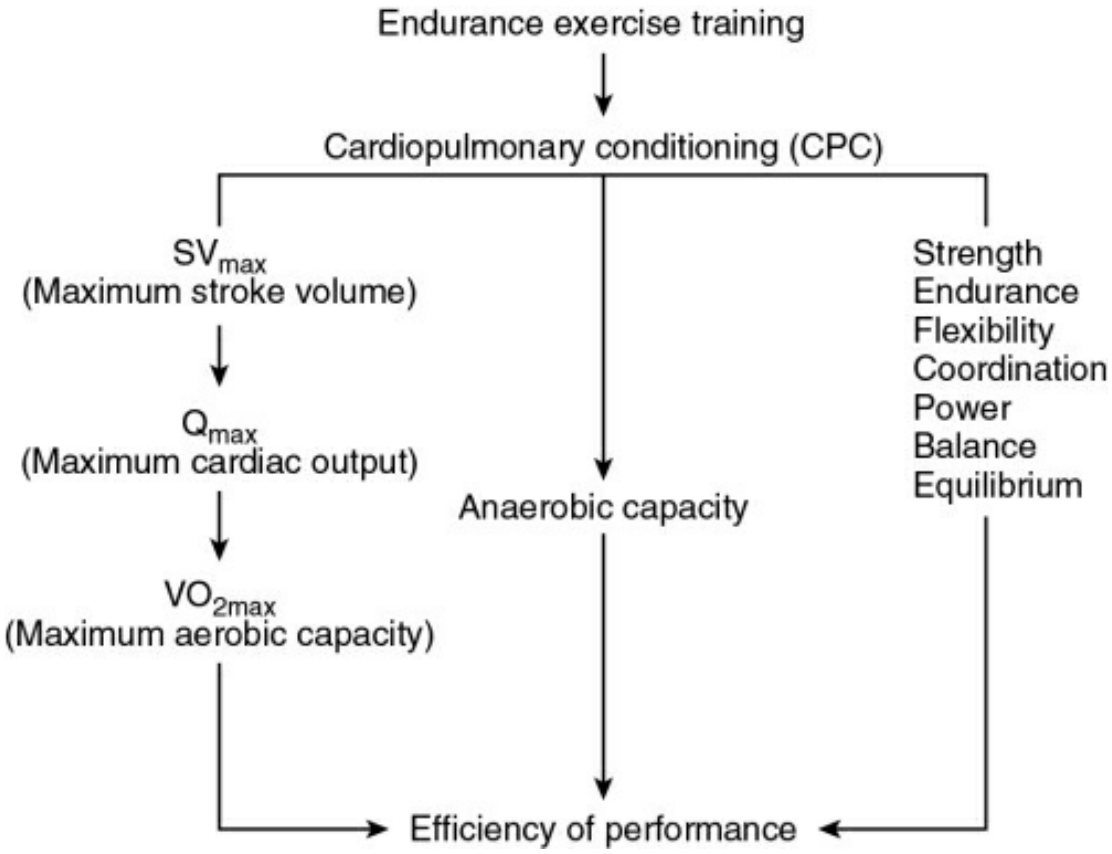

FIG. 39-1Role of endurance training in improving sport performance.

Therefore, ideally, any exercise training should begin with low-grade endurance training. The methodology and contraindications of endurance training are included under the heading of CPC in Chapter 1. However, the following modifications are needed in the endurance training for an athlete:

■ The exercise programme for all the three phases of CPC, i.e., warm-up, conditioning and cool-down, needs to be formulated in such a way that it includes the movements which are specific to a particular sport for which the athlete is being trained.

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■ The aim of endurance training in an athlete is to improve functional capacity and AT to the maximum for optimal performance. It is achieved by faster increase in the intensity component of exercise. Therefore, the intensity of exercise training should be increased to reach the level of 85–90% of VO_{2max} at the earliest, of course with all the safety precautions.

■ The conditioning phase exercise scheme should include exercise modes as per the needs of the sports, e.g., for the sports needing explosive burst of energy, the conditioning phases should be planned by using correct circuit weight training (CWT) exercise which incorporates rapid bursts of explosive energy during the particular forceful activity of the sport (e.g., weightlifting, javelin throw).

For the sports needing sustained activity, the conditioning phase exercise scheme should mimic the same movements against resistance (e.g., long distance running, marathon).

