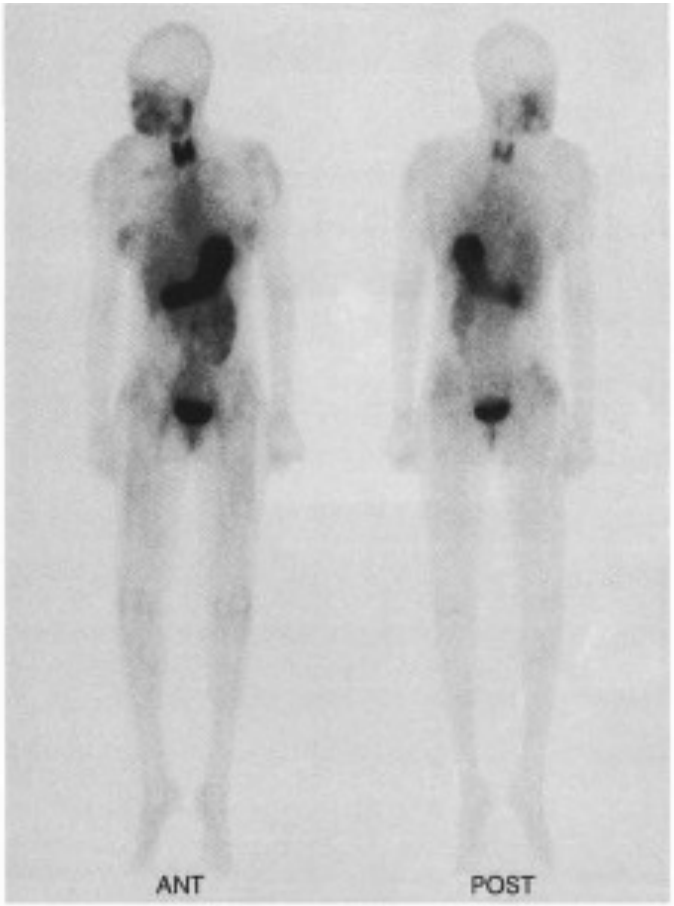
Tc-99m HMPAO and osteomyelitis

1. A negative bone scan rules out osteomyelitis with a high degree of certainty.
2. A bone marrow can improve the specificity of a leukocyte study if there is displaced normal marrow. This is most helpful in the hips and knees.
3. In-111 leukocytes can make same diagnosis. The superior imaging resolution of Tc-99m HMPAO often better differentiates soft tissue and bone infection. Ga-67 is less specific because increased uptake occurs with bone remodeling from any cause.
4. Patient A: soft tissue uptake. No bone uptake rules out osteomyelitis, consistent cellulitis. Patient B: soft tissue and bone localization consistent with osteomyelitis.

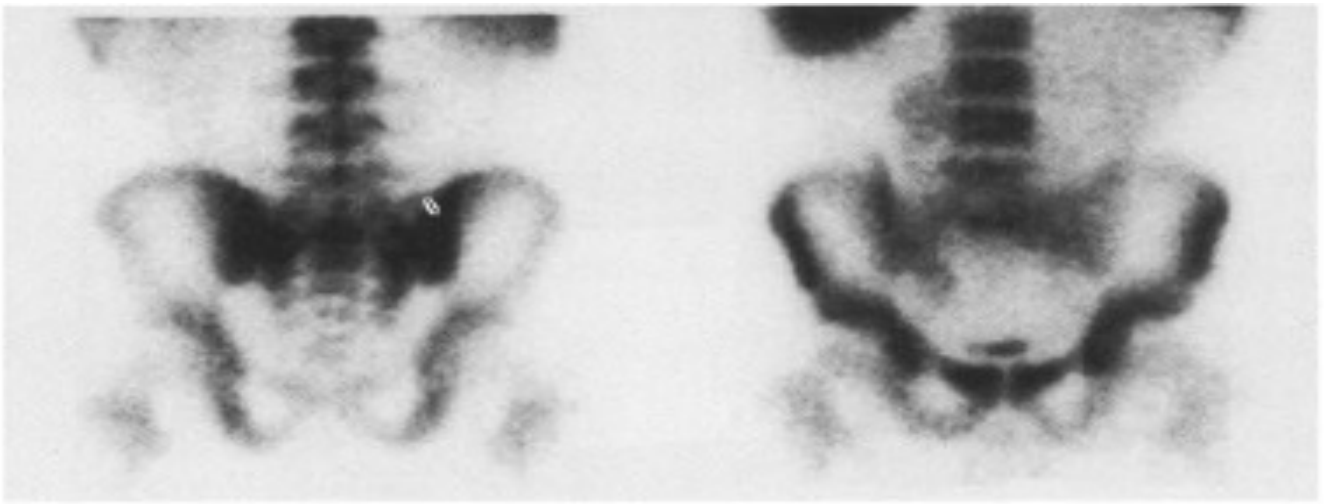


A 49-year-old man was referred for ^{99m}Tc HM-PAO leukocyte study to locate the source of *Staphylococcus aureus* sepsis.

1. What are the scintigraphic findings?
2. What is your interpretation of the study?
3. What are the most common causes for false-positive radiolabeled leukocyte studies?
4. What is the optimal imaging period for ^{67}Ga, ^{111}In oxine leukocytes, ^{99m}Tc HM-PAO leukocytes for infection imaging?

Tc-99m HMPAO leukocytes free Tc-99m pertechnetate

1. Activity in the salivary glands, thyroid, stomach, bowel and bladder.
2. Free Tc-99m pertechnetate.
3. Gastrointestinal bleeding, swallowed leukocytes from oropharyngeal, esophageal or lung inflammation/ infection, accessory spleen, uninfected postoperative surgical wounds, intestinal stomas.
4. Ga-67 = 48 hours, In-111 oxine leukocytes = 24 hours, Tc-99m HMPAO = 1 to 4 hours.

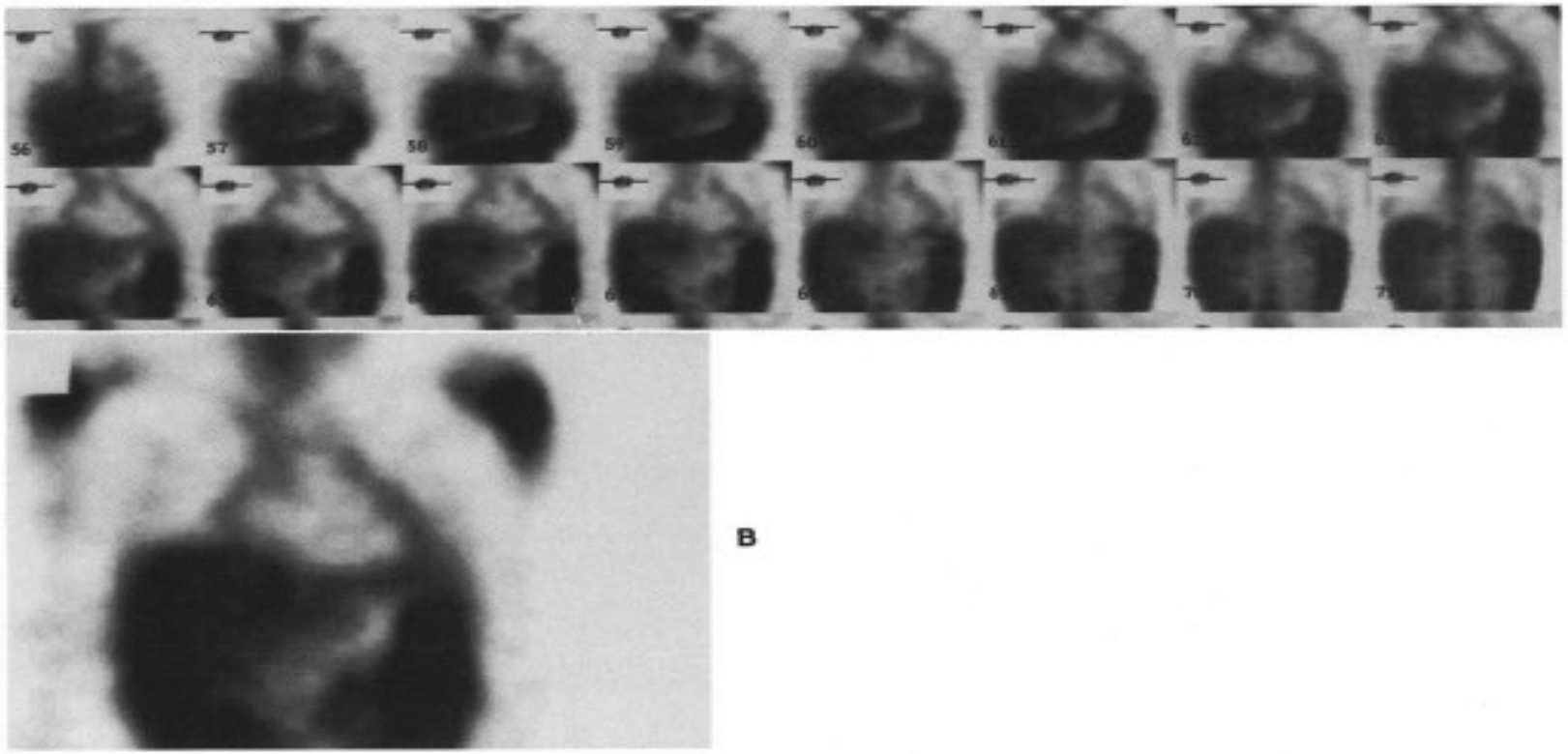


A 25-year-old man has fever and abdominal pain. ^{99m}Tc HM-PAO–labeled leukocyte images.

1. Which leukocytes are labeled with the two radiopharmaceuticals used for leukocyte scans?
2. What is the explanation for the prominent skeletal uptake?
3. What is the optimal imaging time for ^{111}In oxine–labeled leukocytes and ^{99m}Tc HM-PAO leukocytes?
4. Give an image interpretation and diagnosis in this case.

Intraabdominal abscess

1. Tc-99m HMPAO binds only to neutrophils. In-111 oxine binds to mixed leukocytes.
2. Normal bone marrow distribution of the radiolabeled leukocytes.
3. Abdominal imaging: Tc-99m HMPAO images are acquired at 1 to 2 hours because hepatobiliary, intestinal and renal clearance occurs subsequently, complicating interpretation. Extremity imaging: 2 to 6 hours. In-111 leukocytes: 24 hours. Four hour imaging for inflammatory bowel disease because sloughing of intestinal mucosa leukocytes may occur and 24 hour may be misleading.
4. Infection in the right lower quadrant overlying the sacroiliac joint in the anterior view and lateral right of the spine. The patient had a perforated appendix.



A

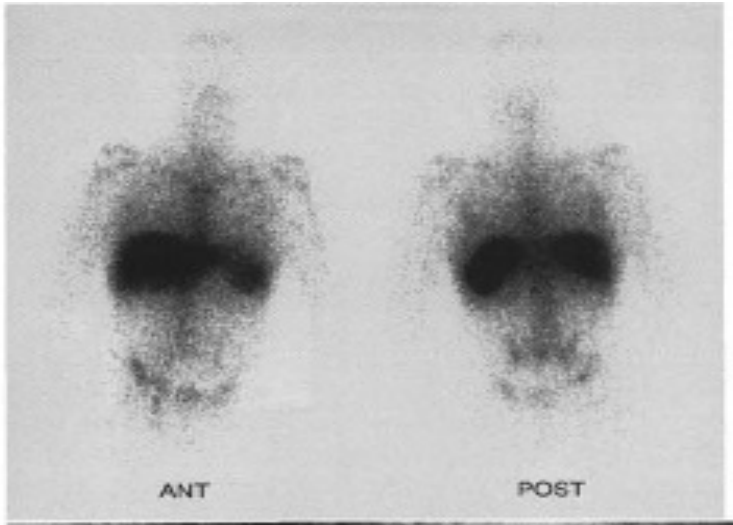
B

An 8-year-old girl with juvenile rheumatoid arthritis and persistent fever after resolution of recent pneumonia. She has no current symptoms of arthritis.

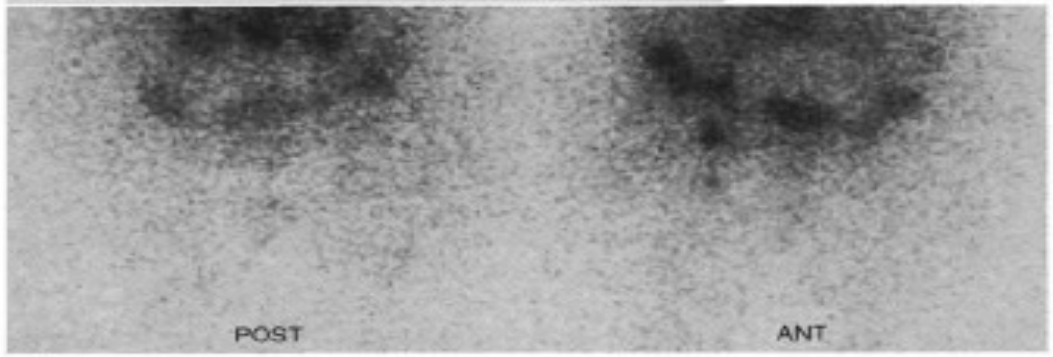
1. Describe the findings on ^{67}Ga sequential coronal SPECT chest images *(A)* and a selected enlarged image *(B)*. Image intensity is high. What is the differential diagnosis?
2. What is the advantage of ^{67}Ga over indium- or technetium-labeled leukocytes for fever of unknown origin?
3. What is the target organ (highest radiation absorbed dose) for ^{67}Ga?
4. Which pulmonary infections or inflammatory diseases show increased ^{67}Ga uptake?

Pericarditis – Ga-67

1. Abnormal uptake in myocardium, pericardium or both consistent with pericarditis or myocarditis. The patient developed a pericardial fraction rub the day after the Ga-67 scan. Incidental note of normal liver uptake and transverse and left colon clearance.
2. Ga-67 shows uptake not only with inflammation and infection, but also in tumors that can sometimes be the cause of persistent fever e.g.. lymphoma.
3. Large bowel = 4.5 rads.
4. Most pulmonary inflammatory and infectious diseases. Uptake is nonspecific, although the pattern of uptake and the clinical setting, e.g. AIDS may be helpful in determine the differential diagnosis.



A



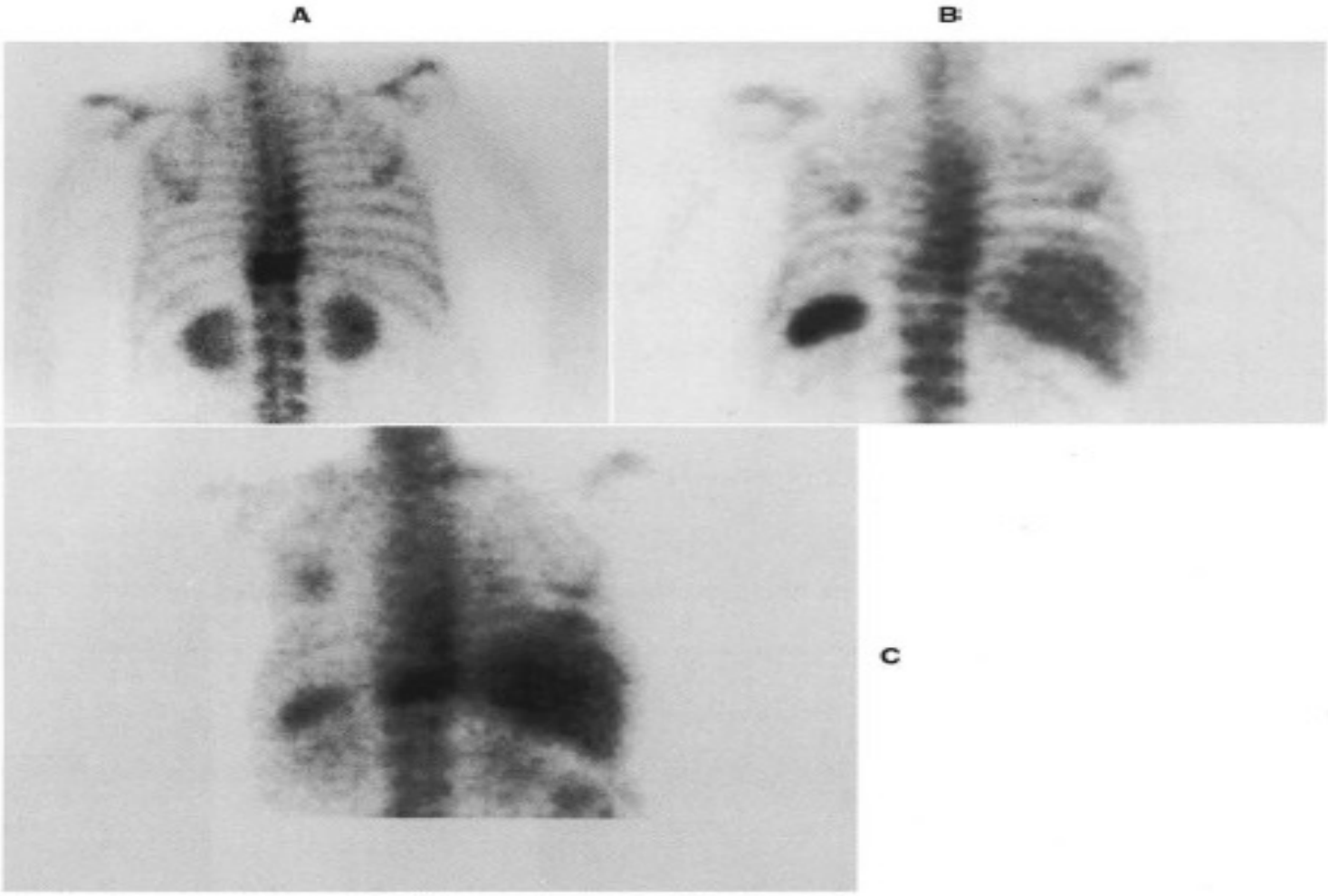
B

A 56-year-old paraplegic patient has fever of uncertain origin. No localizing signs or symptoms are present.

1. Which radiopharmaceutical was used? What others could be used for this purpose?
2. Which organ receives the highest radiation absorbed dose? Estimate the dose.
3. What is your interpretation of this whole-body scan *(A)* and pelvic spot *(B)?*
4. What is the photopeak(s) of the radionuclide used? What is its half-life?

Right ileum osteomyelitis

1. In-111 oxine or Tc-99m HMPAO leukocytes, Ga-67 could also be used. The intense spleen uptake is consistent with a radiolabeled leukocyte study. In-111 oxine leukocytes were used. The image resolution is poor compared with Tc-99m leukocytes.
2. Spleen, 15 – 20 rads.
3. Abnormal focal uptake in right groin and right ileum, indicating osteomyelitis.
4. 173, 247 keV. Physical half life is 77 hours.

