***Factors favoring union*:** Head injury/ICU patients, alkalinity (high pH), high oxygen tension, immobilisation and micromotion at fracture site, stability, compression at fracture site, platelet products (platelet rich plasma), etc. favor callus formation and union. Younger age, closed fracture, fracture in cancellous bone and spiral fracture heal better. Pediatric patients has high union and remodeling rate.

***Factors hindering union*:** Inadequate immobilization (commonest cause), old age, open fracture, distraction at fracture site, soft tissue interposition at fracture site, malnutrition, smoking, alcohol, comorbidities, radiation therapy, infection, pathological fracture, intra-articular fractures, all heal poorly. **However, osteoporosis per se does not lead to nonunion.**

Common Sites of Nonunion

- Fracture neck of femur
- Scaphoid
- Talus
- Lower third of tibia (overall commonest site)
- Lateral condyle of humerus

Malunion is mostly seen in metaphyseal fractures (cancellous bone), viz. supracondylar fracture of humerus, Colles' fracture, clavicle, intertrochanteric fractures, etc.

***Principles of treatment in nonunion*—**open reduction is done with freshening of fracture margins till bleeding bone ends are found and removal of all fibrous tissue, stable internal fixation with **bone grafting (mandatory step)**. Postoperatively the limb is supported with a splint/slab. However, if the nonunion is infected, then the choice of fixation changes:

- LRS (limb reconstruction system; a special type of external fixator)
- Ilizarov—if bone gap/bone loss present and bone lengthening is desired.

***Chemicals speeding up fracture union*—**bone marrow aspirate, platelet-rich plasma, bone morphogenetic proteins (BMP 2 and 7), etc.

Bone Grafting

Ideal bone graft should have the property of osteogenesis (supplying bone forming cells), osteoconduction (providing a scaffold for bone formation) and osteoinduction (recruiting host cells to form new bone).

Different types of bone grafts

- Cancellous —possesses all three properties. The cancellous bone graft is slowly replaced by new bone by a complex process known as "creeping substitution". Graft donor sites—iliac crest (for large amount of graft), metaphyseal area of bones (for small graft)—olecranon, tibia metaphysis, radial styloid, greater trochanter, distal femoral condyle, etc. Bone graft from iliac crest is most commonly taken from highest point of iliac crest. However, considering the percutaneous location, posterosuperior iliac spine is the best source of cancellous bone graft.
- Cortical—no osteogenic property, poor induction but better osteoconduction. Fibula is the ideal and most common site of cortical bone graft. Other sites—ribs.
- Tricortical bone graft—all three properties. Iliac crest is the most common site. Anterior iliac crest is the best source of bicortical and corticocancellous graft.
- Vascularized grafting—here along with the bone graft its vessels are also grafted to the recipient site, most commonly done using fibula. In nonunion where larger gap is present, vascularized fibular graft may be done to enhance chances of union.

Pathological Fracture

Fractures occurring in diseased bones subjected to trivial trauma are known as pathogical fractures. Here fractures occur after a trivial force in a pathologically weakened bone, not enough to cause fracture in a normal bone. Pathological cause may be systemic disease (osteoporosis, rickets, scurvy) or localized (infection, malignancy or metastasis). Vertebral bodies (DL spine) are the most common site of fracture followed by neck of femur and distal end radius. Most common cause—<60 years is metastasis and after > 60 years/overall is osteoporosis. In India, most common cause is nutritional osteoporosis.

after initial callus formation), Sarmiento cast is applied after moulding it to the fractured limb. Weight bearing is allowed (after 2 days of cast application), whereby fracture site is compressed and fastens healing. Nearby joints are not included in cast, thus their function is not compromised (therefore no joint stiffness).
- Indications—fracture humerus (commonest), tibia (PTB cast—misnomer), ulna, etc.
- It does not help primarily in reducing a fracture but the hydrostatic pressure helps in maintaining the reduction achieved while cast application.
- It is not useful in open fractures.

