Bone diseases

- Radiological signs of bone diseases need longer time to develop in adults than in children
- Normal X ray of the bone does not exclude the presence of a pathology, e.g. in osteomyelitis in children, scaphoid # in the first week

**Conventional radiological signs of bone diseases:**

1. decreased bone density:
   (a) Focal: lytic area or area of bone destruction.
   (b) General: osteopenia (either osteoporosis or osteomalacia).
2. Increase bone density: sclerosis (focal or generalized).
3. periosteal reaction:
   (a) definition: new bone formation by the periosteum
   (b) normal periosteum is not visible normally
   (c) types or periosteal reaction does not correlate with specific diagnosis e.g. Codman’s triangle seen in osteosarcoma may be seen in other aggressive lesions
   (d) causes:
      • trauma
      • infection
      • inflammation
      • metabolic: thyroid achropachy, hypertrophic osteoarthropathy, hypervitaminosis A
      • tumors
      • vascular: venous stasis
      • congenital: physiological in 35% of infants between 1-6 months, congenital syphilis, osteogenesis imperfecta

4. cortical thickening
   (a) Cortical thickening caused by lying down of new bone by the periosteum for long duration of time. It indicates slow process. The thickened cortex appears irregular & dense.
   (b) Causes: chronic osteomyelitis, stress #, healed trauma bone tumors as osteoid osteoma

5. Alteration of trabecular pattern
   (a) definition: reduction in the number of trabeculae with alteration in the remaining trabeculae
   (b) in osteoporosis, there is cortical thinning & trabeculae that remain become more prominent than usual
   (c) in Paget’s disease the trabeculae are thickened & extend into the compact cortex that normally devoid of trabeculae
6. Alteration in the shape of the bone: as in osteogenesis imperfecta, acromegaly & expanding bone tumors.

7. Alteration of bone age
   - best site of assessment of bone age is at the wrist, hands, in newborn the knee joint
   - in cretinism there is delayed appearance of the epiphyseal bone centers

**Radionuclide bone scan**
- $^{99m}$Tc Diphosphonate is bone seeking agent however it is also taken up by soft tissue calcifications, areas of tissue damage, soft tissue tumors
- Given I.V, excreted in urine
- Indications
  1. detection of metastases
  2. detection of osteomyelitis
  3. determine if the lesion is solitary or multiple
  4. investigation of painful hip prosthesis
  5. in case of negative or equivocal X-ray findings when there is high index of suspicion as in early osteomyelitis
- positive scan shown as increased uptake (hot areas): trauma, tumor, Paget`s disease, infection, infarction
- correlation with plain radiograph is frequently essential.

**CT scan**
- reserved for selected cases
  1. abnormality in complex bones as the spine, pelvis, face & skull
  2. determination of the local extent of bone tumor within & outside the bone when planning conservative surgery
  3. 3D CT is useful in planning corrective surgery for # & bone deformity
  4. As a guide for bone biopsy.
- bone window setting is required for optimum results

**MRI**
- indications:
  1. excellent in showing the intra & extra osseous extent of bone pathology
  2. investigation of disc herniation & spinal stenosis
  3. assessment of soft tissue masses
  4. assessment of cartilage, ligaments & meniscal injury
  5. diagnosis & assessment of avascular necrosis
- calcified structures produce signal void areas on MRI
SOLITARY BONE LESION

- **CAUSES**
  1. bone tumors (benign, malignant)
  2. tumor-like conditions (fibrous cortical defect, fibrous dysplasia, bone cyst)
  3. osteomyelitis
  4. conditions of uncertain origin (histiocytosis X, osteoid osteoma)

- the age of the patient is of utmost importance as some conditions tend to occur in specific age groups

- **assessment of radiological findings in bone lesion**

  1. **edge**:
     (a) well defined clear cut with narrow zone of transition indicates benign or slowly growing lesion
     (b) ill defined wide zone of transition indicates aggressive rapidly growing lesion as osteomyelitis & malignant tumors
     (c) metastases & myeloma lie in the middle of the spectrum (well defined lytic lesion with no sclerotic margin)

  2. **adjacent cortex**:
     (a) cortical destruction: aggressive lesions as in osteomyelitis & malignant tumors
     (b) cortical expansion with no destruction in benign conditions as fibrous dysplasia or enchondroma

  3. **periosteal reaction**: in the absence of trauma periosteal reaction indicates aggressive lesion
     (a) osteomyelitis
     (b) malignant tumors: osteosarcoma, Ewing’s sarcoma
     (c) metastasis (occasionally) particularly Neuroblastoma
     (d) histiocytosis