(b) **Strength training:** To improve strength, the principle of overloading the cardiorespiratory system through properly graded progressive resistive exercise (PRE) is the rule of thumb. It is achieved through the following major modes of exercise:

(i) Bench press: Strengthens mainly deltoid, triceps and pectoral muscles

(ii) Squat: For quadriceps, glutei and trunk extensors

(iii) Power clean: For strengthening the body's major muscle

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groups (i.e., upper extremities, lower extremities and trunk); power clean is important to improve speed, coordination, timing, balance as well as explosive power

(c) **Free weight training:** The great advantage of this modality is that, besides strengthening the prime movers, it strengthens the synergistic as well as stabilizer muscle groups, tendons and ligaments. As it involves the need to balance resistance during the movement which puts overload on the ligaments and tendons, it improves their excursion and tensile strength (e.g., weight training with barbells or dumbbells), whereas strength training with machines improves only the strength of the prime mover muscle groups.

(d) **Agility training:** Agility training develops balance, coordination and mobility at a faster pace. It includes specific agility drills like jumping rope, combination of forward running – turning, bending and running backwards. Two-leg hop, one-leg hop, cross-over run are also extremely helpful in improving overall agility in sports.

(e) **Speed strength, or power training:** It is also known as *polymetrics*. It is the most important component of the sudden burst of explosive power. It requires conditioning of the neuromuscular system to react quickly and at the same time forcefully during stretch-shortening actions. An athlete's speed, strength or power depends upon how fast the muscle action switches from an eccentric contraction to a concentric one. It can be achieved best by a series of progressive exercises that will mimic principal movements involved in relation to a particular sport. The exercise must be done fast

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with sudden burst of energy.

Begin with speedy jumps, hops, bounds or running drills. Progress gradually to against graded resistance by using heavier objects than those used in a particular sport (e.g., using heavier bat in cricket). This has been proved by the little master-blaster Sachin Tendulkar (who uses a heavy bat).

Strength base for polymetrics is an ability to perform one repetition maximum (1 RM) in the squat of one and a half times the body weight.

(f) **Body stretches and relaxation:** Vigorous exercise should be followed by slow body stretches during the cool-down phase. This is followed by relaxation techniques.

Depending upon the specific requirements of the sport, the modes of exercise are incorporated and emphasized in the sessions of exercise training programmes. The guidelines drawn by Kulund (1988) are extremely useful in formulating the exercise training schedule to any sport (Table 39-6).

Table 39-6

Sport-Related Specific Exercise Training Programme

Sport	**Specific Needs**	**Exercise Mode**
1. Basketball	High vertical jump, wrist and hand strength, agility	Polymetrics with high pulls, power clean, squat, rope climbing, fingertip push ups Various jumps like backward, forward,

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		sideways, bench and rope jumps
2. Field events, shot put, discus throw, javelin throw	Trunk strengthening to use whole body force to throw	Bench press, squat, power clean, resistive trunk twisting, trunk curls and hyperextension
Hammer throw	Throwing action	Mimicking throwing action against pulley resistance
	Body balancing in space	Trampoline work
3. Swimming	Over 90% work is through arms	Arm exercise against resistance like hand pad tube or float
	Endurance	Circuit weight training (CWT) to improve cardiovascular endurance and body fitness
4. Football	Short burst of explosive energy for running, blocking and tackling	High-intensity explosive burst exercise
	Strength especially at hips and legs	Power training for hip, knee, ankle and foot

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5. Weightlifting	Short explosive bursts of energy in arms to lift	General conditioning
	Strength and power to pick up weight and to lift it overhead with extra shoulder external rotation	Volume training rather than intensity training

Phases of exercise training

Exercise training progresses through three phases:

Phase I: It is also called *foundation phase*. It involves improvement in the basic physical fitness to reach performance peak whenever necessary. Endurance or conditioning exercise training includes exercise at low intensity but with high repetitions.

Phase II: It is called *preparatory phase*. The aim is to improve strength by hypertrophy of the maximally involved muscle groups. It involves exercise at high intensity with low rate of repetitions. During this, regular sessions of agility drills are also included.

Phase III: It is a precompetition phase in which sport-specific activities are performed against highest possible resistance with further reduction in the repetitions.

Agility drills are also increased to reach a level of peak

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performance.