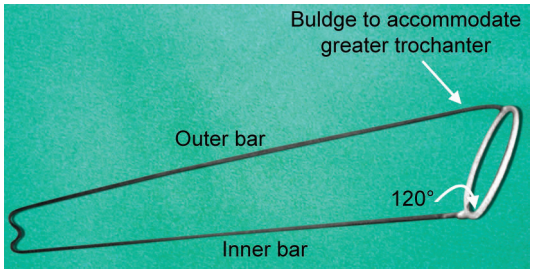

Fig. 2.3: Thomas splint [Two outer bars attached proximally by a ring suspended at 120°, outer bar is bent to accommodate the greater trochanter. Inner part of the ring is most troublesome, may cause sore in groin]

Physiotherapy
It deals with physical exercises, mechanical and electrotherapy for various indications, like pain relief, joint stiffness, range of movement, etc.

Heat Therapy
- Superficial heat penetrates only the superficial structures (skin and subcutaneous tissue).
  - For example, hot bath, paraffin wax bath, infrared lamp, moist air cabinet.
- Deep heat penetrates till muscle.
  - Short wave diathermy, microwave diathermy, ultrasonic therapy.

Electrotherapy
- TENS: Transcutaneous electrical nerve stimulation.
- Interferential therapy.

OPERATIVE MANAGEMENT

AO Principles
- Preservation of blood supply of bone during dissection
- Acceptable (preferably anatomical) reduction of fracture
- Stable internal fixation and
- Active mobilization of joints.

Timing of Surgery
- Emergency—surgery should be done as early as possible in life/limb threatening injuries
  - Vascular injury, irreducible dislocation/fracture dislocation of major joints, fracture dislocation with vascular injury (knee), compartment syndrome, compound fracture with bone exposed, any abscess, septic arthritis, spinal injuries (cauda equina, with deteriorating neurological deficit).
- Urgency—done within 1–2 days
  - Intra-articular fracture, fracture NOF, pediatric fracture (lateral condyle humerus/displaced supracondylar humerus).
- Elective—surgery can be done after proper planning in a length of time
  - Joint replacement surgery
  - Ligament surgeries (arthroscopic surgery).
  - Long bone fracture.

Closed Reduction v/s Open Reduction
The basic essence of closed reduction is that fracture site is not opened and thus the fracture hematoma is retained, which has high osteogenic potential, therefore, this mode of reduction has higher chances of union, whereas in open reduction fracture site is opened and fracture hematoma is exposed. Closed reduction is aided by C-arm guidance/image intensifier. In conservative management, reduction is done by closed reduction and fracture is immobilised by slab/cast. While in surgical management, reduction can be either done by open or closed reduction and fracture fixed with an implant which may be internal/external fixation. In closed reduction, implant is inserted

Table 3.4: Uses of MRI in orthopedics

Investigation of choice in soft tissue (marrow, brain, spine, muscles, tendons, ligaments, cartilage, nerves) pathology detection

Trauma

- Not routinely used
- Investigation of choice (IOC) for unilateral stress fracture (bone scan can be preferred for bilateral stress fracture) and occult fracture like occult fracture neck of femur
- Bone contusions can be seen, even when cortex is intact
- Traumatic tendon ruptures, hematomas

Infection/inflammation

- MRI is IOC in acute, subacute and chronic OM as it shows status of marrow of involved bone as well as adjacent soft tissues
- Also, the preferred modality in septic arthritis and soft-tissue infections like pyo-myositis, necrotizing fasciitis

Tumors

- Useful in assessing intramedullary spread, skip lesions, soft-tissue extent, status of adjacent neurovascular bundles
- (The gold standard investigation for tumors is biopsy)

Avascular necrosis/Perthes' disease—MRI is the investigation of choice

Taken from Fundamentals of Orthopedics by Mohindra and Jain (2nd ed., Jaypee publishers)

Role of contrast in MRI: Both CT scan and MRI employ use of contrast medium to further enhance the pathology and make its identification easier. While CT scans use iodine or barium compounds as contrast, gadolinium compounds are commonly employed as contrast material in MRI.

For visualizing joint pathologies, contrast materials can either be given by intravenous injection (indirect arthrography) or can be directly injected into the joint (direct arthrography).

BONE SCAN

Bone scan is a nuclear medicine test, i.e. it makes use of a small amount of radioactive substance (technetium 99m—labeled methylene diphosphonate) called tracer, to scan body tissues, especially bones. The tracer is injected into a vein and as it perfuses various tissues, the activity (radiations emitted by various tissues with uptake) is detected by using a gamma camera.