  4. **calcification**:
     (a) well defined, patchy popcorn indicates cartilaginous origin
     (b) ill defined spicules indicate osteoid forming tumors as in osteosarcoma

  5. **soft tissue swelling**:
     (a) ill defined swelling with blurring of the tissue fat planes due to edema seen in inflammation as osteomyelitis)
     (b) well defined swelling with displacement of clear cut fat planes seen in tumors

  6. **site**:
     (a) metaphyseal lesion as osteomyelitis
     (b) subarticular as giant cell tumor
     (c) appendicular skeleton as in primary bone tumor
     (d) axial skeleton as MM & metastases
MALGNANT BONE TUMORS

- secondary bone tumors (metastases) are the commonest malignant tumors affecting the bone
- osteosarcoma is the commonest primary malignant bone tumor in young adults
- conventional X ray is satisfactory modality for the initial diagnosis, CT & MRI are useful to show the extent within the bone marrow & soft tissue involvement
- general features on X ray are area of bone destruction or sclerosis with ill defined margins, wide zone of transition & periosteal reaction with or without cortical destruction & soft tissue swelling

OSTEOSARCOMA

- age: 5-20 yrs, elderly with Paget's disease
- site: metaphyseal around the knee joint
- findings:
  1. poorly defined destruction
  2. sun ray speculation (periosteal reaction)
  3. elevation of the periosteum at the margin producing the so-called Codman's triangle
  4. cortical destruction
  5. soft tissue swelling

CHONDROSARCOMA

- age:30-50 yrs
- site: pelvic bones, scapula, humerus, femora
- may arise as malignant degeneration in cartilage cap of osteochondroma (1%) & in its benign counterpart enchondroma when occurring only in the long bones (25% risk)
- findings:
  1. ill defined expanding lytic lesion
  2. flecks of calcification
  3. may have periosteal reaction
  4. large extra osseous component

FIBROSARCOMA & MALIGNANT FIBROUS HISTIOCYTOMA

- rare
- age: more than 40 yrs
- site: around the knee
- findings: ill defined destruction with periosteal reaction
- D.Dx: osteosarcoma, metastases, lymphoma
EwING`S SARCOMA
- Highly malignant with tendency to metastasize
- age: children
- site: shaft of long bone
- findings: ill defined destruction with onion peal periosteal reaction

GIANT CELL TUMOR
- slowly growing, locally invasive, rarely metastasize
- age: after closure of epiphysis (20-40 yrs)
- site: around knee & wrist joints
- findings: lytic, expansile lesion, subarticular in location, fairly well defined margin, thinning of the cortex (sometimes with destruction of cortex)

LYMPHOMA OF THE BONE
- rare
- usually associated with systemic involvement
- findings: sclerotic bone lesion (occasionally causes bone destruction)

BENIGN BONE TUMORS & TUMOR LIKE LESIONS

Features of benign tumors in X ray film
- Well demarcated
- Cortical expansion but no destruction unless pathological fracture occurred
- No periosteal reaction (unless pathological #)
- No soft tissue mass
- No or little increase in uptake on bone scan (unless pathological #)

ENCHONDROMA
- Site: small bones of the hands & feet, sometimes affect long bones (here it carries risk of malignant transformation)
- C/F: painless asymptomatic swelling
- Findings: lytic lesion with expansion & thinning of the cortex, no periosteal reaction unless pathological fracture develops
- 1% risk of malignant transformation in solitary type
- multiple enchondromatosis (Ollier` s disease) affect long bones & carry 10% risk of malignant transformation
FIBROUS CORTICAL DEFECT & NOF
- common chance findings in children
- site: affect diaphysis of long bone
- findings: well defined lucent areas in cortex

FIBROUS DYSPLASIA
- defect in the osteoblastic development & maturation as a result of mutation
- types: monostotic & polyostotic
- monostotic
  1. age: 10 – 30 yrs
  2. site: ribs, proximal femur, craniofacial bones
  3. usually asymptomatic
- polyostotic
  1. age: at first decade
  2. usually unilateral, asymptomatic
  3. site: femur, tibia, pelvis, cranial bones, spine, feet
  4. causes leg length discrepancy, shepherd crook deformity, facial asymmetry, rib deformity, tibial bowing
  5. may be associated with endocrine disorders: precocious puberty, hyperthyroidism, hyperparathyroidism, acromegaly, DM,
  6. findings: lytic, expansile, sclerotic margin