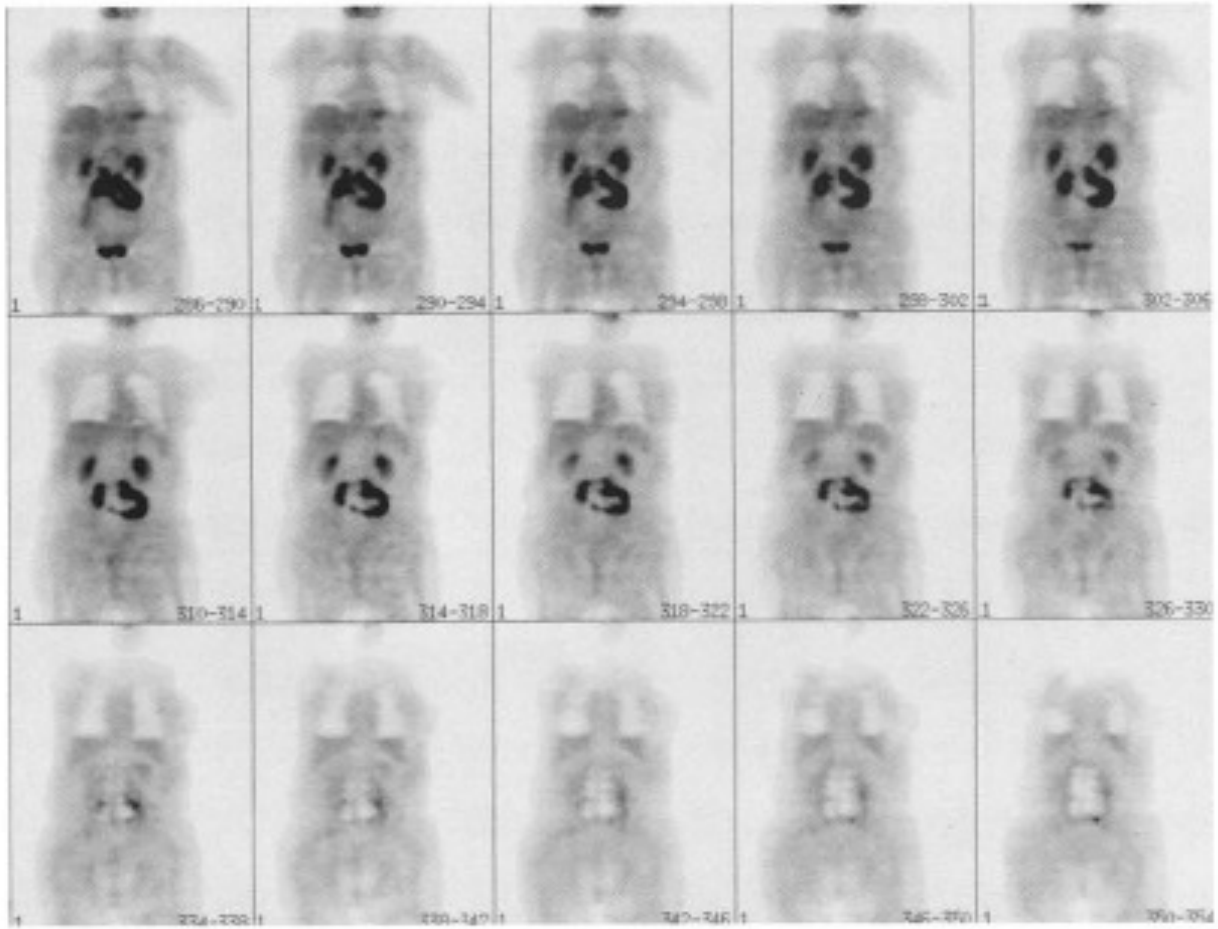


A 67-year-old patient has low-grade fever, back pain, and suspected osteomyelitis of the lumbar spine. *A*, ^{99m}Tc MDP bone scan; *B*, ^{111}In oxine leukocyte study; and *C*, Ga-67 study. Negative radiograph.

1. Describe the scintigraphic findings of these three studies.
2. What is the differential diagnosis of the ^{111}In study alone?
3. What is your interpretation of the three studies?
4. What is the false-negative rate for ^{111}In oxine leukocyte studies for vertebral osteomyelitis?

Osteomyelitis of spine

1. Bone scan shows increased uptake of the T11 vertebrae. In-111 oxine leukocyte shows decreased uptake in the same region. Ga-67 shows increased uptake that matches the bone scan in relative intensity.
2. Osteomyelitis fracture, infarction, metastasis, orthopedic hardware, surgical defect, Paget's disease, radiation therapy.
3. Osteomyelitis in this clinical setting. Many of the diseases listed can be excluded by history and radiographs.
4. As high as 40%.

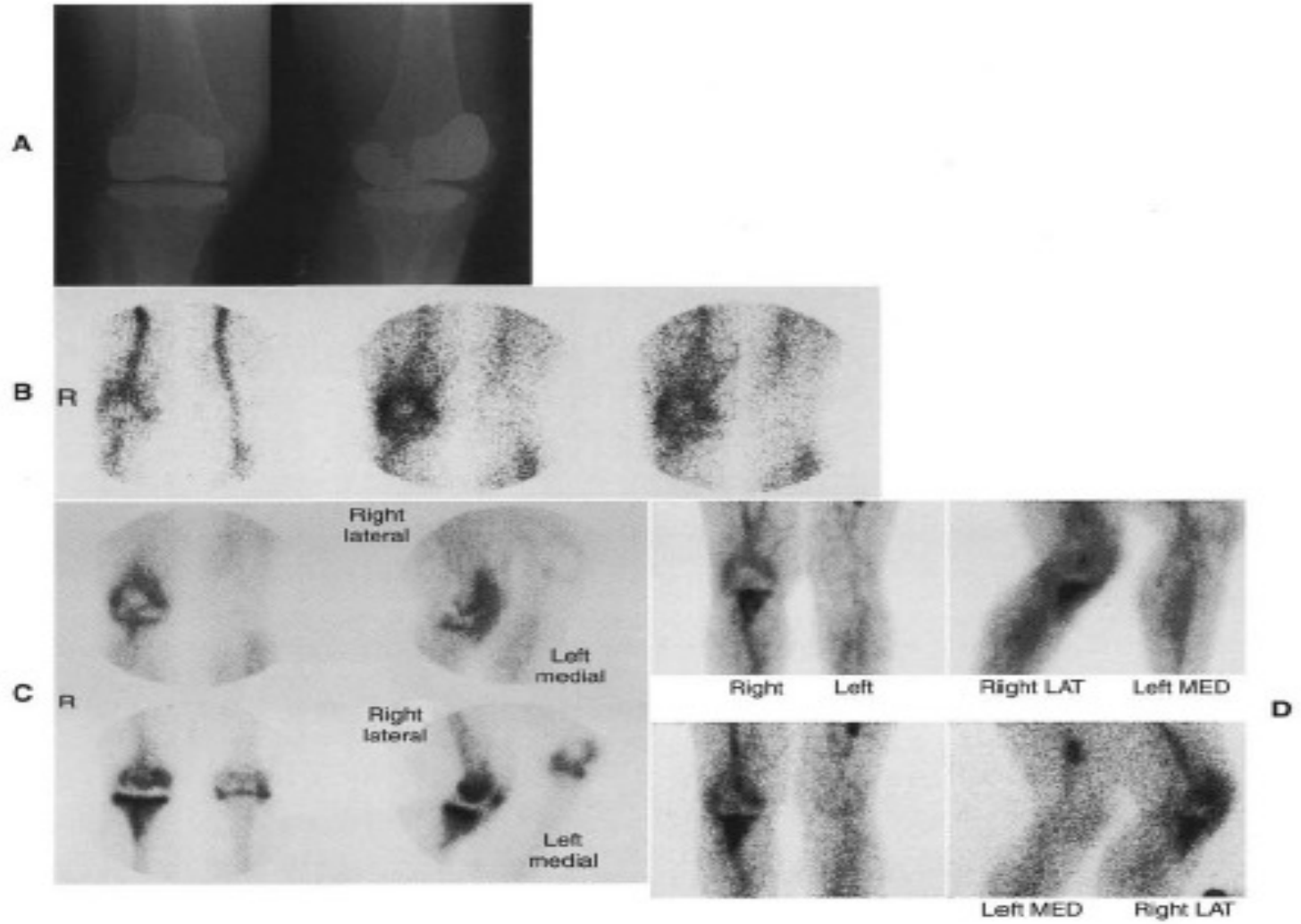


A 64-year-old woman has non-Hodgkin's lymphoma. Tumor involvement of lumbar vertebral bodies required resection and fusion. Pain and low-grade fever were noted 12 weeks after surgery.

1. Describe the FDG-PET findings.
2. Give your interpretation.
3. Can infection have increased FDG uptake? Why?
4. What is the energy photopeak of ^{18}F? What is the photopeak of ^{11}C, ^{13}N, ^{15}O?

FDG PET paraspinal infection

1. Intense uptake involving the retroperitoneum anterior to the recent lumbar fusion surgery.
2. Consistent with postoperative infection.
3. Yes. Leukocytes and macrophages utilize glucose.
4. All positron emitters have 511 keV photopeak. F-18, C-11, N-13 , O15.



Rule out infected right knee prosthesis. Radiograph *(A)*.

1. Describe the three-phase bone scan findings. *B*, Flow; *C*, immediate *(above)* blood pool and delayed *(below)* images.
2. Describe the ^{99m}Tc HM-PAO leukocyte study *(D, above)* and ^{99m}Tc sulfur colloid study *(D, below)*.
3. What is the purpose of the ^{99m}Tc sulfur colloid study?
4. Interpret the study.

Knee athroplasty TRO infection

1. Increased blood flow in the right knee.
2. Increased uptake in the proximal tibia on both.
3. Serves as a template for normal marrow distribution.
4. Negative for infected prosthesis.

Skeletal imaging

Pearls & Pitfalls

Skeletal imaging

- Common indications for bone scans include evaluation of primary osseous or metastatic neoplasm, avascular necrosis, trauma, infection and less commonly, arthritis or RSD.
- When bone scans are performed with Tc-99m diphosphonate agents, normal skeletal activity should be reasonably symmetric left and right sites.

Pearls & Pitfalls

Skeletal imaging

- Look at the kidney activity for potential abnormalities. A large amount of activity of diffuse soft tissue activity remaining at 4 hours is frequently due to renal insufficiency.
- Activity in the lower cervical region is frequently due to benign causes such as degenerative changes.

Pearls & Pitfalls

Skeletal imaging

- A lesion that is hot all three phases of a bone scan can be osteomyelitis bit also may be an acute fracture, hypervascular tumor, neuropathic joint or RSD.
- A flare phenomenon is most likely seen within 1 to 3 months therapy completion.

Pearls & Pitfalls

Skeletal imaging

- Paget's disease is commonly seen as intense activity in the skull, femur, vertebral body or half of the pelvis. It is usually polyostotic but may be monostotic and may cause bowing of a femur.
- Good visualization of the bones and not the kidneys may indicate a superscan due to diffuse metastases or hyperparathyroidism.

Pearls & Pitfalls

Skeletal imaging

- Focal hot lesions in multiple adjacent ribs are essentially always due to fracture.
- Long lesions running along the length of a rib are not usually fractures.
- Multiple sequential cold vertebral bodies are almost due to radiation therapy.
- Tumors that commonly cause cold (photopenic) metastatic lesions including kidney, lung, thyroid and breast tumors.

Pearls & Pitfalls

Skeletal imaging

- Stress fractures usually occur in the pelvis and below the knees, they can be seen as focal or fusiform primary cortical activity.
- Bilaterally increased activity along the cortex of the tibias may be due to shin splints, hypertrophic osteoarthropathy or periosteal reaction.

Pearls & Pitfalls

Skeletal imaging

- A loose hip prosthesis is suggested by activity at the tip and near the lesser trochanter.
- An infected prosthesis usually has activity all along the length of the shaft.
- Postoperative activity around a cemented prosthesis can normally persist for 6 months to 1 year and activity around a noncemented prosthesis can normally persist for 2 to 3 years.

Pearls & Pitfalls

Skeletal imaging

- Diffuse liver activity on a bone scan is probably due to hepatic necrosis or radiopharmaceutical problem.
- Focal liver activity is often due to metastasis from colon, breast, ovary or lung.
- Diffused splenic activity due to splenic infarction.
- Diffused renal parenchymal activity is probably due to chemotherapy.

Pearls & Pitfalls

Skeletal imaging

- Increased activity in two adjacent vertebral bodies in the absence of compression fractures suggests diskitis especially in a child.
- Osteomyelitis, acute fractures, vascular tumors such as Ewing's sarcoma and RSD are hot on angiographic, blood pool and delayed bone scan images.

Pearls & Pitfalls

Skeletal imaging

- Cellulitis is hot on the 1st two phases but fades on delayed images.
- Shin splints have normal angiographic and blood pool images but are hot on delayed views in the posteromedial aspect of the tibias.
- Osteomyelitis usually does not cross joints.
- Increased activity seen on both sides of a joint is more likely due to septic arthritis.

Bone structure

- Gross level
- Tissue level
- Cellular level
- Molecular level

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Bone structure

- **Gross level**
- Tissue level
- Cellular level
- Molecular level

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Gross level

Consist two major parts:

-Axial skeleton (right)

-Appendicular skeleton(left)

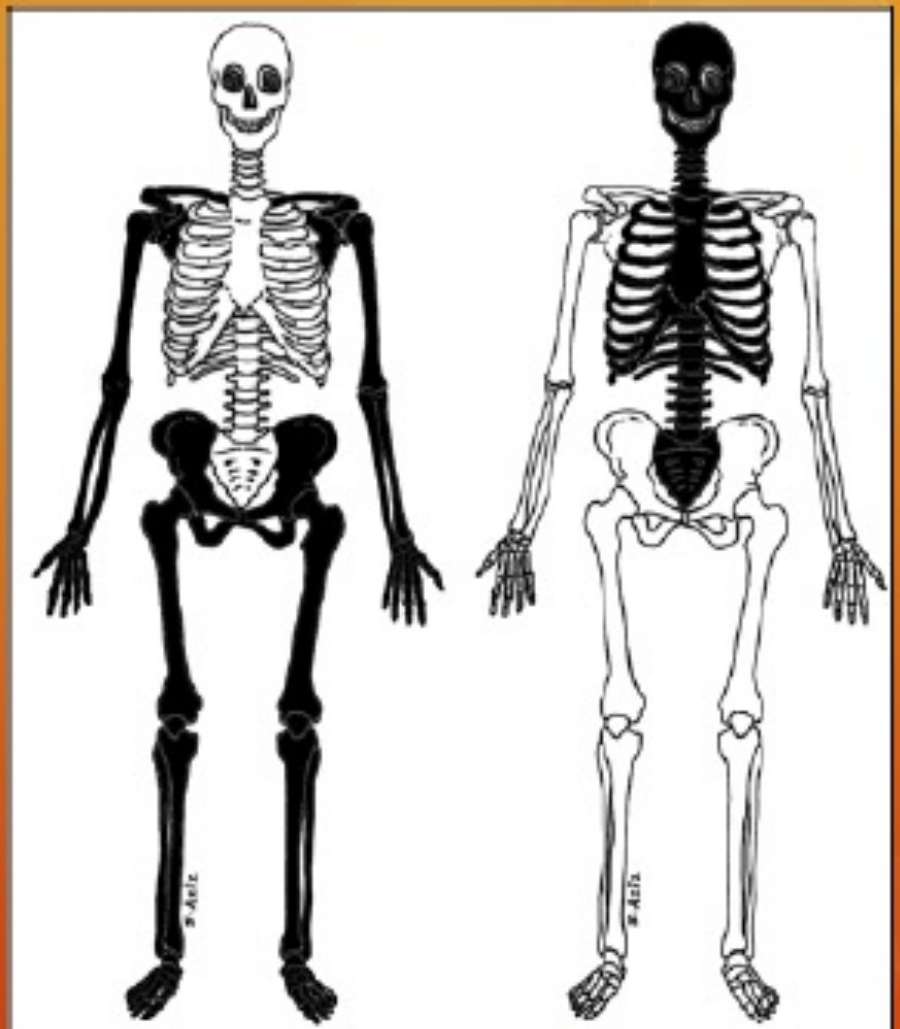

Fig. 6.1. Axial (*right*) and appendicular (*left*) skeletons

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Bone structure

- Gross level
- **Tissue level**
- Cellular level
- Molecular level

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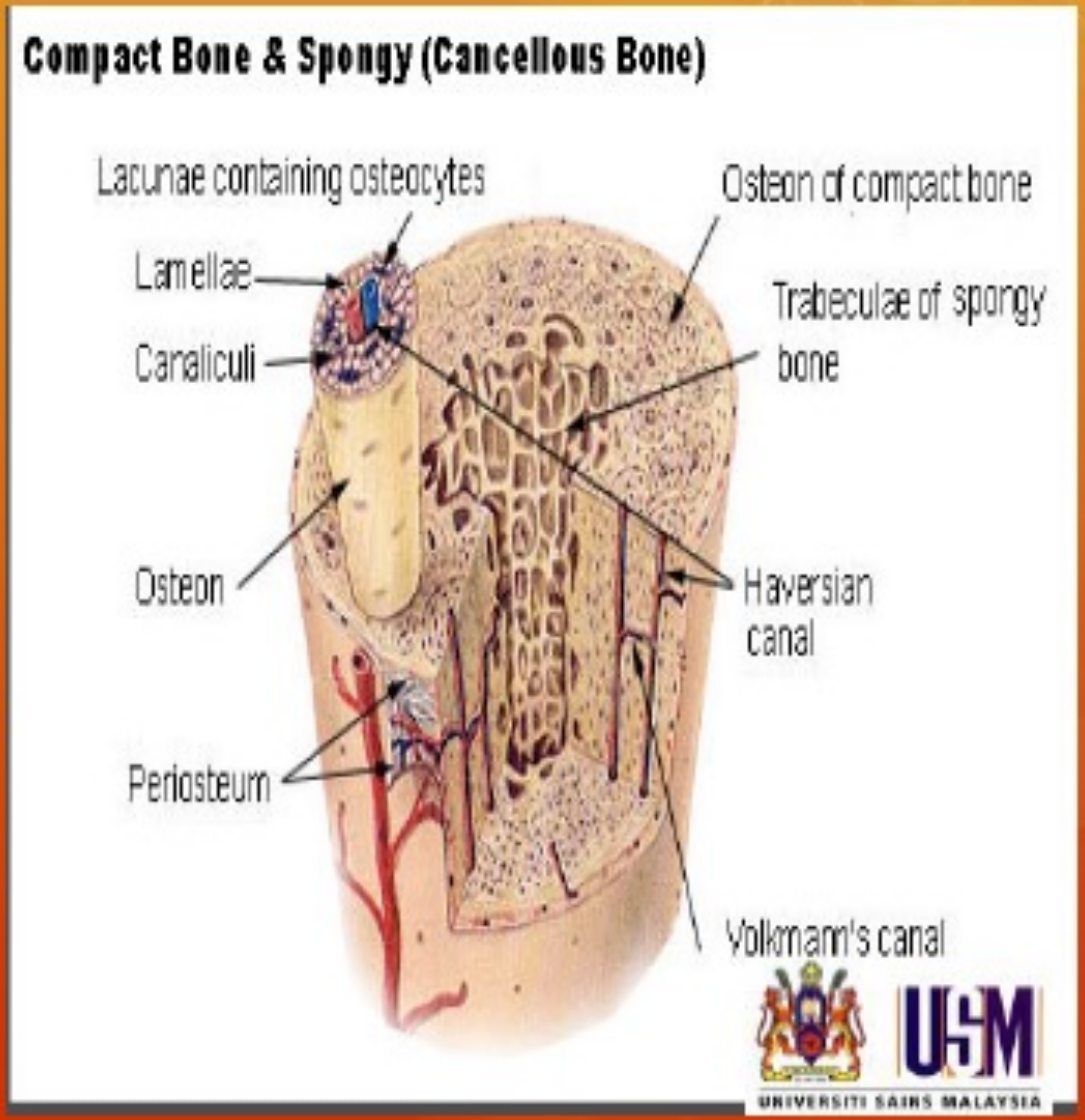
Tissue level