Activity in bone scan is recorded in three phases:

1. Early perfusion/flow phase (image taken 2–5 seconds after injection)
2. Middle blood pooling phase (image taken 5 min after injection)
3. Delayed bone phase (image taken 2–4 hours after injection): After 2–4 hours, most of isotope in blood is metabolized while the rest is taken up by bone, so bone pathologies can be elucidated. Areas with increased bone turnover/osteoblastic activity appear as areas of increased uptake (hot spots) on the scan and vice versa.

Uses of bone scan are given in Table 3.5.

Table 3.5: Uses of bone scan

Hot spots (*increased tracer uptake*): Metastasis, trauma, neoplasm, infection.

Cold spots (*decreased tracer uptake*): Multiple myeloma, histiocytosis X, metastasis from renal cell carcinoma/thyroid carcinoma (due to replacement of normal bone or marrow).

Superscan (*generalized/diffuse increased uptake*): Hyperparathyroidism, renal osteodystrophy, widespread Paget's disease, diffuse metastasis.

Taken from Fundamentals of Orthopedics by Mohindra and Jain (2nd ed., Jaypee publishers)

Some important points about bone scan to remember:

- In stress fracture, MRI is the investigation of choice but in cases with B/L stress fracture bone scan becomes the IOC.
- Lesions with lytic activity do not show activity in bone scan, e.g. multiple myeloma.
- Bone scan cannot identify the source of unknown primary but it can pick up tumors with bone to bone metastasis, e.g. (pneumonic) ONE: Osteosarcoma, neuroblastoma, Ewing's sarcoma.

- Breathing
- Defibrillation

The BLS protocol continues until:

- The patient regains a pulse
- The rescuer is relieved with another rescuer of higher training (i.e. an ALS team member)
- The rescuer is too physically tired to continue CPR
- The patient is pronounced dead by a doctor.

ADVANCED LIFE SUPPORT (ALS) AND ADVANCED CARDIOVASCULAR LIFE SUPPORT (ACLS)

- The most important point to highlight in the advanced life support system is the use of cardiac monitors to analyse the patient's heart rhythm (Table 4.3).
- In contrast to an AED in BLS, where the machine decides when and how to shock a patient, the ACLS team leader makes those decisions based on rhythms on the monitor and patient's vital signs.
- The legitimate factor in the decision to terminate resuscitation is an $ETCO_2$ (End tidal CO_2 production) of less than 10 mm Hg, measured on waveform capnography, after at least 20 minutes of resuscitation.

Table 4.3: Drugs used in ALS protocol for CPR

Rhythm	*Drugs**
Shockable	Adrenaline 1 mg after 2nd shock and then every 2nd cycle Amiodarone 300 mg after 3rd shock
Non-shockable	Adrenaline 1 mg immediately and then every 2nd cycle

**Caution*: Routine atropine use is no longer recommended unless there is high risk for bradycardia

DAMAGE CONTROL ORTHOPEDICS (DCO)

Involves staging definitive management to avoid adding trauma to patient during vulnerable period. It is well known that intraoperative hypotension increases mortality rate in patients with head injury. So staging definitive management in such polytrauma patients would improve the outcome.

- Parameters that help decide who should be treated with DCO
  - Injury Severity Score* (ISS)>40 (without thoracic trauma)
  - ISS >20 with thoracic trauma
  - GCS of 8 or below
  - Multiple injuries with severe pelvic/abdominal trauma and hemorrhagic shock
  - Bilateral femoral fractures
  - Pulmonary contusion noted on radiographs
  - Hypothermia <35°C
  - Head injury with AIS of 3 or greater

Optimal Time of Surgery

The decision to operate and surgical timing on multiple injured trauma patients remains controversial. Patients are at increased risk of ARDS and multisystem failure during acute inflammatory window (period from 2 to 5 days characterized by a surge in inflammatory markers), therefore, only potentially life-threatening injuries should be treated in this period including:

- Compartment syndrome
- Fractures with vascular injuries
- Unreduced dislocations
- Long bone fractures
- Unstable spine fractures
- Open fractures

*Each injury is assigned an AIS (abbreviated injury score) and six body regions (head, face, chest, abdomen, extremities, including pelvis and external) are taken into consideration. Only the highest AIS score in each body region is used. The ISS score is the sum of squares of scores of three most severely injured regions. The score helps predict chances of survival.