SOLITARY BONE CYST
- age: young adults & children
- site: long bones
- findings: well defined expanding lytic lesion

ANEURYSMAL BONE CYST
- benign but may be aggressive appearance, thought to form secondary to underlying primary bone tumor
- age: children & young adults
- site: spine, long bones, pelvis
- findings:
  1. purely lytic
  2. massive cortical expansion
  3. CT, MRI show blood pools within the cyst
  4. D.Dx: giant cell tumor

OSTEOID OSTEOMA
- Age: young adults
- Site: tibia, femur
- Findings: lucent area with specks of calcification known as the nidus surrounded by sclerotic rim with or without periosteal reaction
• Radionuclide bone scan used when normal or equivocal X ray findings: area of increased uptake.

**EOSINOPHILIC GRANULOMA**
- age: young adults
- site: skull, pelvis, ribs, femur
- findings:
  1. well or ill defined destruction, sometimes with sclerotic rim
  2. solitary or multiple
  3. sometimes with periosteal reaction
  4. extensive skull involvement causes geographical skull

**OSTEOMYELITIS (OM)**
- age: infants & young children
- site: metaphysis of long bones
- plain film is positive only after 10-14 days from the initiation of the symptoms
- Tc⁹⁹m bone scan shows increase uptake in the first few days
- In¹¹¹ labelled WBC shows increased uptake in OM & cellulitis
  1. increase uptake in the early blood pool phase seen in both conditions
  2. persistent increase in uptake in the delayed phase seen in OM only
- MRI sensitive in early OM in showing pus accumulation & bone edema
- US: useful in early OM to show sub periosteal collection
- X ray findings in acute OM
  1. early stage: negative
  2. area of bone destruction
  3. periosteal reaction may be so extensive to surround the bone forming involucrum
  4. part of the bone may separate to form sequestrum
  5. ill defined soft tissue swelling
- X ray findings in chronic OM (Brodie’s abscess)
  1. bone thickening & sclerosis
  2. loss of corticomedullary differentiation
  3. presence of sequestra & bone destruction
  4. presence of sinuses best seen on CT
  5. growth disparity, bone deformity
**TUBERCULOSIS OF BONE**

1. Tuberculous OM
   - Age: children less than 5 yrs
   - Spread from infected joint
   - Any bone affected
   - Findings: ill defined lytic lesion with varying degree of periosteal reaction
   - Complications: advanced epiphyseal maturity due to hyperemia, premature closure of epiphysis

2. Tuberculous spondylitis
   - More common in African or Asian pt., more common in AIDS pt.
   - Little symptoms in comparison with the degree of bone changes

3. Tuberculous arthritis

**Distinction between OM & malignant bone tumor**

1. clinical history
2. X ray is usually normal at the initial presentation of OM while its abnormal in bone tumors
3. chronic OM can simulate benign bone tumors

**BONE INFARCTION**

- causes:
  1. occlusion of the vessel: thrombosis as in thromboembolic disease & Polycythemia RV, by fat as in pancreatitis, by gas as in Caisson disease
  2. vessel wall disease: RA, SLE, arteriosclerosis
  3. external compression of the vessel by blood after trauma, by fat in patient with Cushing disease, by lipid filled histiocytes in Gaucher`s disease
- findings
  1. normal X ray initially
  2. area of rarefaction
  3. variable degree of periosteal reaction
  4. healing by irregular medullary calcification
Multiple Focal Bone Lesions

METASTASES

- seen in bone with active haemopoiesis (spine, skull, ribs, pelvis, humeri, femora)
- MRI is very sensitive in the detection of metastases in pt. with known primary tumor especially if there is suspicion of spinal cord compression, but it is expensive & need long duration. Lytic lesions appear hypo & hyper intense on T1 & T2 WI respectively. Sclerotic metastases appear hypointense on both T1 & T2 WI
- 30% of metastases seen in radionuclide bone scan are not visible on radiographs
- radionuclide scan is useful in detection of metastases. If find solitary or few lesions of increased uptake need to perform X ray to exclude benign tumor or fracture
- CT is not useful as skeletal survey as it is costly, time consuming & with increased dose of radiation
- Types of metastases:
  1. osteolytic: most common causes: Neuroblastoma (in children), breast (adult female), bronchus (adult male), thyroid, kidney, colon. The vertebral pedicles are often involved
  2. osteoblastic: prostate, breast, lymphoma, carcinoid, medulloblastoma, mucinous adenocarcinoma of GIT, TCC of bladder, pancreas, Neuroblastoma. These are frequent in the pelvis & spine & may be indistinguishable from Paget’s disease
  3. mixed: breast, prostate, lymphoma
  4. solitary expansile bubbly metastases with soft tissue involvement: thyroid, kidney
  5. bone metastases with sunburst periosteal reactions: prostate, retinoblastoma, Neuroblastoma, colon
  6. calcifying metastases: breast, osteosarcoma, testicular, thyroid, ovary, mucinous adenocarcinoma of GIT origin