Two types of tissue:

- Compact or cortical
- Cancellous/trabecular/spongy bone



Bone structure

- Gross level
- Tissue level
- **Cellular level**
- Molecular level

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Cellular level

Major structural elements	Function
Bone cells	
Osteoblasts	Synthesize collagen and proteoglycans, stimulate osteoclast resorptive activity
Osteocytes	Maintain bone matrix
Osteoclasts	Resorb bone, assist with mineral homeostasis

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- **Osteolysis/ Bone destruction** = osteolytic activity > osteoblastic activity

- **Osteosclerosis/ Increased bone density** = osteoblastic activity > osteoclastic activity

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Bone structure

- Gross level
- Tissue level
- Cellular level
- **Molecular level**

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Molecular level

Bone matrix	
Organic matrix:	
Collagen fibers	Provide support and tensile strength
Proteoglycans	Control transport of ionized materials through matrix
Sialoprotein	Promotes calcification
Osteocalcin	Inhibits calcium/phosphate precipitation, promotes bone resorption
Laminin	Stabilizes basement membranes in bone
Osteonectin	Binds calcium to bones
Albumin	Transports essential elements to matrix
Inorganic matrix:	
Calcium	Crystallizes to provide rigidity and compressive strength
Phosphate	Regulates vitamin D and thereby promotes mineralization

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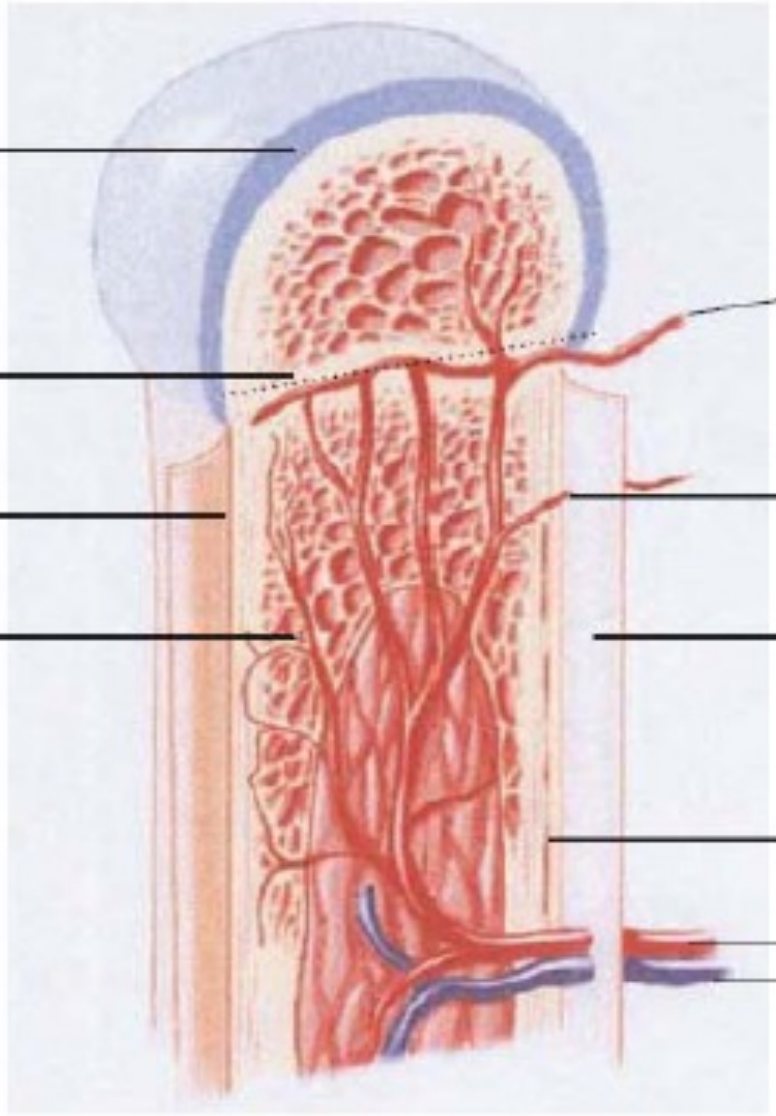
Blood supply



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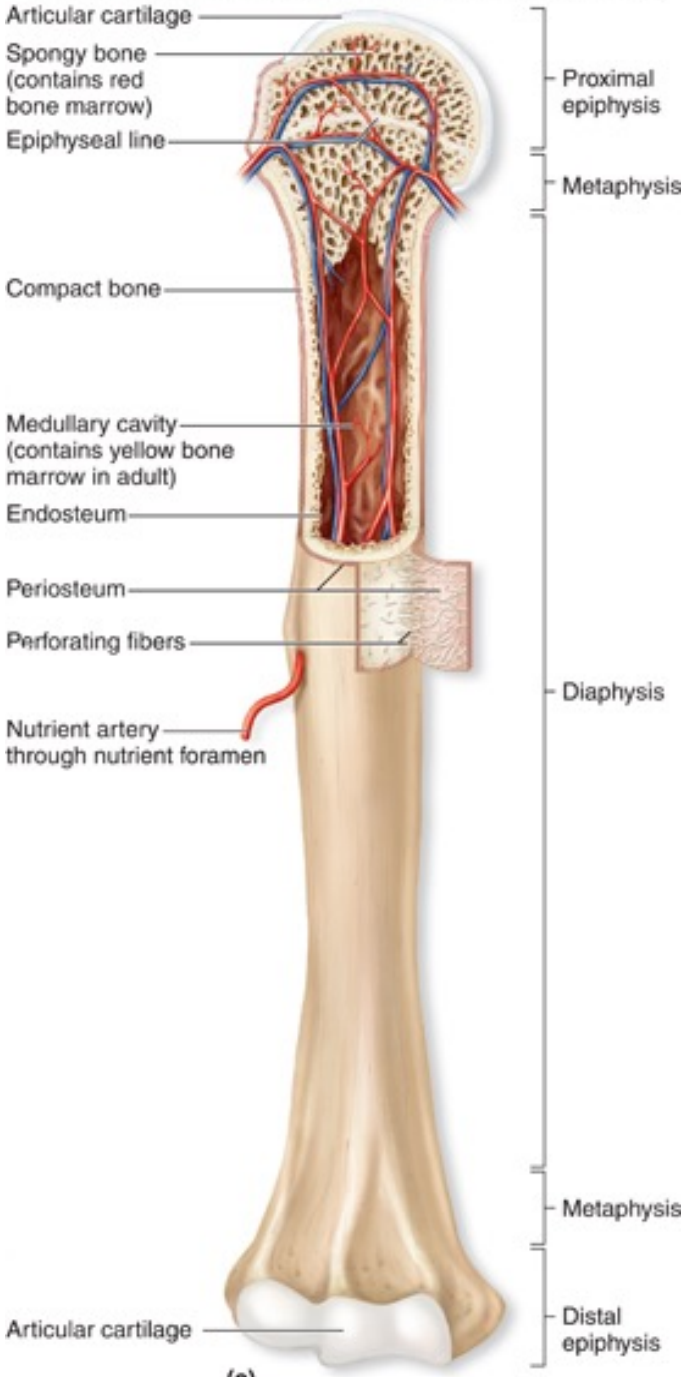

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Bone scintigraphy

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Common Indications of Bone Scan

- Bone Tumours
  - Benign bone tumours
  - Malignant bone tumours
  - Bone metastases
- Infection & Inflammation
  - Acute Osteomyelitis vs. Soft tissue inflammation
  - Subacute & Chronic Osteomyelitis
  - Septic arthritis
  - Aseptic arthritis
- Traumatic Bone disease
  - Equivocal X-Ray finding after trauma
  - Stress fracture
  - Child abuse
  - Polytrauma
  - Complications of fracture & Therapy
- Sudeck's Atrophy
  - Reflex sympathetic dystrophy syndrome
- Bone scan guided surgery
  - e.g. Osteoid Osteoma
- Bone Dysplasias
  - Fibrous dysplasia
- Bone prosthesis evaluation
  - Infection
  - Loosening
- Inflammatory joint disease
  - Rheumatoid arthritis
- Aseptic necrosis
  - Legg-Calve-Perthes disease
  - Aseptic necrosis other than Perthes
  - Avascular necosis of bones (e.g., Femoral head AVN)
  - Sickle cell disease

Bone pain for bone scan

Metastatic tumors

Benign bone tumor : osteoid osteoma

Trauma

Avascular necrosis

Infection

Osteomalacia

Paget's

Contraindications

Pregnancy and lactating mother

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Radioisotopes

Isotope	Half life	Energy	Radiation types
Technetium 99m	6 hr	140 KeV	gamma
Florine 18	110 min	511 KeV	Positron, gamma

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Radiopharmaceutical

MDP, HDP, HMDP

Average activity is 300 – 1110 MBq (8-30 mCi)

Calculated dosage for children using graysdale scale

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Tc-99m pertechnitate preparation, there are 3 form of technetium	Reduced hydrolyzed technetium
	Free pertechnetate
	Chelated technetium

Liver uptake in bone scan	Reduced hydrolyzed technetium
	Excess amount of aluminum in Tc-99m MDP preparation
	Excess amount of stannous ion in Tc-99m MDP preparation

Excess amount of aluminum in Tc-99m SC preparation	Lungs uptake
Tc-99m pertechnetate	Thyroid
	Gastric mucosa

dosage

Type of patients	dosage
Adult	740 – 1110 MBq (20-30 mCi)
Obese	11 – 13 MBq/kg (300 – 350 uCi/kg)
Pediatrics	Minimum dose 1.0 mCi (37 MBq) – static 2.0 mCi (74 MBq) – 3 phase Max dose 20 mCi (740 MBq) 0.06 mCi (2.2 MBq)/kg

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Patient preparation

Good hydration

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Waiting time and duration of scan

Waiting time post injection:

Immediate

2 – 3 hours

Scanning time:

40 minutes

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Normal hot area

- Sacroiliac joints
- Hip joints
- Glenoid fossa
- Acrromiaclavicular joints
- Ends of long bones
- Growing epiphyses
- Kidney
- Soft tissue necrosis
- Soft tissue calcification
- Fractures and orthopaedic surgery

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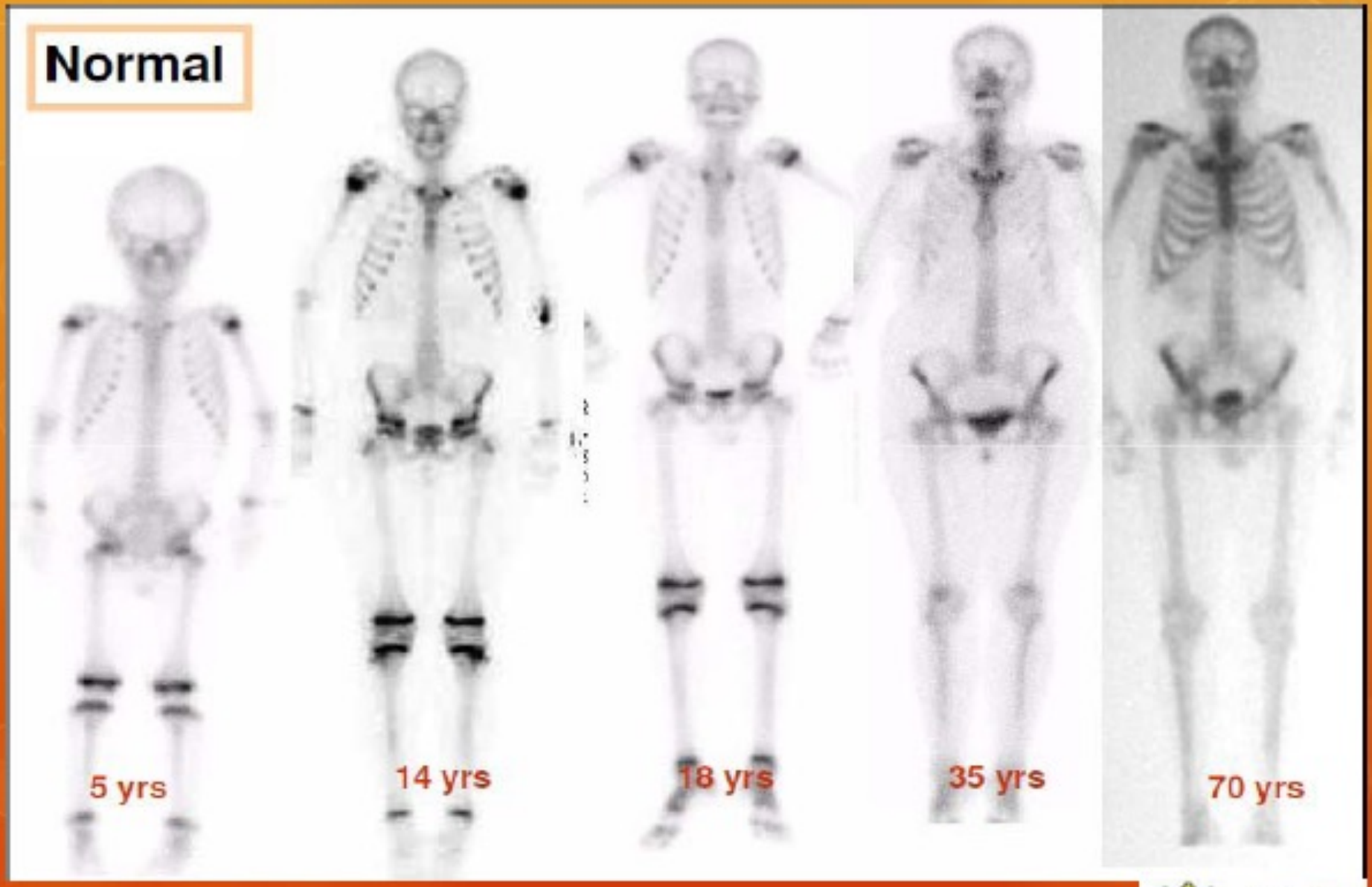

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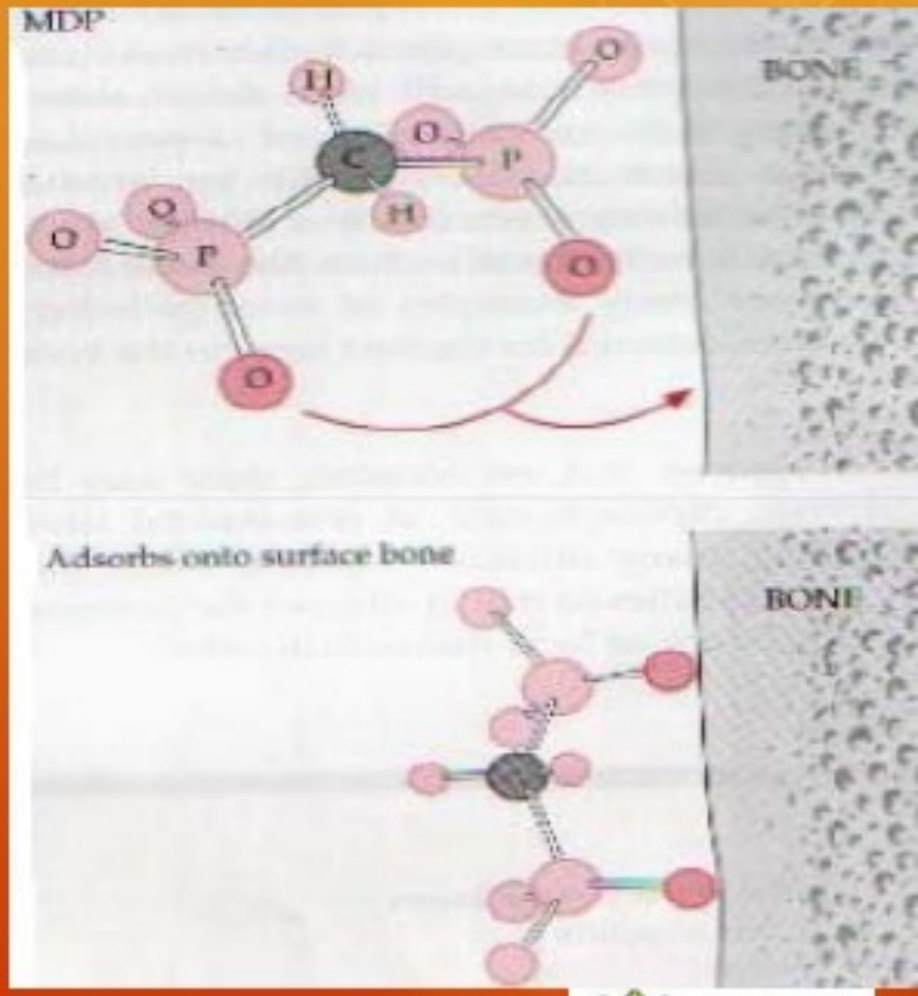
Mechanism of Tc-99m MDP

- Chemical bonding at the sites on surface of hydroxyapitate crystal
- Tc-99m is released – hydrolyzed – bind to bone