Fitness test for returning to sports after injury: It is extremely important to subject an athlete to a critical fitness test before giving clearance to return to vigorous competitive sports. The test includes the following:

■ There should be no tenderness over the injured area

■ Injured area should not hurt during:

■ Normal daily activities

■ Resistive movements to the involved musculoskeletal components

■ Passive full range of motion to the affected joint

■ Ensure adequacy of strength, endurance, flexibility, agility, coordination and balance of the muscles, tendons, ligaments, bones and joints by short bouts of sports trial.

■ Fitness test for runners: Ensure the ability to extend knee with 20 lb × 10 in 45 s.

■ For contact sports: Ensure the ability to lift 45 lb × 10 in less than 45 s.

■ The athlete with injury to the lower limb must not limp while running.

■ When injury is to the upper limb, there should be no comparable loss of timing of that limb.

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■ The athlete has an ability to full squat on both the legs or one leg and full press-up.

■ The athlete does not need any support or strapping except the one needed to hold on a dressing (Wright, 1976, 1981).

Before giving final clearance to the athlete to resume vigorous sports, the fitness test should be given on the field in the circumstances realistic to a particular sport with keen observation of the injured area.

4. grooming of the specific athletic skill

Objective physiotherapeutic programme to enhance the specialized skill of an athlete

The recent trend of identifying young talents and grooming them for a particular skill opened up a new dimension to the role of physiotherapy. Scientifically planned and properly executed physiotherapy procedures have the potential to contribute significantly in enhancing the specialized skill of an athlete, as we suggested earlier (Joshi et al., 1987).

Methodology of objective physiotherapy

(a) To begin with, kinematics of the movements involved in the specialized skill are recorded.

(b) Next, a critical analysis of the biomechanical and musculoskeletal aspects involved in the specialized skill is done.

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(c) Then, on the basis of these evaluations, objective planning is done by selecting suitable physiotherapeutic modalities to enhance the specialized skill and given a trial.

(d) If found acceptable and beneficial, it should be continued in a well-controlled manner over a period of time without a break.

(e) Objective evaluation is done to assess the response of the specialized training.

(f) If needed, suitable alterations are done and the physiotherapeutic regime is continued.

To illustrate further, take an example of a youngster who has been selected as a potential spin bowler in cricket.

The basic needs to enhance the skill of a spin bowler are as follows:

1. To enhance the ability to spin a ball

2. To improve the ability to generate explosive force at the shoulder girdle, shoulder joint and the upper back at the time of delivering a ball

1. To augment the spin, the major requirement is to improve mobility at the wrist, MP, PIP and DIP joints of the bowling hand.

Earlier studies have proved that the mobility and dynamic flexibility of musculoskeletal complexes are modifiable by local warming or by low-volume cycloidal vibrations. Lately,

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De Dyene, in 2001, has demonstrated the pathophysiology of passive strength in augmenting the length of a musculotendinous complex. On the basis of these findings, we believe that properly formulated training in the following sequential order could enhance mobility of the joints of wrist and hand:

(a) Session of paraffin wax bath to wrist, thumb and fingers

(b) Followed immediately by mobilization procedures like low-intensity sustained stretches to these joints

(c) Followed by a programme of dynamic flexibility work on the field

When the force and coordination of wrist and fingers in gripping and releasing the ball are adequate, excessive mobility achieved through the sessions of specific physiotherapy at the wrist and fingers will certainly enhance the skill of a spin bowler. This has been amply proved by the example of BS Chandrashekhar, famous Indian spin bowler of the seventies. He could viciously spin the ball because of the excessive mobility of forearm and wrist as a result of post-polio residual paralysis.

2. The second objective of improving the ability to generate effective explosive force at the time of delivering the ball can be achieved through polymetric strength training mode. The upper extremity PNF pattern of extension–adduction–medial rotation, along with shoulder girdle protrusion and trunk flexion with rotation over the contralateral leg, is ideal. This pattern should be practised in standing against resistance by

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pulley and weight system. This technique, besides mimicking the exact pattern of movement during bowling, provides excessive recruitment of the motor units to the specific combination of the muscle groups involved in the action of delivering a ball.

Explosive force at shoulder and upper trunk at the time of delivering the ball from arm overhead to the angle of its release is important. To achieve this, a technique of isometric holds at an angle requiring maximum explosive force could prove extremely effective.

Thus, critical analysis of the specialized skill and appropriate selection and correct application of a physiotherapeutic modality can enhance the performance of an athlete by increasing the efficiency of the specific skill.

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