MULTIPLE MYELOMA

- site: axial skeleton
- findings:
  1. well demarcated lytic lesion occasionally with expansion of the bone
  2. generalized form can resemble osteoporosis
  3. solitary type (plasmacytoma): represent early stage of MM, precede it by 1-20 yrs. Negative Ig G spike in the serum. It affect the thoracic, lumbar spine, pelvis, ribs, femora. Seen as expansile lytic ill defined lesion with soft tissue mass. Need to be differentiated from giant cell tumor, aneurysmal bone cysts, solitary metastasis from thyroid or kidney tumors
• bone scan shows area of increased uptake, sometimes no increase in uptake even when the lesion is grossly destructive on radiograph
• myeloma resemble metastases in every thing except that its more well defined, cause bone expansion & spares vertebral pedicle

**LEUKAEMIA OF THE BONE**
• involvement of the bone in children is not uncommon while it is rare in adults
• findings: metaphyseal lesion, ill defined permiative bone destruction

**MULTIPLE PERIOSTEAL REACTIONS**
• non accidental injury: the hallmark is the presence of multiple fractures at various stages of repair, separation of distal epiphysis & fragmentation & irregularity of the metaphysis
• wide spread bone infection as congenital syphilis
• venous stasis & ulceration of the legs: low grade periosteal reaction & cortical thickening seen
• hypertrophic pulmonary osteoarthropathy:
  1. causes: thoracic (CA bronchus, pleural fibroma, bronchiactasis, lung abscess), extra thoracic (ulcerative colitis, TB intestine, Crohn’s disease, cirrhosis bile duct tumors, CA pancreas, CML)
  2. findings: wide spread periosteal reaction around bones of the forearm & lower legs extending to involve the hands & feet bones when severe
• Scurvy:
  1. age: 6-9 months
  2. site: distal femur, proximal & distal tibia & fibula, proximal humerus, distal radius & ulna, sternal ends of ribs
  3. findings:
     • ground glass osteoporosis
     • cortical thinning
     • Wimberger line: dense line surrounding the epiphysis
     • Frankle line: white line at the ZPC

**Osteoporosis**
• Pathophysiology: reduction in the bone matrix that subsequently results in reduced calcium contents
• Causes:
  1. idiopathic: divided according to age of onset into juvenile, senile & post menopausal (most common). Fifty percent of women over 60 yrs have osteoporosis
  2. Cushing syndrome & steroid therapy
3. disuse: occur after immobilization for fracture treatment or local pain
4. Sudeck’s atrophy: disorder of the sympathetic nervous system where sever osteoporosis & soft tissue edema occur disproportionate to the trauma or the degree of disuse

- findings: the changes are best seen in the spine
  1. overall reduction in bone density with clear pencilled in cortex
  2. collapse of the vertebral bodies that represent compression fracture resulting in wedged vertebra with widening of the disc space
  3. long bones appear with thin cortex with resorption of many trabeculae but those that remain stands out clearly

- the diagnosis of osteoporosis need to be made after the exclusion of other possible causes of reduced bone density:
  1. metastatic carcinoma
  2. multiple myeloma
  3. hyperparathyroidism
  4. osteomalacia
- screening for osteoporosis to initiate hormonal therapy in at risk population. Bone mass assessed by quantitative CT or by dual energy X ray

**Rickets & Osteomalacia**
- Pathophysiology: poor mineralization of osteoid. If occur before epiphyseal closure it's Rickets, after that called osteomalacia
- causes:
  1. dietary deficiency of vit. D, lack of exposure to sun light
  2. malabsorption
  3. renal disorders
- findings in Rickets the findings are maximum at areas of bone growth so best seen at the knee, wrist & ankles:
  1. deficient Zone of Provisional Calcification & the metaphysis is wide, irregularly mineralized & cupped
  2. increased distance between the growing epiphysis & metaphysis
  3. generalized decrease in bone density
  4. deformity of bones due to softening
  5. greenstick fractures are common
- findings in osteomalacia:
  1. decrease bone density
  2. thin cortex & trabeculae
  3. loosier’s zones: these are thin short lucent lines with sclerotic margins running across the cortex at right angle, best seen in the scapula, medial aspect of the femoral neck & pubic rami
4. vertebral collapse resulting in biconcave vertebra with widened disc space
5. bowing of the femur
6. in severe cases the pelvic side walls bend inwards resulting in triradiate pelvis