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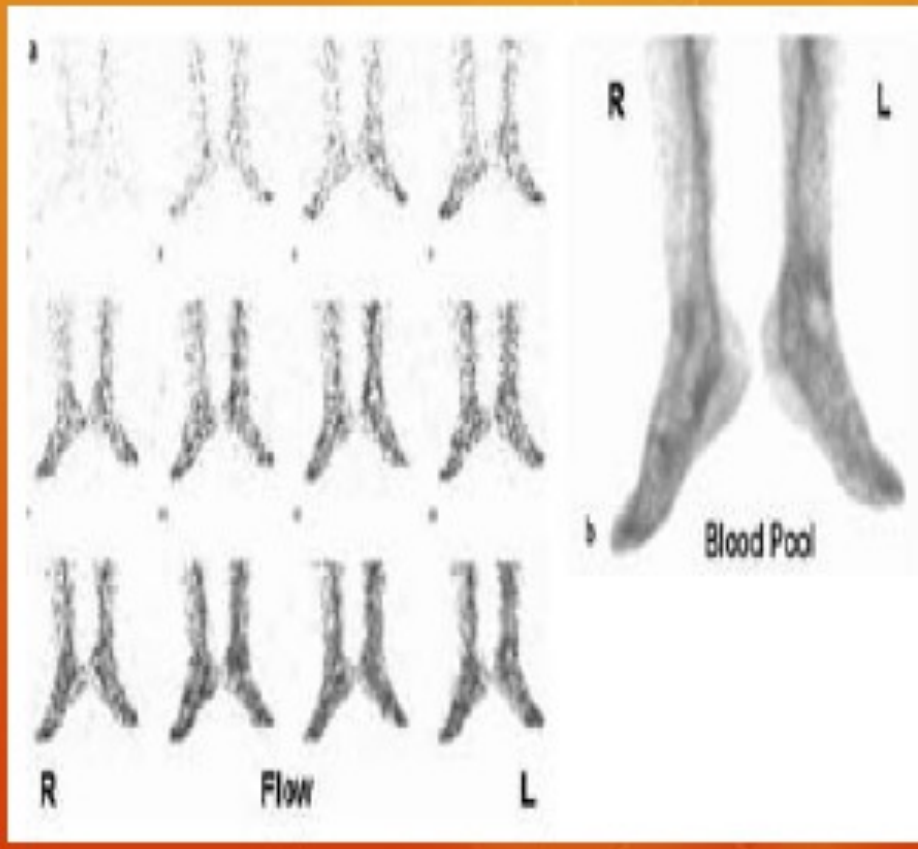
Mechanism of Tc-99m MDP

EARLY PERFUSION AND BLOOD POOL:

- Intravenous injection
- Diffusion out from the vascular compartment into extra cellular fluid compartment
- Involves 78% of injected dose
- Biological half life is 2.5 minutes
- Tc-99m MDP concentration in normal tissue related to blood flow and vascularity



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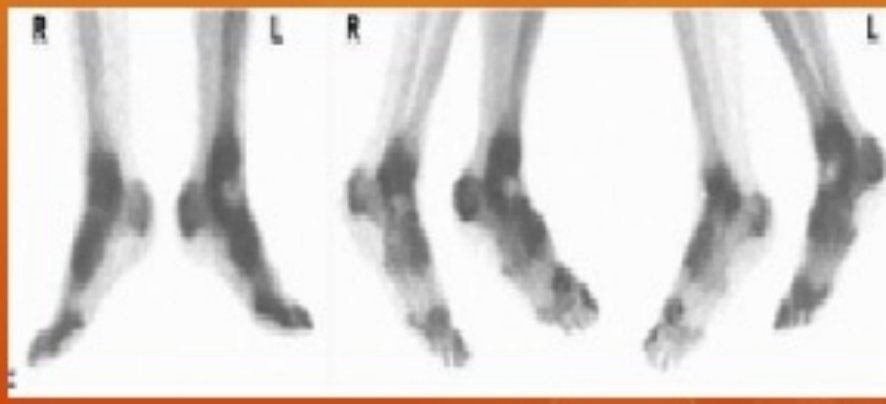
Mechanism of Tc-99m MDP

DELAYED BONE UPTAKE:

- By 3 – 4 hours, nearly 60% of injected activity gets fixed to the bones
- Remainder excreted in the urine
- The 3 – 4 hours uptake in the normal tissues is proportional to their calcium content



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Metastatic bone disease

Bone tumors

Benign	Malignant
Osteoid osteoma	Osteosarcoma
Giant cell tumor	Ewing’s sarcoma
Fibrous dysplasia	Chondrosarcoma

Effects of treatment:"FLARE"

- Flare on bone scintigraphy may be seen shortly after commencing chemotherapy treatment
- (Flare = increased number of lesions and intensity of tracer uptake as compared with baseline bone scan due to bone remodeling after successful healing of bone metastasis.)

  >
- bone scans done within the first 3months must be interpreted with caution and correlated with clinical and radiological findings to avoid inappropriate discontinuation

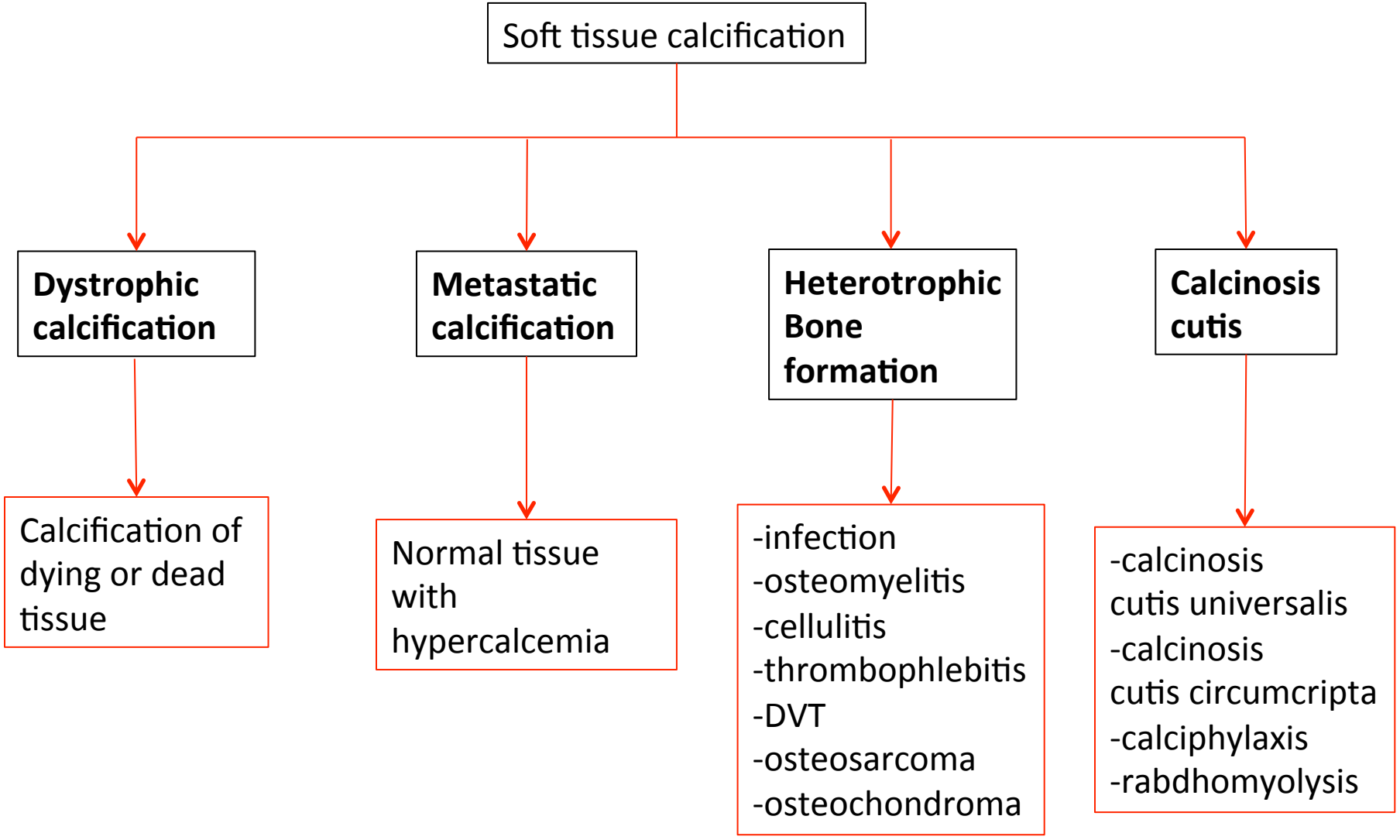
Bilateral increased uptake of renal in bone scan	Urinary tract obstruction
	Acute tubular necrosis
	Chemotherapy
	Radiation nephritis
	Thalassemia
	Hypercalcemia
	Nephrocalcinosis
	Nephrotoxic antibiotic

Bilateral decreased uptake of renal in bone scan "superscan"	Tumors	Non tumor
	Prostate	Renal failure
	Lungs carcinoma	Nephrectomy
	Breast carcinoma	Hyperparathyroidism
	Bladder carcinoma	Osteomalacia
	Lymphoma	Fibrous dysplasia
		Paget's disease
		Renal osteodystrophy

Tumors that metastasize to bone	Breast carcinoma
	Lungs carcinoma
	Prostate carcinoma
	Lymphoma
	Thyroid carcinoma
	Renal carcinoma
	Neuroblastoma

Tumors falsely normal in bone scan	Multiple myeloma
	Severe anaplastic tumors
	Lytic lesions

Differential diagnosis of cold defect in bone scan	Metal artifact
	Radiation changes
	Barium in bowel
	Early avascular necrosis
	Multiple myeloma
	Benign tumor
	Cysts
	Osseous metastasis
	Tumor marrow involvement


Soft tissue calcification
Dystrophic calcification
Metastatic calcification
Heterotrophic Bone formation
Calcinosis cutis
Calcification of dying or dead tissue
Normal tissue with hypercalcemia
-infection
-osteomyelitis
-cellulitis
-thrombophlebitis
-DVT
-osteosarcoma
-osteochondroma
-calcinosis cutis universalis
-calcinosis cutis circumcripta
-calciphylaxis
-rabdhomyolysis

Soft tissue accumulation of diphosphonate

Infarct

Amyloid

Muscle: myositis ossificans

Fibroids

Tumors: meningioma/neuroblastoma

Systemic sclerosis

Histocytosis X

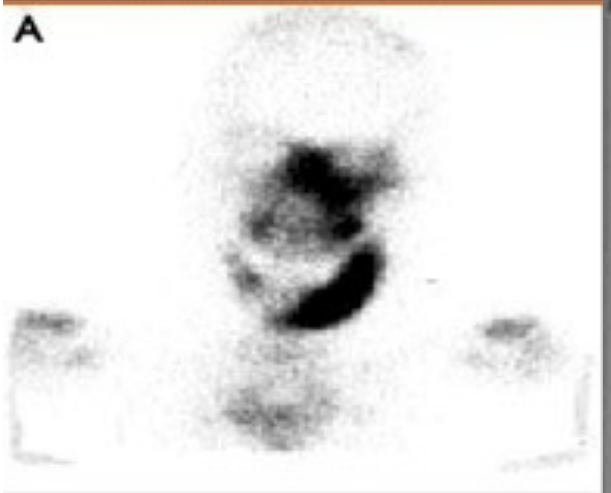
- Disease in which there are focal accumulation of macrophages in various organs including bones

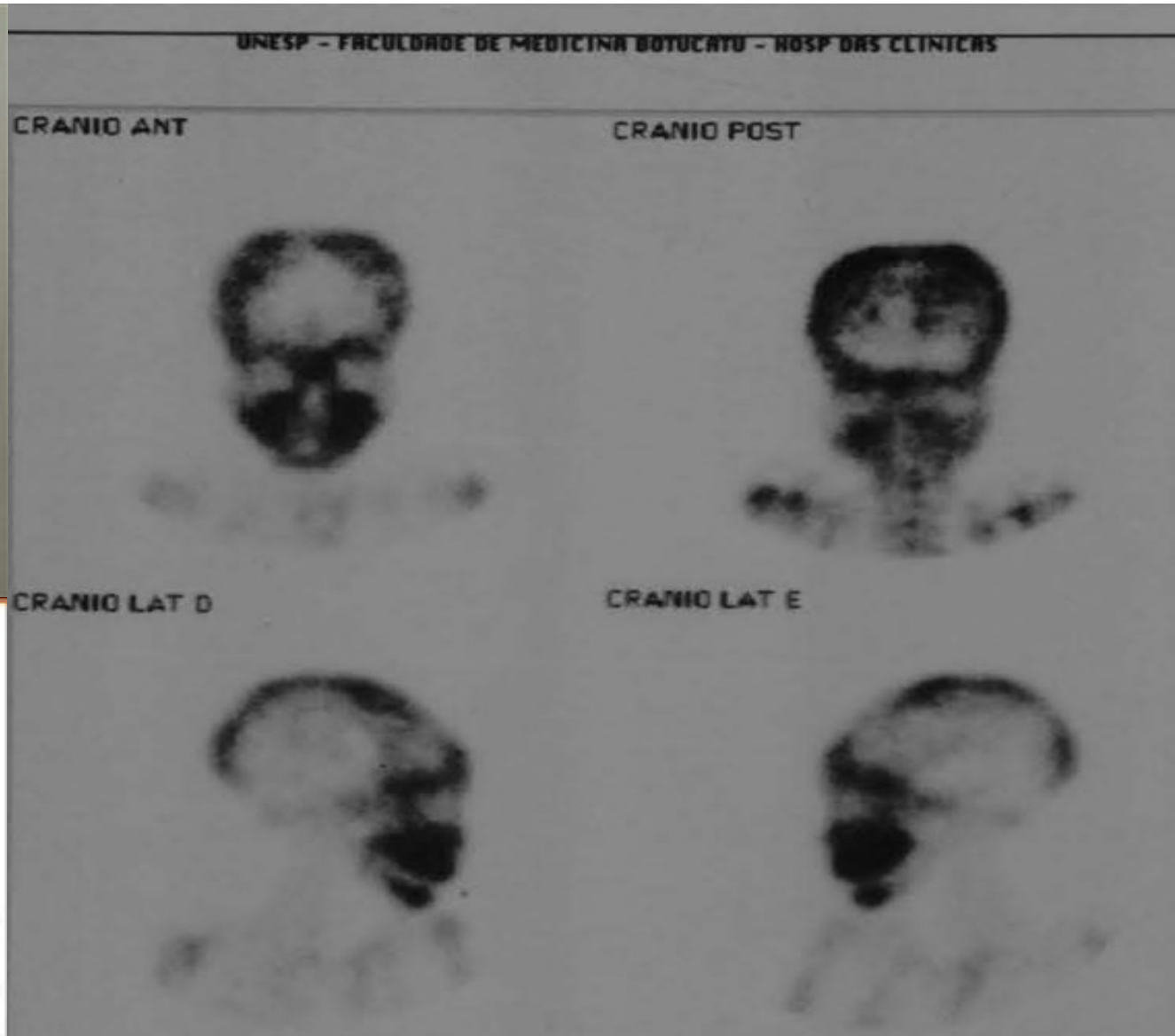
- Triad:

1. Letterer-Siwe disease
2. Hand-Schuller-Cristian disease
3. Eosinophilic granuloma of bone

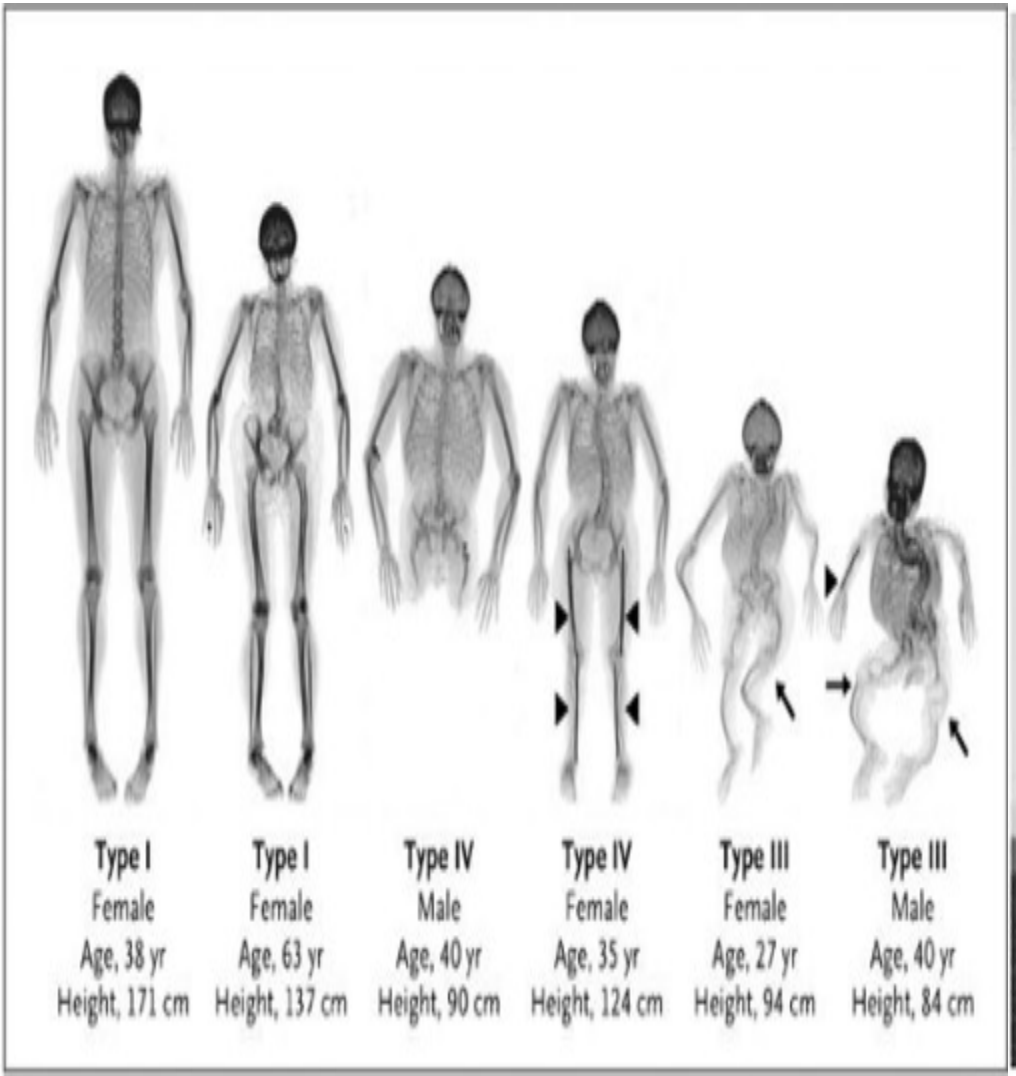
Bone dysplasia's a/w skeletal tracer uptake	Fibrous dysplasia
	Osteogenic imperfecta
	Albers-Schöenberg Disease (Marble Bones)
	Englemann’s disease
	Malorheosthosis
	Ribbing’s disease

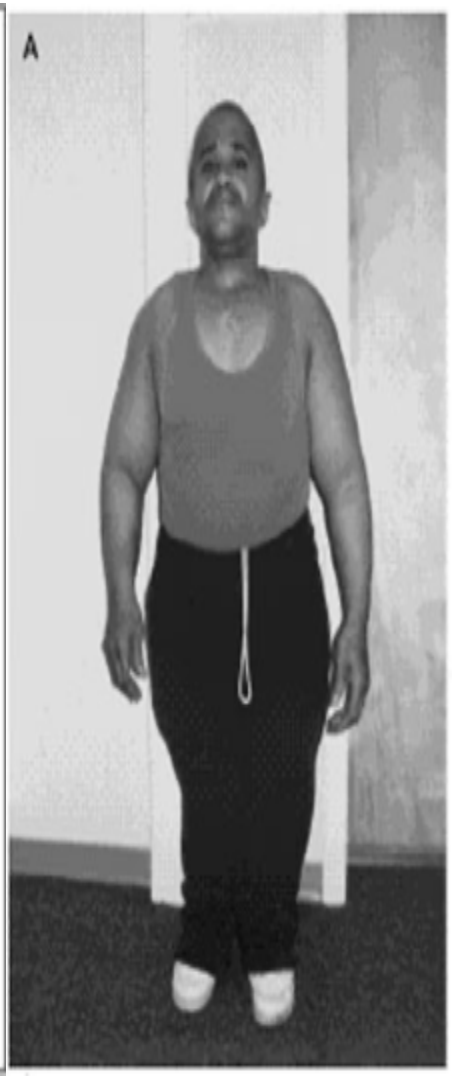
Fibrous dysplasia





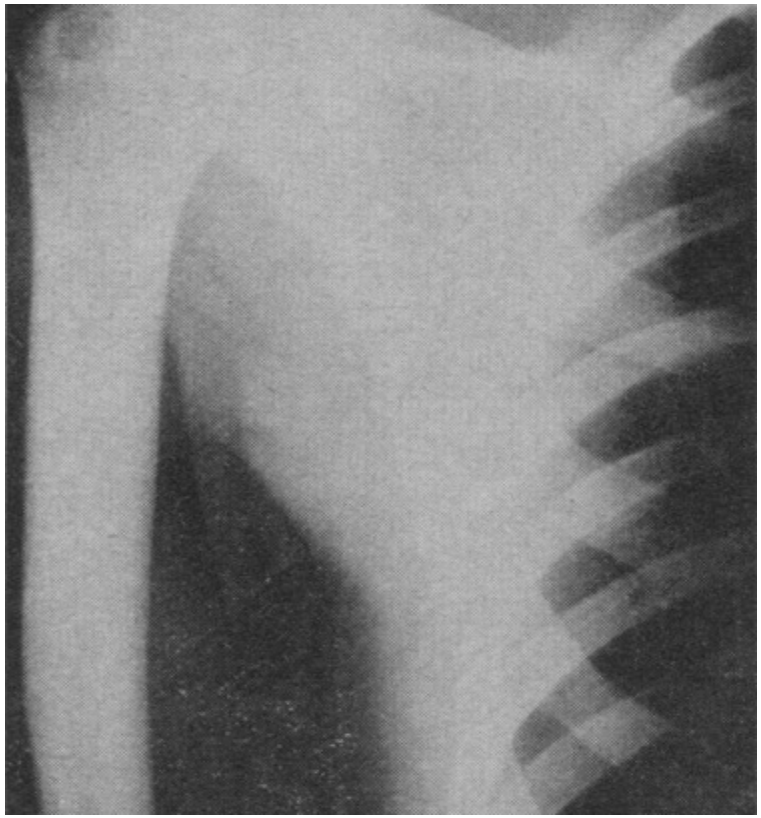
Osteogenic imperfecta





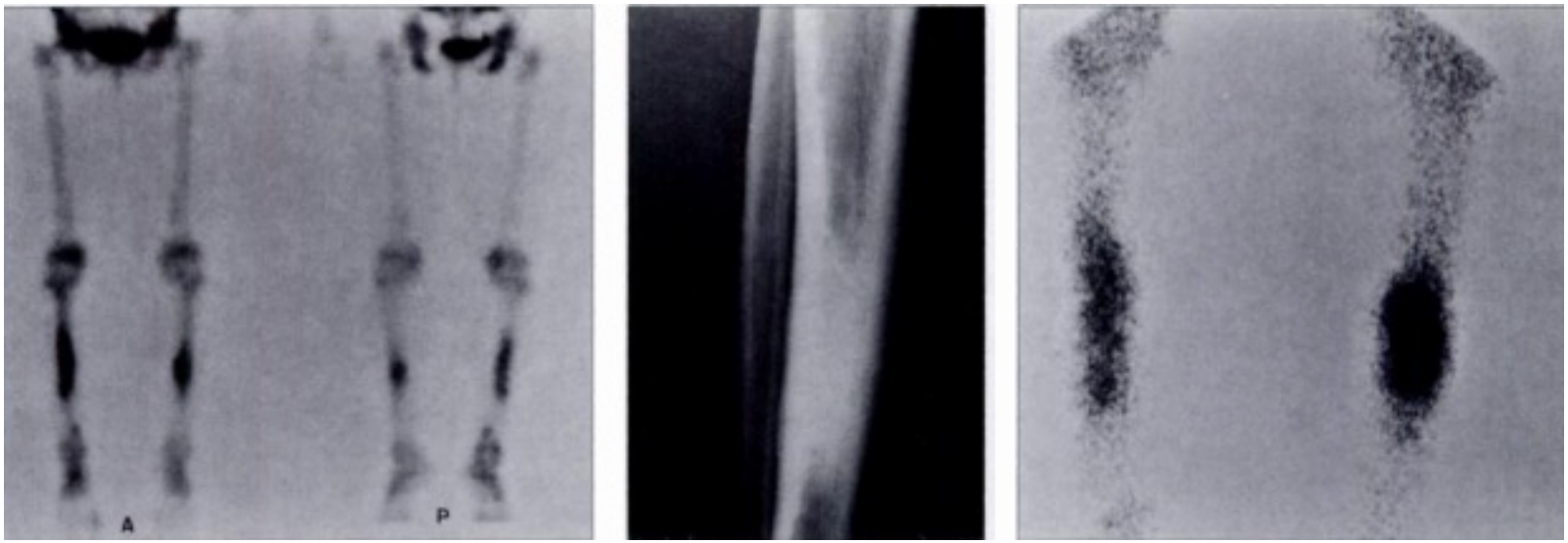
Osteopetrosis

- **Albers-Schöenberg Disease (Marble Bones)**

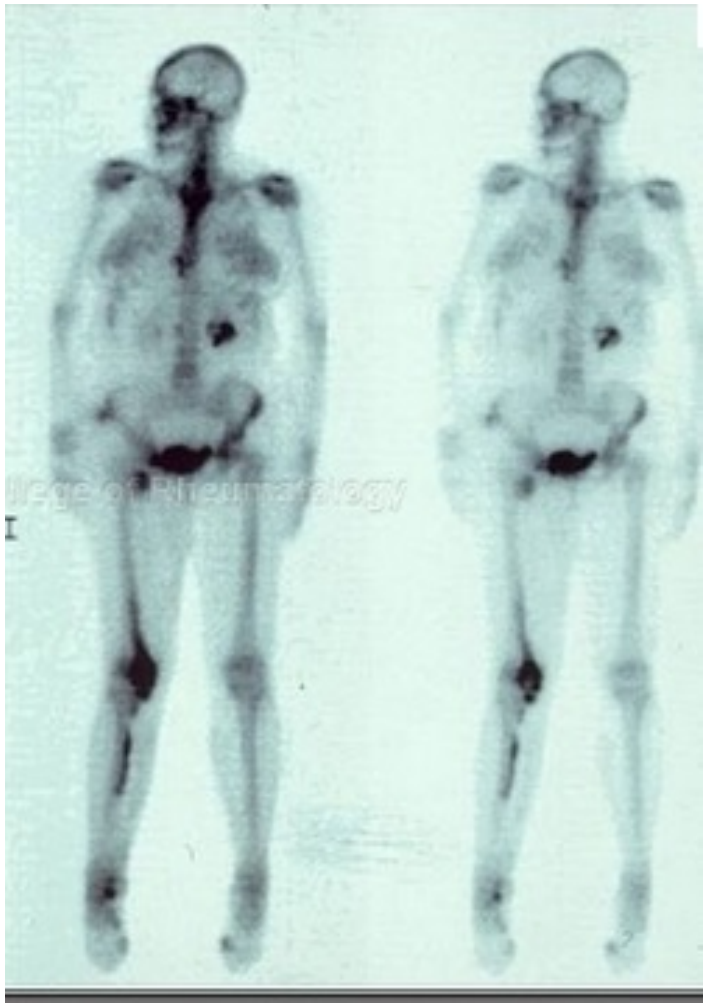


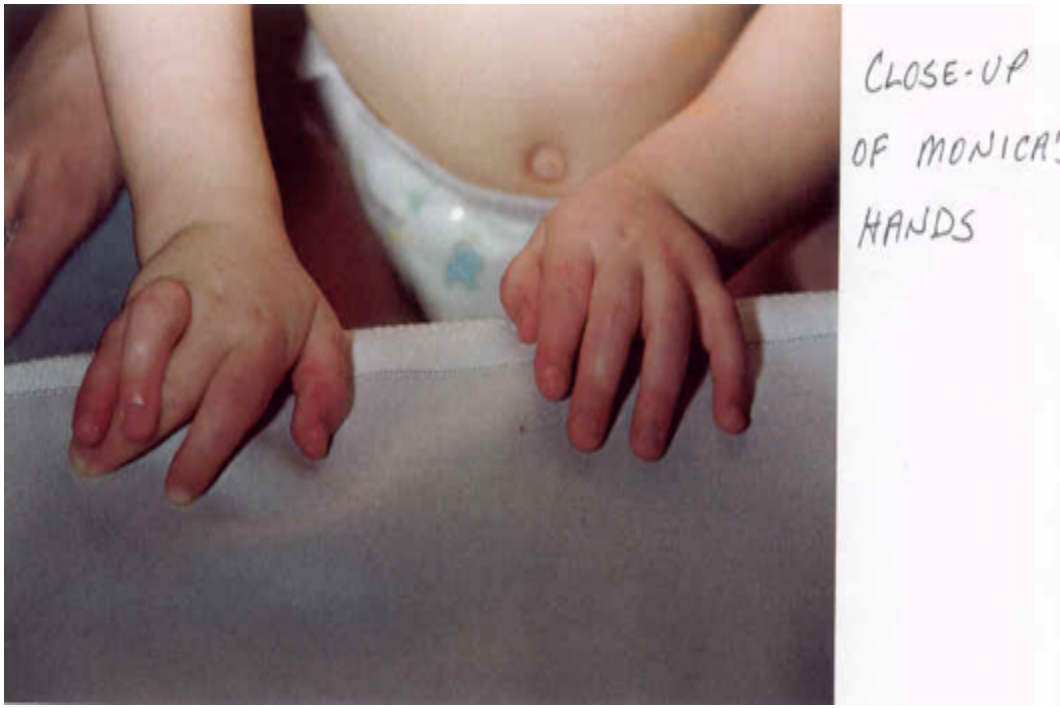
Englemann’s disease

Ribbing's disease
(multiple diaphyseal sclerosis)



Melorheostosis





Metabolic bone disease	Paget's disease (osteitis deformans)
	Osteoporosis
	osteomalacia & Rickets
	Hyperparathyroidism
	Renal osteodystrophy
	Hypertrophic osteoathroplathy

Metabolic bone disease

Disease	**Renal osteodystrophy**	**Primary hyperparathyroidism**	**Osteomalacia**	**Aluminum induced osteomalacia**	**Osteoporosis**
Cause of +ve bone scan	Hyperparathyroid	Hyperparathyroid	Hyperparathyroid	-	Fracture
Differentiating features	Metabolic features: No tracer in bladder	Metabolic features: Uncommon: brown tumor & ectopic calcification	Metabolic features: pseudofractures	Long bone uptake High background activity	Intense linear uptake at site of vertebral fracture May be low/ patchy uptake at axial skeletal

PAGET'S DISEASE

PAGET'S DISEASE

- Named after Sir James Paget (1814-1899)
- First described *osteitis deformans* in 1877
- Nonmalignant disease involving accelerated bone resorption followed by deposition of dense, chaotic, and ineffectively mineralized bone matrix
- Aetiology is unknown - possibly due to a viral infection
- Often an incidental finding on x-ray in an asymptomatic patient
- Serum alkaline phosphatase is increased

PHASES OF DISEASE

- Paget's disease occurs in three phases:- osteolytic, mixed and osteoblastic
- **Osteolytic phase** consists of intense osteoclastic activity and bone resorption, with bone turnover as high as 20 times the normal rate
- **In mixed phase**, osteoblasts begin to produce an abundance of woven bone, but mineralization is ineffective
- In the final **osteoblastic phase**, dense cortical and trabecular bone deposition dominates, but it is sclerotic, disorganized, and weaker than normal bone

COMPLICATIONS

- **Pathological fractures** - complete or incomplete
- **Neurological effects**
  - Cranial nerve lesions
  - Spinal cord lesions
- **Osteoarthritis**
- **Sarcomas**
  - Malignant change occurs in less than 1% patients with Paget's disease
  - 50% are osteosarcomas 25% are fibrosarcomas 25% are giant-cell sarcomas
  - The commonest site is the femur
  - Median survival is one year; Only 5% alive at five years
- High output cardiac failure (due to extensive hypervascularization of bone marrow causing AV shunt)

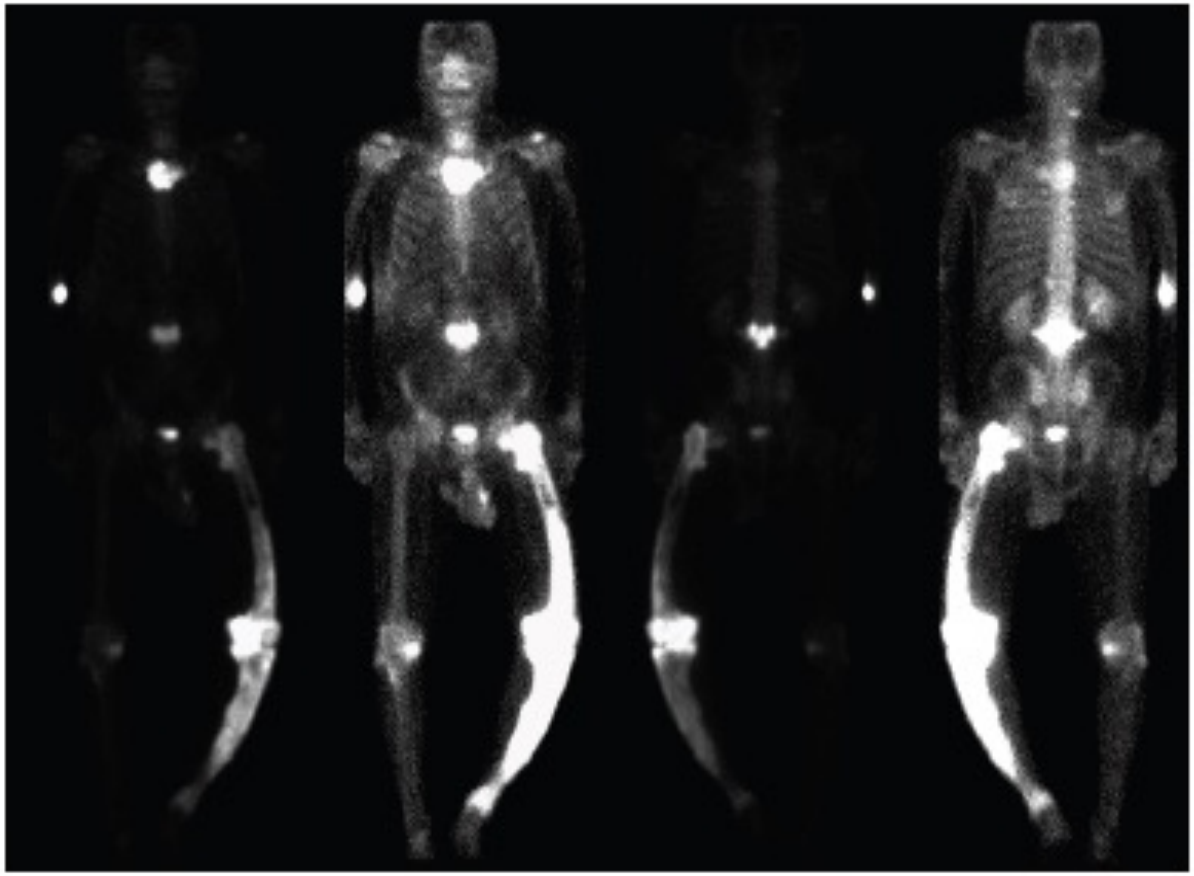
IMAGING

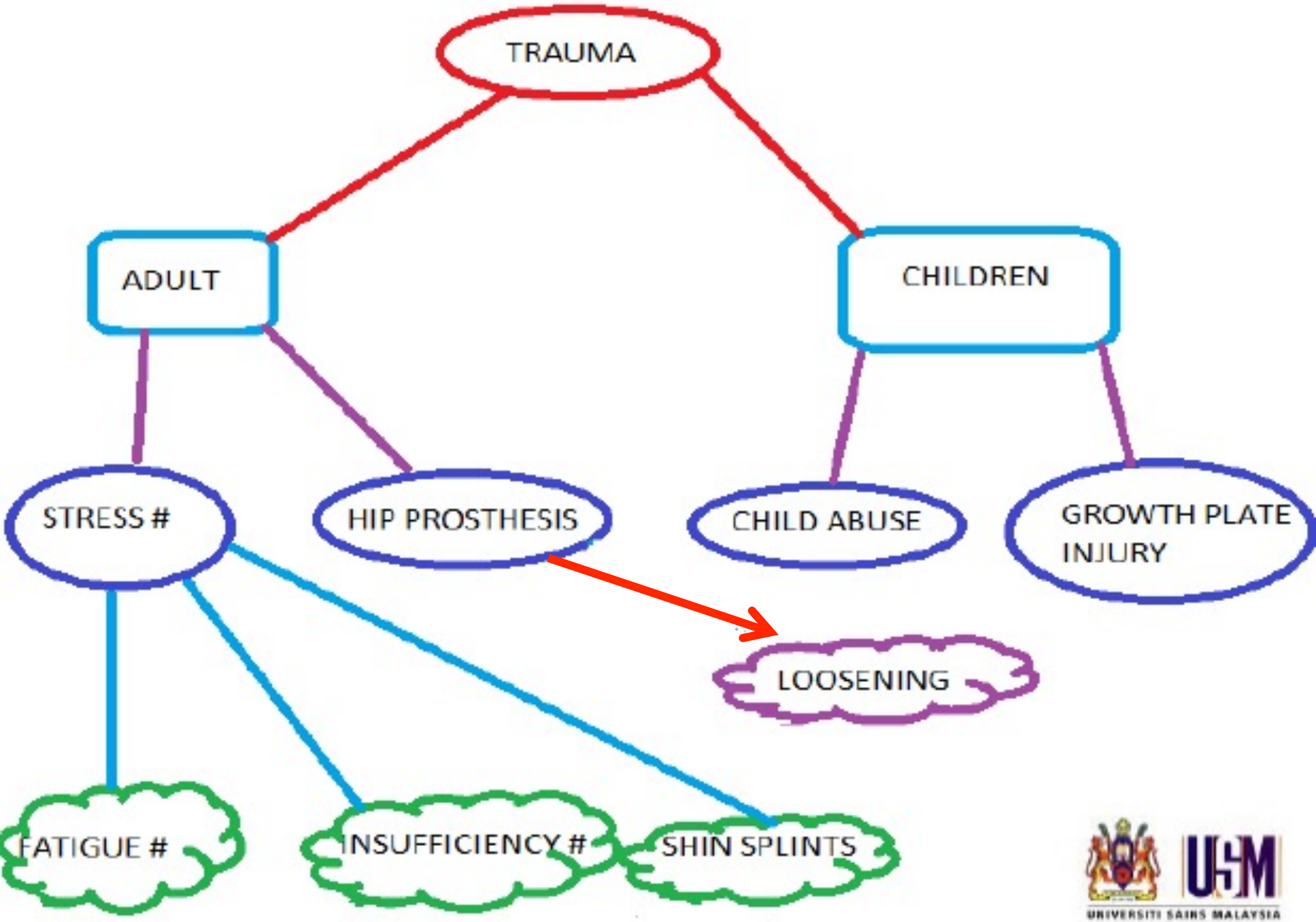
- **Radiographic**
  - Start at the bone extend to the other bone end with V shape transition zone. Increase of bone length → bowing of the long bone.
  - Osteoporosis circumscripta of the skull
  - Flame-shaped lesions in long bones e.g femur
  - Osteolytic lesions
  - Sclerotic bone
  - Fractures, including "banana" or "chalk" transverse fractures
- **Bone scintigraphy**
  - Areas of increased uptake of technetium-99m
  - "Mouse face" pattern on scan of affected vertebra

A technetium 99m-bisphosphonate bone scan of a patient with polyostotic Paget's disease.