**Hyperparathyroidism**
- tumors of the parathyroid glands cause primary hyperparathyroidism while patients with chronic renal failure will develop secondary hyperparathyroidism
- findings:
  1. subperiosteal bone resorption, this is the hallmark of the disease seen particularly in the hands at the radial aspect of the middle phalanges, tip of terminal phalanges & outer end of the clavicle
  2. decrease bone density with loss of corticomedullary differentiation. In advanced disease there is marked deformity
  3. vascular calcification (more common in the secondary type) soft tissue calcification, chondrocalcinosis
  4. Brown tumor: more common in the primary type seen as lytic expansile lesion in any bone particularly the mandible & pelvis

**Renal Osteodystrophy**
- occur in patients with chronic renal failure
- findings:
  1. features of osteomalacia in adults & rickets in children
  2. features of hyperparathyroidism
  3. sclerosis: this is infrequent finding seen as bands of increased density in the spine named as rugger jersey spine & across the metaphysis of long bones

**Generalized increase in bone density**
- sclerotic metastases
- osteopetrosis (Marble bone disease): congenital condition. The bone is brittle & easily fracture but heals normally
- myelosclerosis: replacement of the bone marrow by fibrous tissue & progress to lay down new bone. Splenomegaly is invariably present
ALTERATION IN THE TRABECULAR PATTERN

**Paget`s Disease**
- disease of elderly
- site: pelvis, spine, skull, long bones
- cardinal findings: cortical thickening, coarse trabeculation, increase bone density, bone softening & enlargement result in deformity
- skull involvement:
  1. well demarcated areas of sclerosis with thickening of calvarium giving the cotton wool appearance
  2. basilar invagination: results from bone softening. The odontoid peg impress on foramen magnum with compression of the brain stem
  3. osteoporosis circumscripta: rare form. There is well demarcated area of reduced bone density
- complications:
  1. bone deformity: bowing, shepherd crock deformity of the femoral neck
  2. basilar invagination with neural compression symptoms
  3. pathological fracture
  4. malignant transformation into osteosarcoma

**Haemolytic Anaemia**
- thalassemia & sickle cell anaemia (SCA) result in bone marrow hyperplasia. SCA in addition causes infection & infarction
- bone marrow hyperplasia:
  1. thinning of cortex
  2. increase thickness of bone with resorption of some trabeculae & increase thickness of the remaining
  3. increase diploic space thickness with vertical striation resulting in hair on end appearance
  4. enlargement of ribs, widening of the phalangeas
- infarction:
  1. infarction of the bone ends results in sclerosis & flattening of the femoral & humeral heads
  2. medullary infarction appear as lytic areas with or without periosteal reaction. Healing appears later as areas of irregular medullary calcification

**Sarcoidosis**
- the bones are occasionally affected & usually there is evidence of chest & skin disease at the time appearance of bone involvement
- phalangeas of the feet & hands are the only bones affected
- areas of decrease bone density with prominent trabeculae of lace like pattern. Well defined cysts within the bone may also develop
Radiation Induced Disease of the Bone
- common sites: ribs (following treatment of breast CA), pelvis (after treatment of cervical CA)
- early changes is reduced bone density
- later changes are thinning of the bone with patchy area of sclerosis & lysis
- complications: pathological fractures, development of bone neoplasm

Changes in Bone Shape

Achondroplasia
- defective ossifications of bones formed in cartilages
- shortening of the shaft of the long bones
- deformity of the pelvis (contracted pelvis)

Diaphyseal Aclasia
- multiple bony projections arising from the bone covered by cartilage cap that may calcify
- in the long bones they arise near the metaphysis & grow away from the nearby joint
- transformation into chondrosarcoma suspected when there is rapid increase in size, pain, ill defined edge, extensive calcification in the soft tissue

Acromegaly
- the bone changes are maximum at the hands, feet & face
- increase joint space due to overgrowth of cartilage
- enlargement of the tufts of the terminal phalangeas
- enlargement of the pituitary fossa
- widening of the skull vault
- enlargement of the sinuses & mastoid air cells
- prognathus joint with widening of angle between the body & ramus of the mandible