Paget's disease involving the manubrium, third lumbar vertebrate, and the entire left lower extremity

Third lumbar vertebrae has the appearance of **"Mickey Mouse"** , because of the expansion and marked uptake in the entire vertebral body





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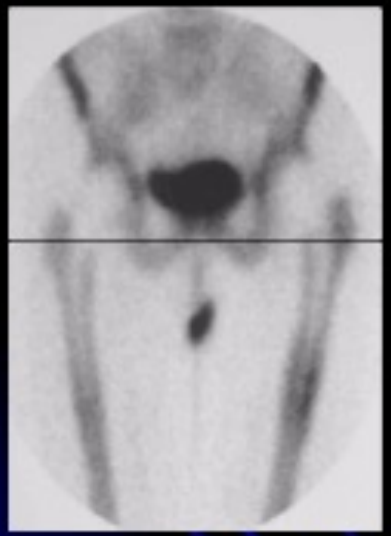
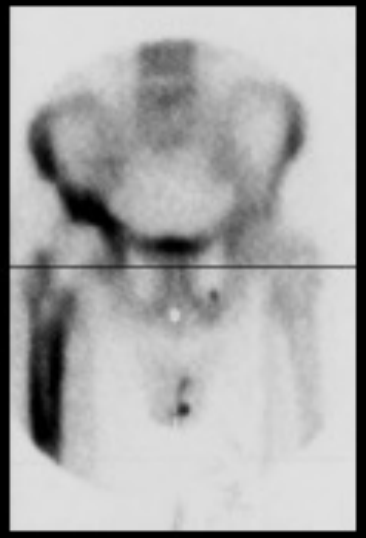
Hip Joint Prosthesis



Normal

Loosening

Focal skeletal phase uptake
At the tip of the hardware

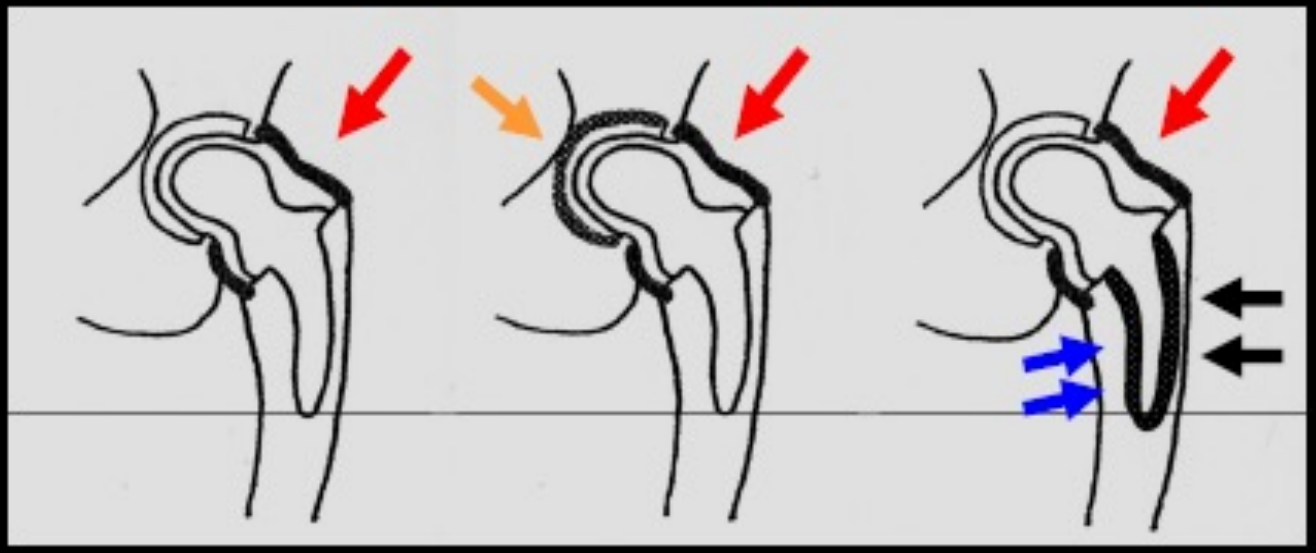


Infection

Increased flow and intense uptake around the prosthesis' stem

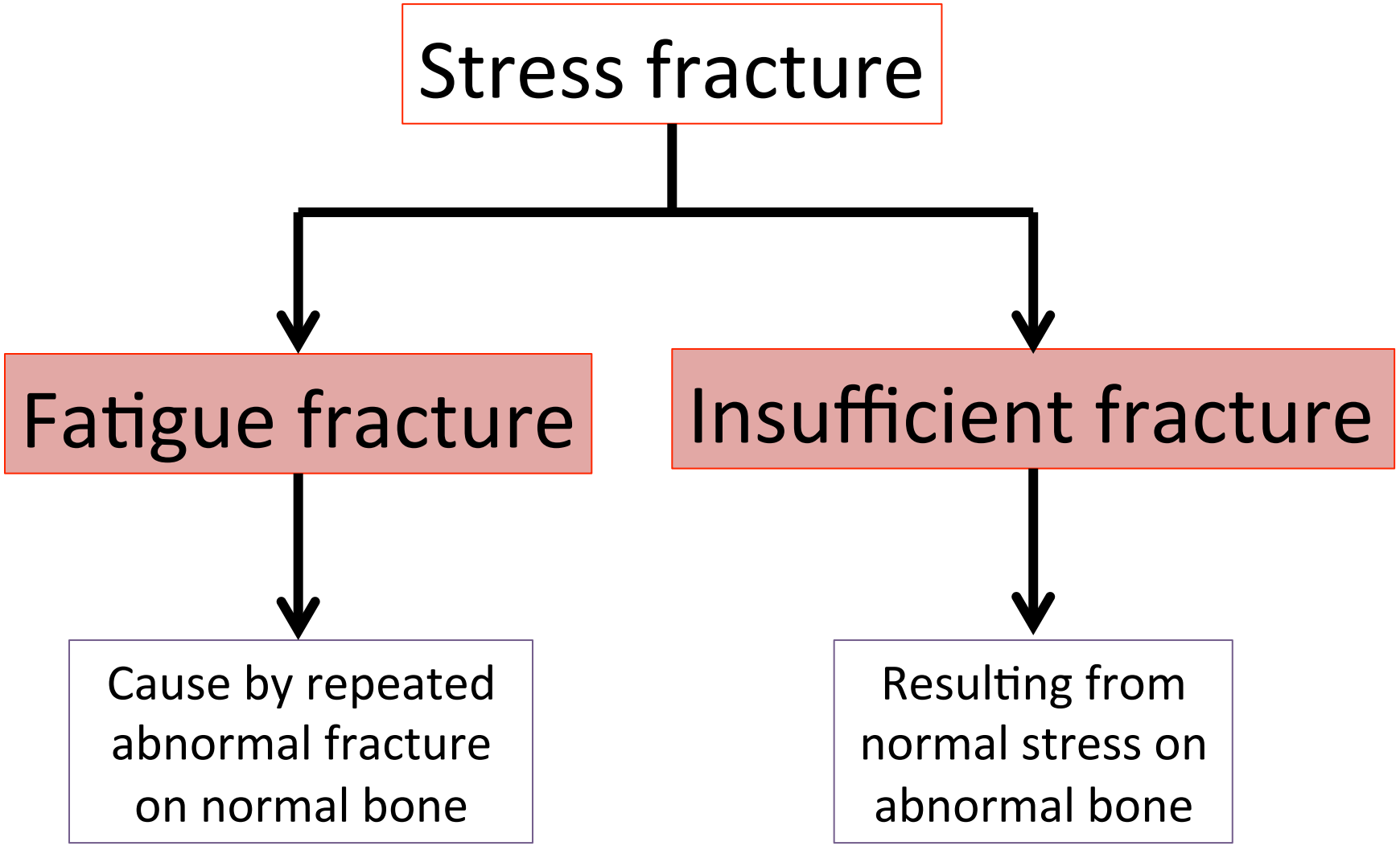
Hip joint prosthesis

Loosening	Infection
Blood pool image is **normal**	Blood pool image is **increased vascularity**
Discrete focus of tracer increased uptake at the tip of femoral prosthesis in delayed image	**Markedly increased tracer uptake** in delayed image

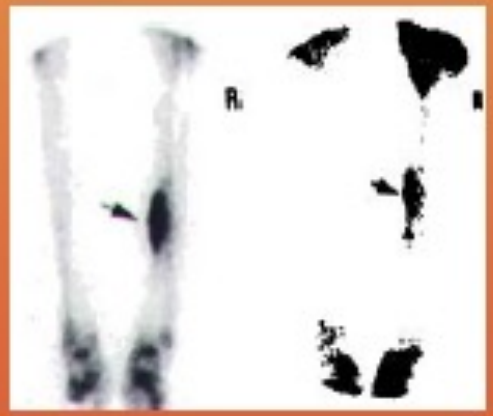
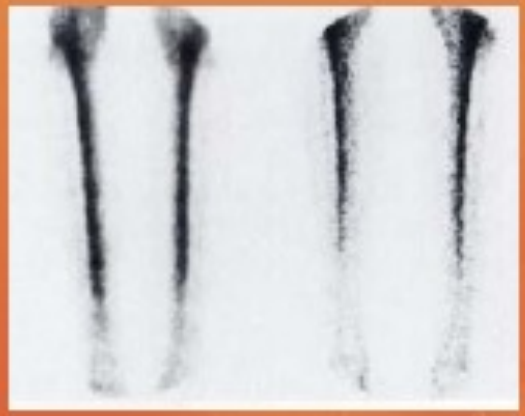


Bursitis Loosening Infe

Modified from
Manthey et al, Nucl Med Commun 2002


Stress fracture
Fatigue fracture
Insufficient fracture
Cause by repeated abnormal fracture on normal bone
Resulting from normal stress on abnormal bone

Stress # & shin splints

	Stress #	Shin splints
Uptake	Focal or fusiform, single or multiple at the cortex	Diffuse nonfocal periosteal uptake along lateral border of the tibiae
Treatment	Rest and analgesics	Anti inflammation
Scan		

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Insufficient

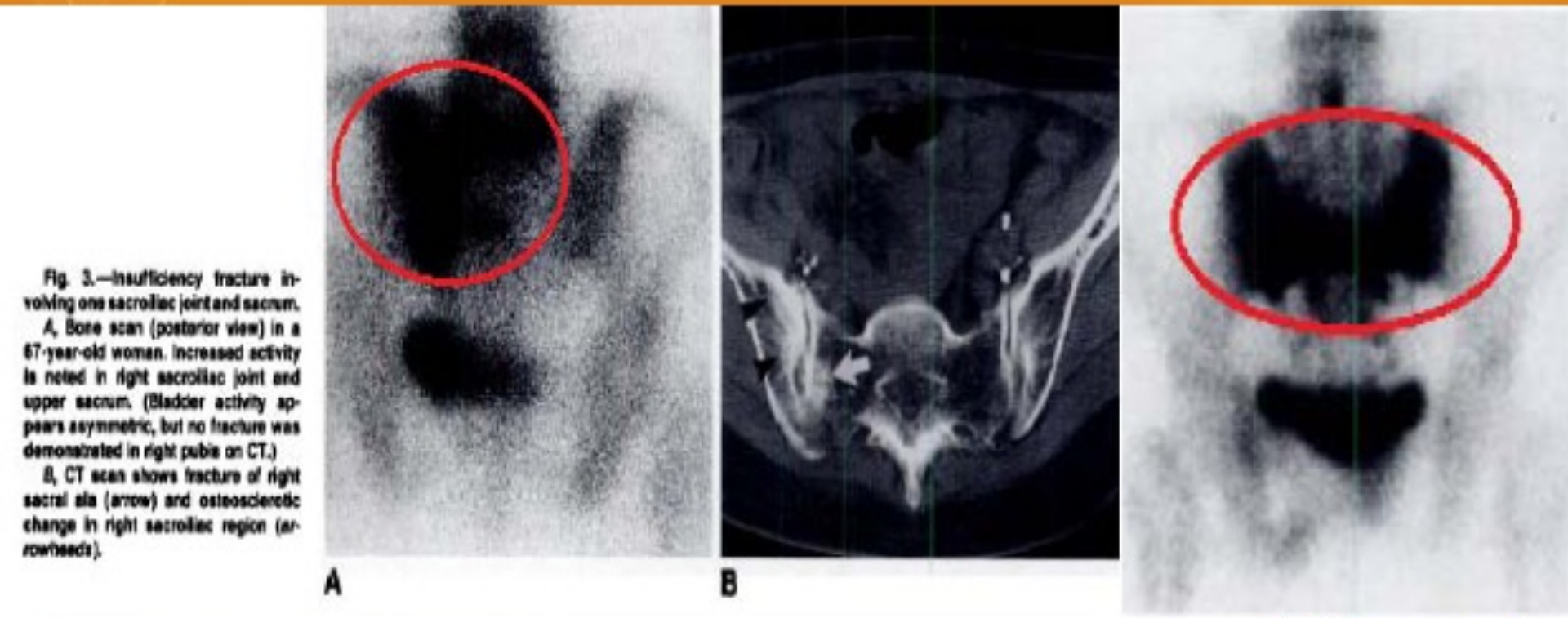

Fig. 3.—Insufficiency fracture involving one sacroiliac joint and sacrum.
A, Bone scan (posterior view) in a 67-year-old woman. Increased activity is noted in right sacroiliac joint and upper sacrum. (Bladder activity appears asymmetric, but no fracture was demonstrated in right pubis on CT.)
B, CT scan shows fracture of right sacral ala (arrow) and osteosclerotic change in right sacroiliac region (arrowheads).

A

B

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TIME POST # TO BECOME NORMAL

SITES	1 YEAR (%)	3 YEARS (%)
VERTEBRAE	59	97
LONG BONES	64	95
RIBS	79	100

ALL SITES	< 1 YEAR	2 – 5 YEARS	> 5 YEARS
	30	62	84

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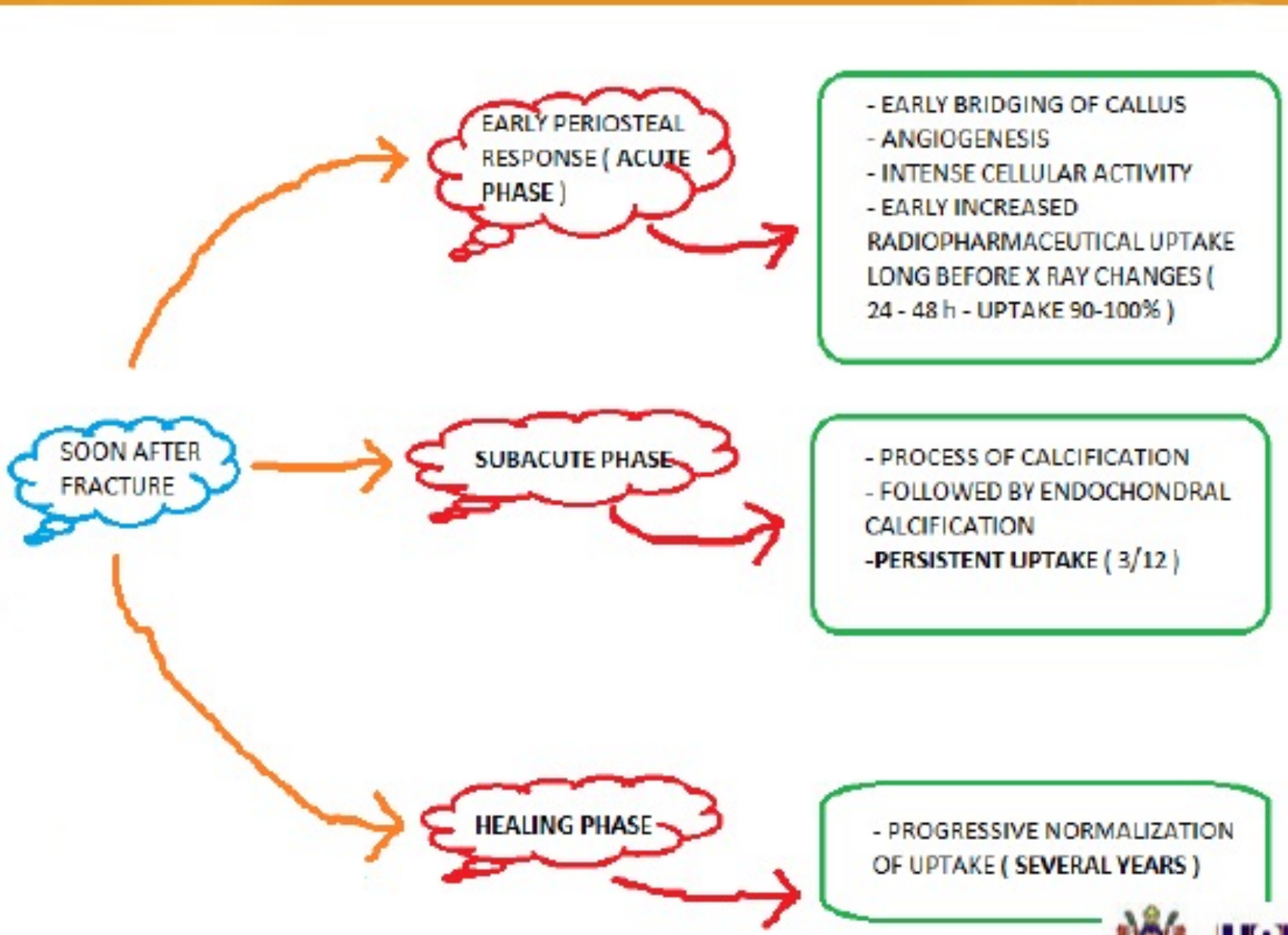

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TIME OF TRAUMA	BLOOD FLOW	BLOOD POOL	DELAYED IMAGES
ACUTE < 4 WEEKS	+	+	+
SUBACUTE 4 – 12 WEEKS	-	+	+
CHRONIC > 12 WEEKS	-	-	+

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The minimum time for a bone scan to become abnormal following fracture was **age dependent**; however, **80%** of all fractures were abnormal **by 24 hr**, and **95% by 72 hr**, after injury. The minimum time for a fracture to return to normal on a bone scan was **5 mo**. Approximately **90%** of the fractures returned to normal by **2 yr** after injury

Philip et al. J Nucl Med, 1979.

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Growth plate injury

- Normal growth plates appear as thin well demarcated linear activity
- Easily missed on imaging
- May lead to growth arrest or angular limb deformities in children

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Growth plate injury

- Segmental increase and decrease in a growth plate is associated with development of angular deformities.
- Trauma or infection directly involving the growth plate

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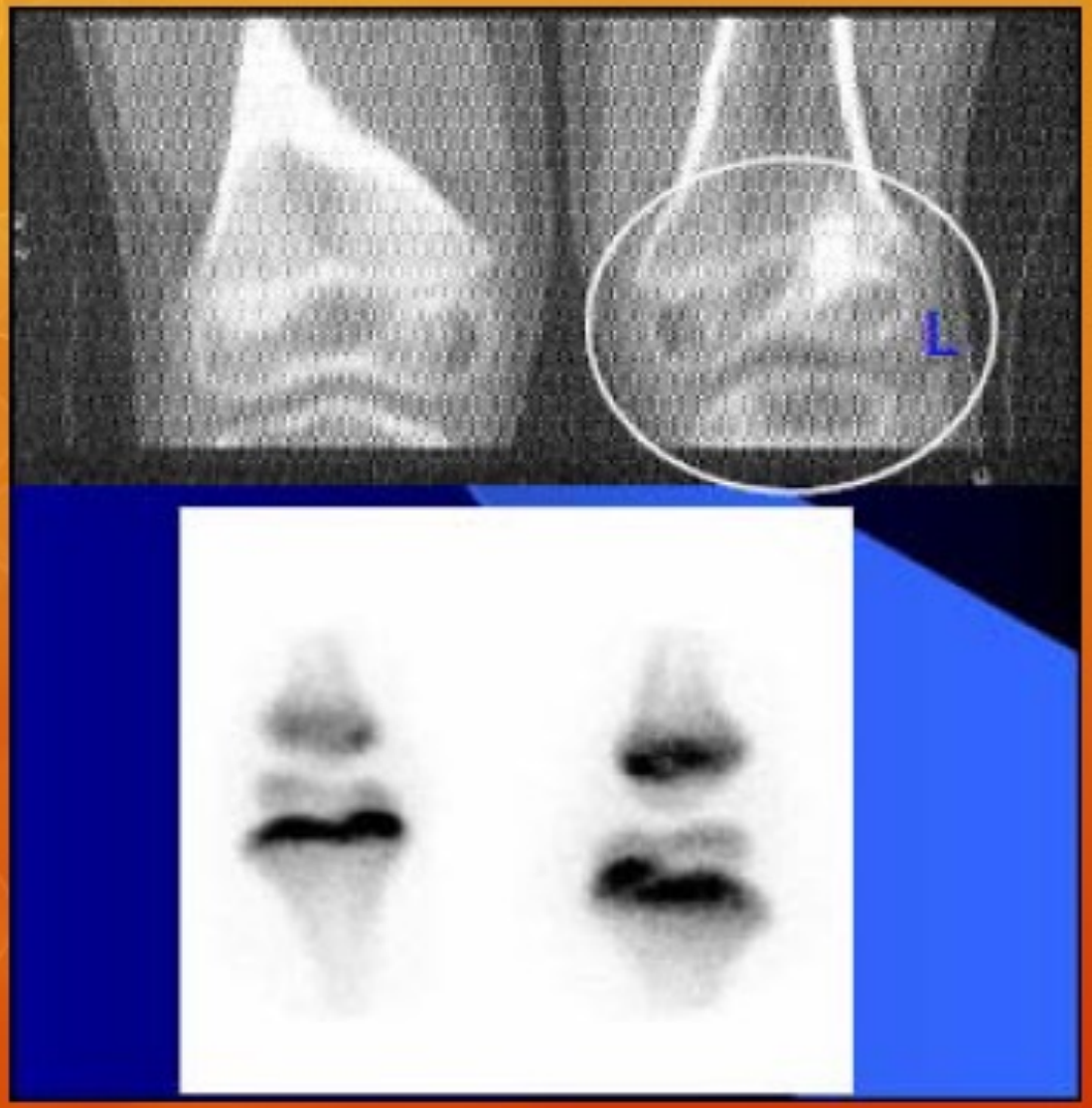

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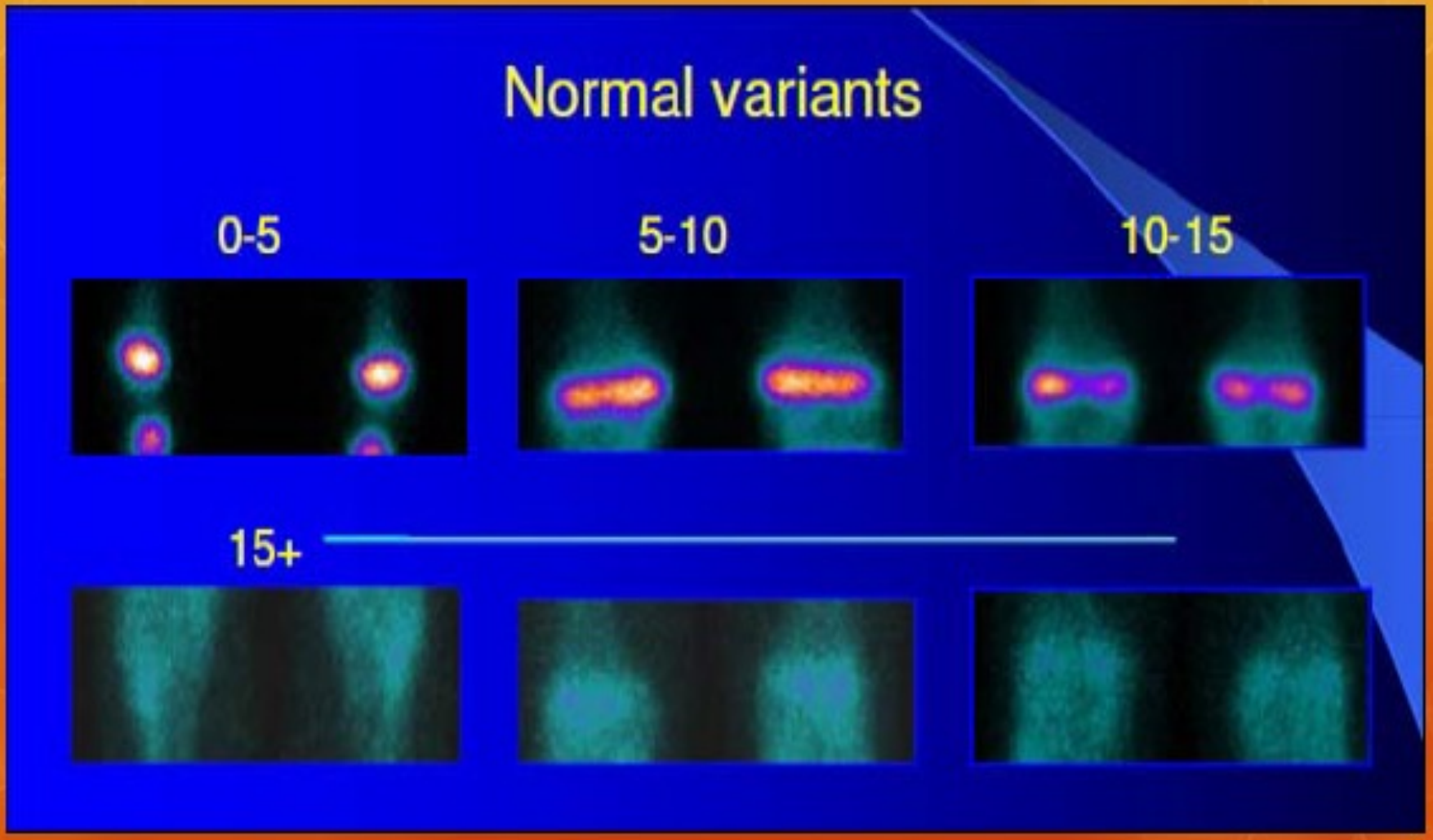
Normal variants



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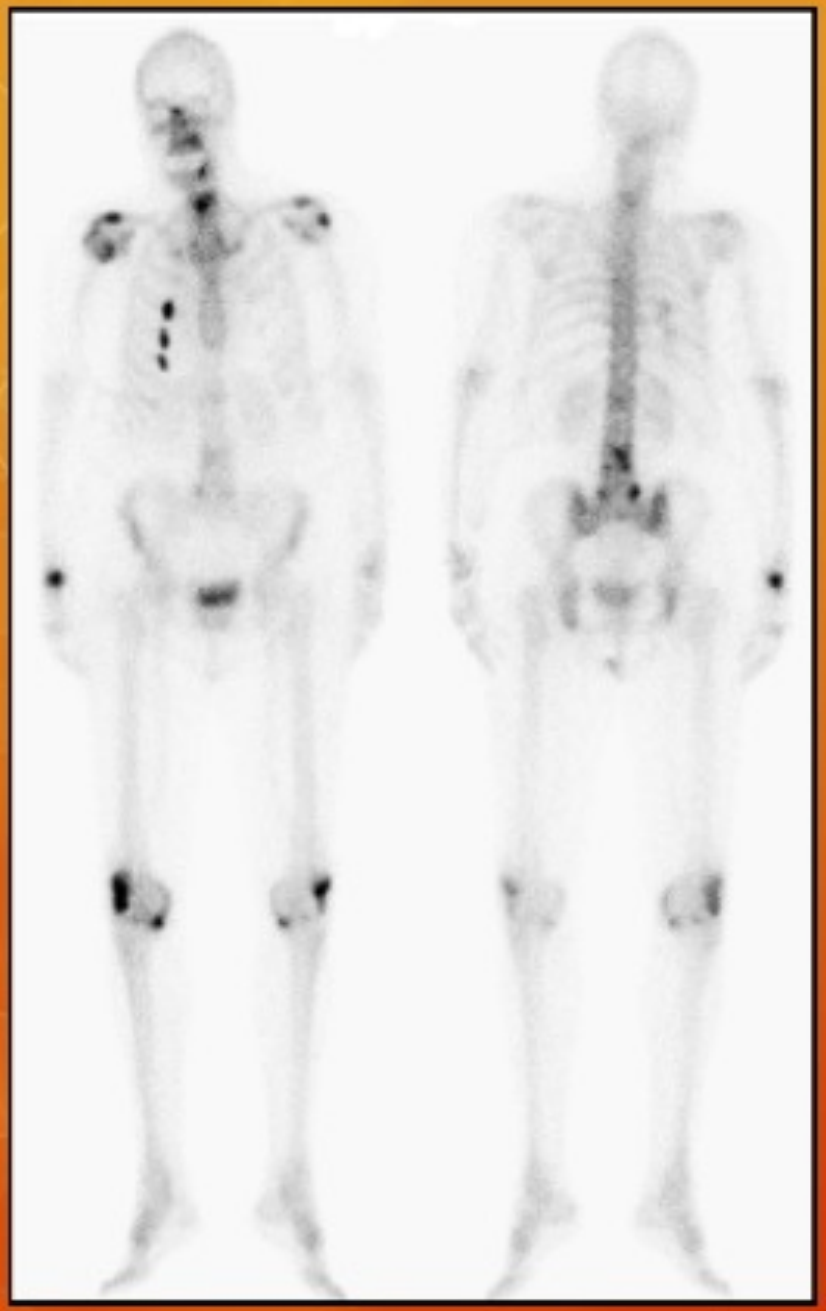
SKELETAL TRAUMA

- Able to demonstrate abnormality early after direct trauma
- Bone scan findings from trauma may persist for quite some time
- 80% of fractures can be visualized by 24 hrs after trauma. The earliest scintigraphic appearance is diffusely increased uptake, most likely the result of hyperemia at the fracture site.

- After 3 days, 95% fractures are positive on scintigraphy.
- In patients under age of 65 yrs, essentially all fractures are positive by this time.

- Advanced age and debilitation are factors contributing to a lack of visualization or delayed visualization of fractures. Maximum degree of fracture uptake occurs 7 or more days after trauma and delayed imaging in this time frame is recommended in difficult or equivocal cases.
- The time a fracture takes to return to normal on the bone scan depends on its location, its stability and the degree of damage to the skeleton.

- 60- 80% of non-displaced uncomplicated fractures revert to normal in 1 year.
- Over 95% revert in 3 years.
- However, there are many instances in which displaced fractures remained positive indefinitely ie structural deformity and post traumatic arthritis.



Fracture of right ribs

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X ray of lower limbs

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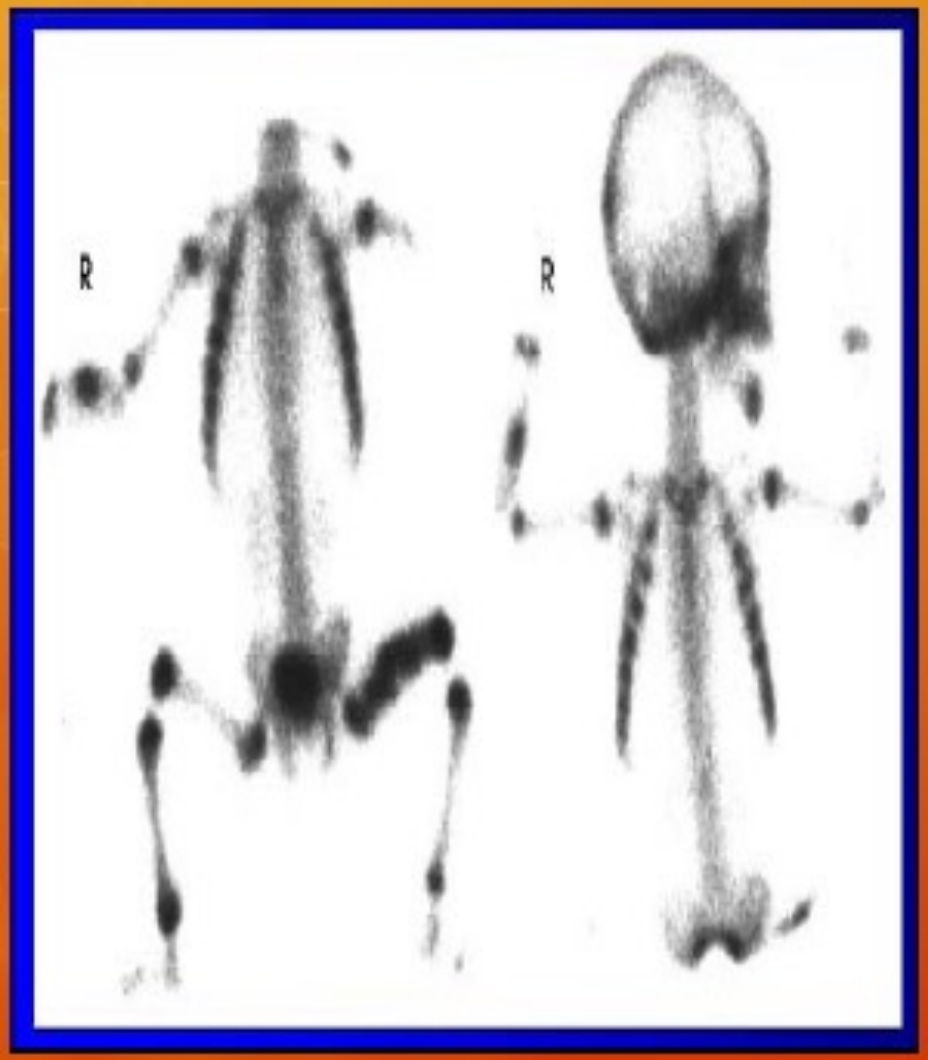

left femur

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Reflex sympathetic dystrophy syndrome

- Poorly understood
- Often forgotten in clinical practice
- Symptoms: pain/tender, swelling and dystrophic skin changes

- Other terms:

Causalgia

Acute atrophy of bone

Sudeck's atrophy

Post traumatic osteoporosis

Shoulder hand syndrome

COMPLEX REGIONAL PAIN SYNDROME

- Previously known as reflex sympathetic dystrophy
- Complex disorder with a variable presentation
- It is an exaggerated response to injury and immobilization with sensory, motor and autonomic features
- Typically, present with pain, edema, and muscle wasting in an affected extremity

- Scintigraphic findings are variable depending on the stage of disease.
- Early disease (up to 5 -6 months) usually shows increased blood flow.
- Later in the course of disease, blood flow may be normal or decreased.

- The classic pattern is unilateral increase in flow and blood pool activity with increased periarticular uptake on delayed images
- Usually involve radiocarpal, metacarpal, intercarpal, metacarpophalangeal and interphalangeal joints
- Only seen in less than 50% of cases but provides the highest diagnostic accuracy

Figure 9: Courtesy of Carlos E. Jimenez, MD

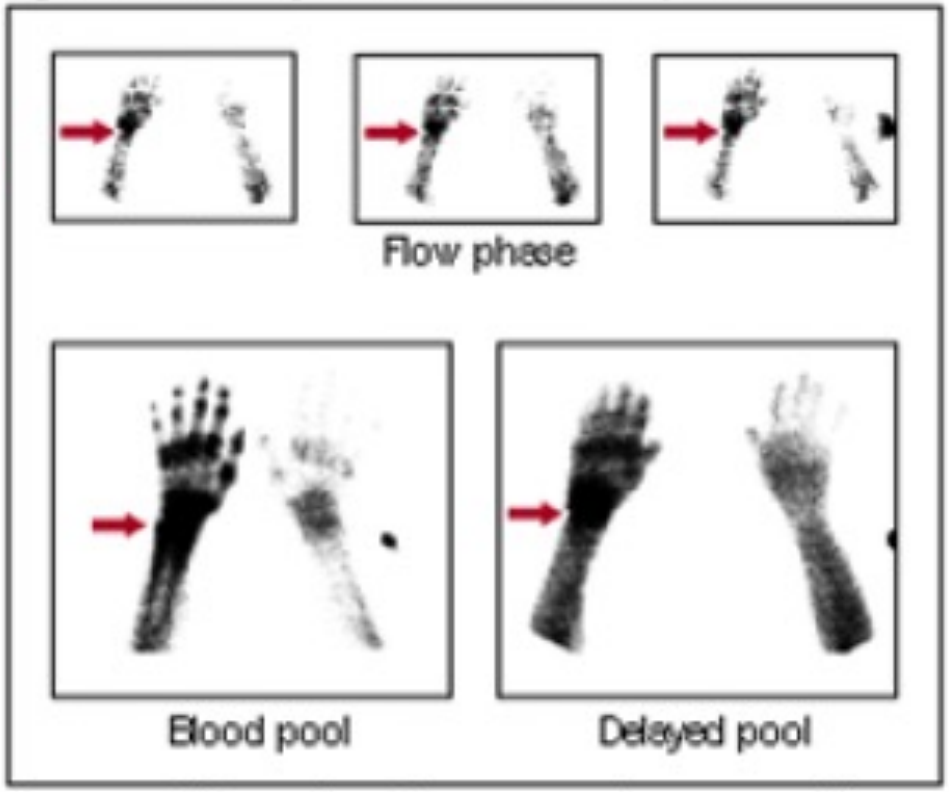
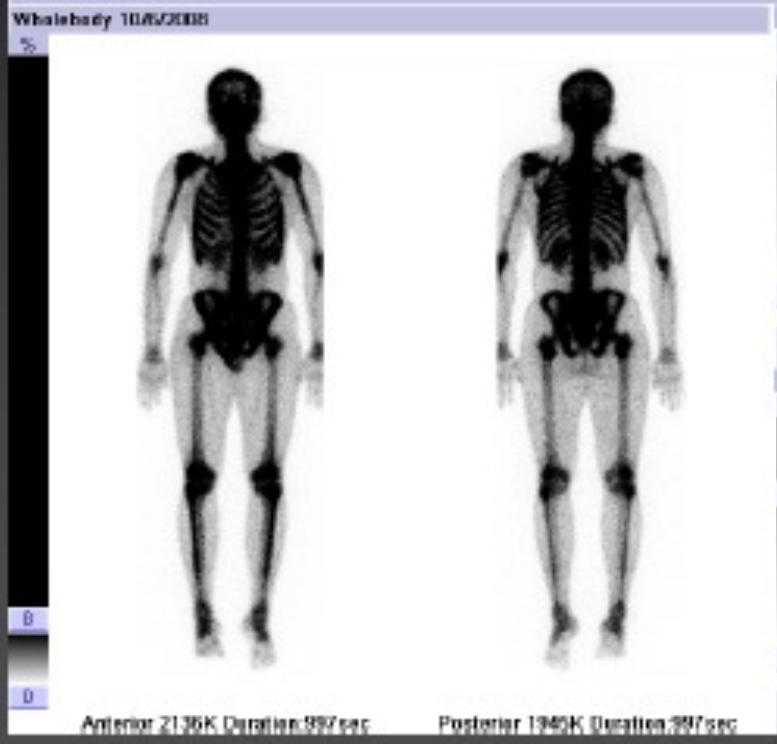
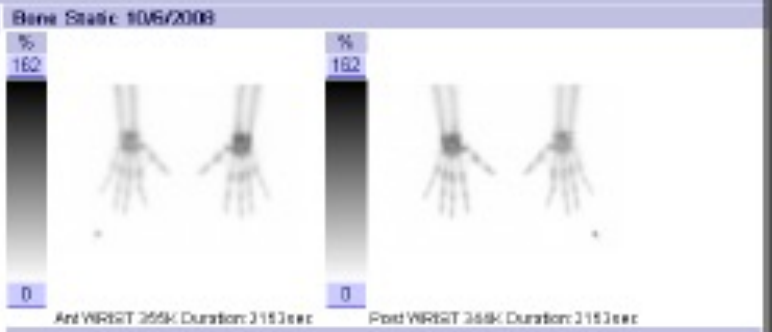


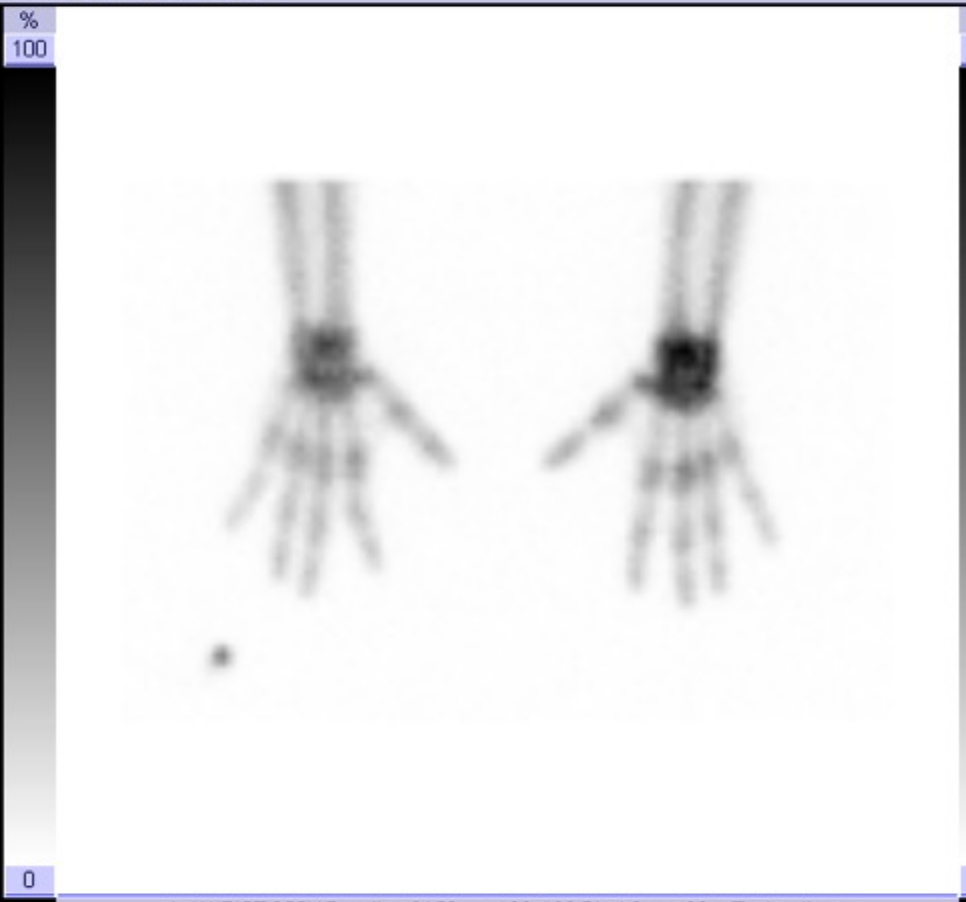
Figure 9. A three-phase bone scan of a 38-year-old recreational basketball player who had a healed fracture of the left distal ulna shows signs consistent with reflex sympathetic dystrophy. The patient had recent onset of diffuse left upper-extremity swelling and pain, and the scans revealed diffuse and intense periarticular uptake (arrows) in the left extremity in all three phases.

Patient Name: ADRIAN GERARD Patient ID: PN 2008/2194 DOB: 9/12/1984 Study Name: Bone Scan
Study Date: 10/6/2008





Bone Static 10/6/2008



Ant WRIST 355K Duration:2153sec 128x128 Pix:4.8mm 99m Technetium

Post WRIST 344K Duration:2153sec 128x128 Pix:4.8mm 99m Technetium

AETIOLOGY

- ALCOHOL
- SICKLE-CELL DISEASE
- ENDO / EXOGENEOUS STEROID
- PANCREATITIS
- TRAUMA / PERTHE'S DISEASE
- IDIOPATHIC
- CAISSON'S DISEASE
- GAUCHER'S DISEASE

Avascular Necrosis

AETIOLOGY

- TRAUMA – Elderly
  - Interruption of the blood supply
- ATRAUMATIC
  - Embolism of air or fat that blocks the blood flow through the blood vessels (Caisson's disease, pancreatitis)
  - Abnormally thick blood (hypercoaguable state) – sickle cell disease, Gaucher's disease
  - Inflammation of the blood vessel walls (vasculitis) – radiation exposure, SLE
  - Drugs - Steroid, NSAIDs

Avascular Necrosis

IMAGING OF AVN

- MRI more sensitive in detection of early AVN
- Assoc. features: bone marrow oedema, articular cartilage damage, joint effusion
- Bone scan – early (photopenia), late (increase uptake)
- Role of imaging:
  - Diagnose the abnormality at an early stage
  - Detect contra-lateral asymptomatic disease
  - Response to treatment

RADIOLOGICAL CHANGES (FICAT)

- Stage 0: No clinical or radiographic findings.
- Stage 1: Clinical symptoms of AVN are present but no radiographic findings.
- Stage 2: Radiographicaly osteopenia, cystic areas, and sclerosis.
- Stage 3: Radiographicaly flattening of the femoral head; a subchondral crescentic area of radiolucency also may be seen.
- Stage 4: Secondary osteoarthritis with associated joint space narrowing.

Avascular Necrosis

STEINBERG CLASSIFICATION

- STAGE 0
  - Asymptomatic
  - Diagnose incidentally
  - No radiographic changes
  - MRI – bone marrow oedema within the femoral head
  - Histology from biopsy shows abnormality
- STAGE I
  - Still no radiographic changes (minor osteoporosis)
  - MRI, bone scan and histology show abnormality

Avascular Necrosis

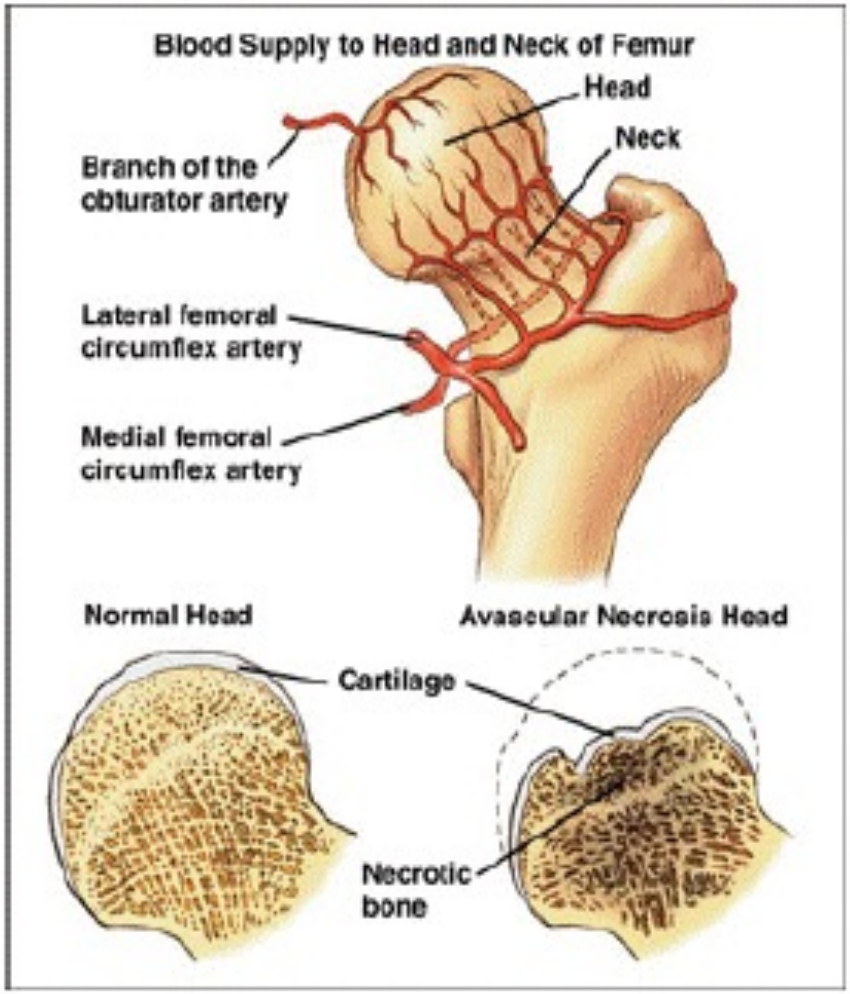
- STAGE II
  - Radiography shows more diffuse osteoporosis and subsequent sclerosis
  - the infarct is distinguished from the normal bone by a shell of reactive tissue
  - On MRI, osteonecrotic lesion demonstrates varying signal intensity; can be analogous to
    - Fat – high on T1, intermediate on T2
    - Blood and hemorrhage – high on T1 and T2
    - Fluid – low on T1 and high on T2
    - Fibrous tissue – low on T1 and T2

- In 80% of cases, the line of demarcation between the normal and abnormal bone is characterized by a 'double line'

- STAGE III
  - Femoral head loses its spherical shape (may only be visible on lateral plain radiograph)
  - On MRI, subchondral fracture – low signal line paralleling the subarticular cortex (all sequences)
  - Joint space remains normal

- STAGE IV
  - Femoral head undergoes further collapse
  - Destruction of the cartilage
  - Reduction in the joint space

AVN OF FEMORAL HEAD



LONG STANDING STEROID THERAPY

AVN – DOUBLE LINE SIGN

- MRI finding seen at the periphery of a region of osteonecrosis.
- Best seen on T2 weighted sequences
- consists of an inner bright T2 line representing granulation tissue and an outer dark line representing sclerotic bone.
- reported in up to 80% of cases

T1

T2

Avascular Necrosis

SLIPPED FEMORAL CAPITAL EPIPHYSES (SUFE)

- Age group: 14 or 15 years
- Present with painful limp
- Displacement of upper femoral epiphysis
- Complication - Avascular necrosis

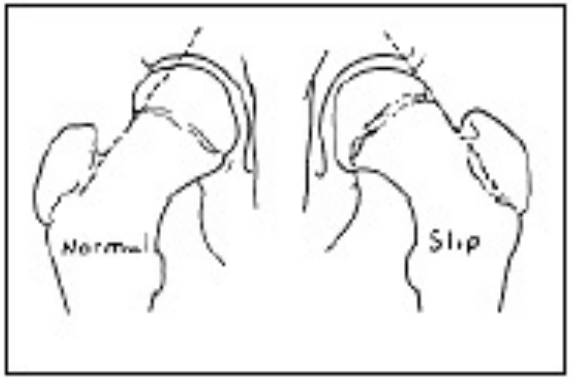
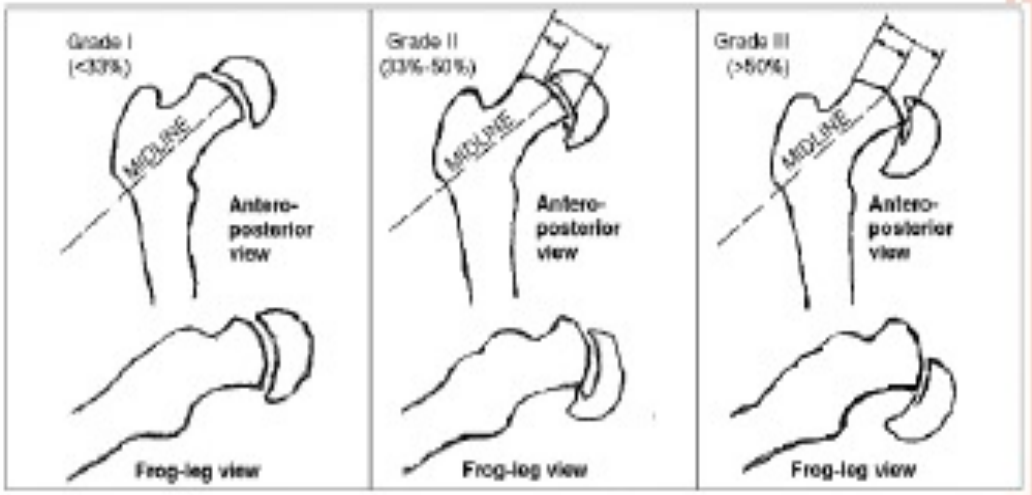
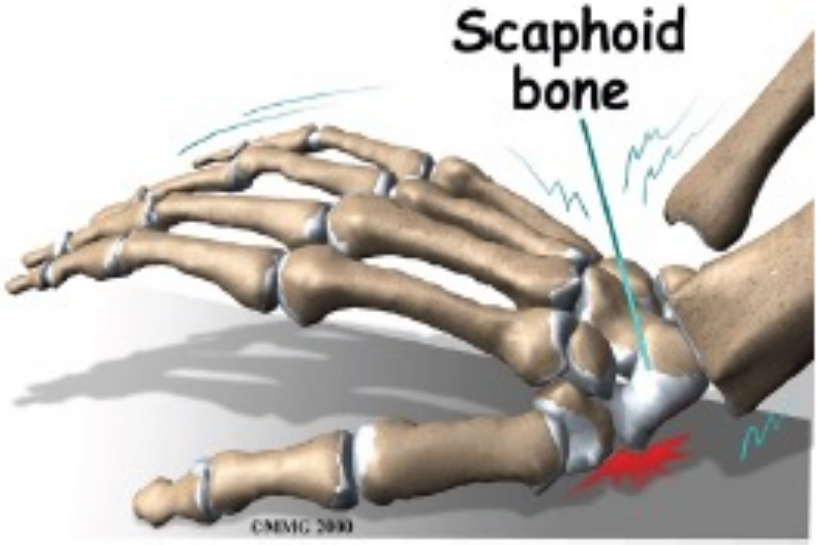


FIG.2 - AP views of hip, normal and slip. Note on slip side how line drawn along superior aspect of femoral neck (Klein's line) fails to intersect epiphysis.



AVN OF SCAPHOID



Avascular Necrosis

AVN OF SCAPHOID

- AVN occur in 30% of cases following scaphoid fracture

Increased density and partial collapse of the proximal pole of the scaphoid (blue arrow) secondary to a fracture of the waist of the scaphoid (red arrow).

The smooth and sclerotic margins of the fracture line suggest non-union

Avascular Necrosis

AVN OF LUNATE (KIENBOCK'S DISEASE)

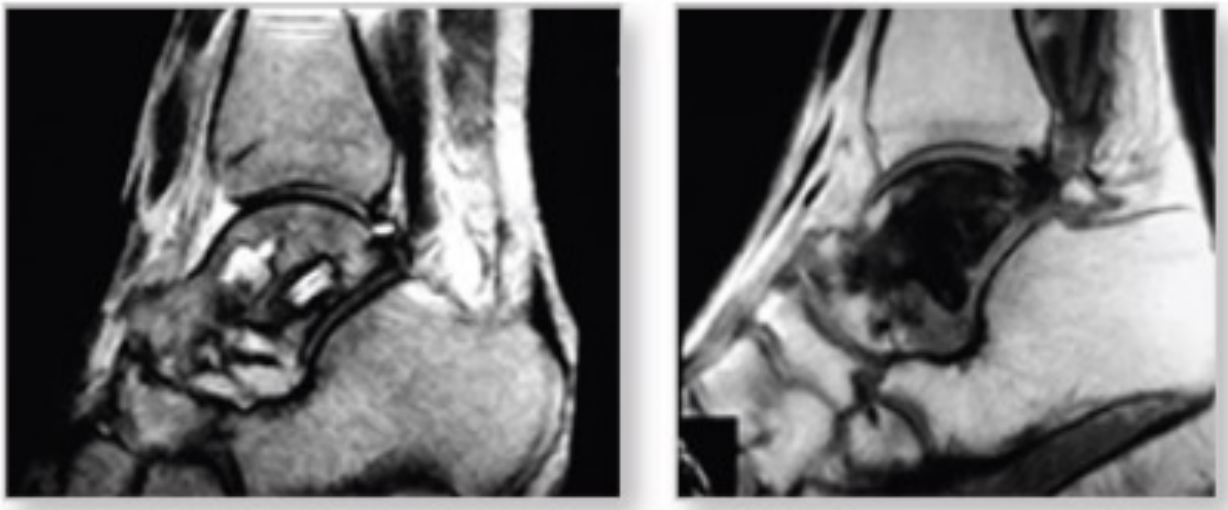
- Causes: Transverse fractures, compression fractures and lunate dislocation

AVN OF CAPITATE

Avascular Necrosis

AVN OF TALUS

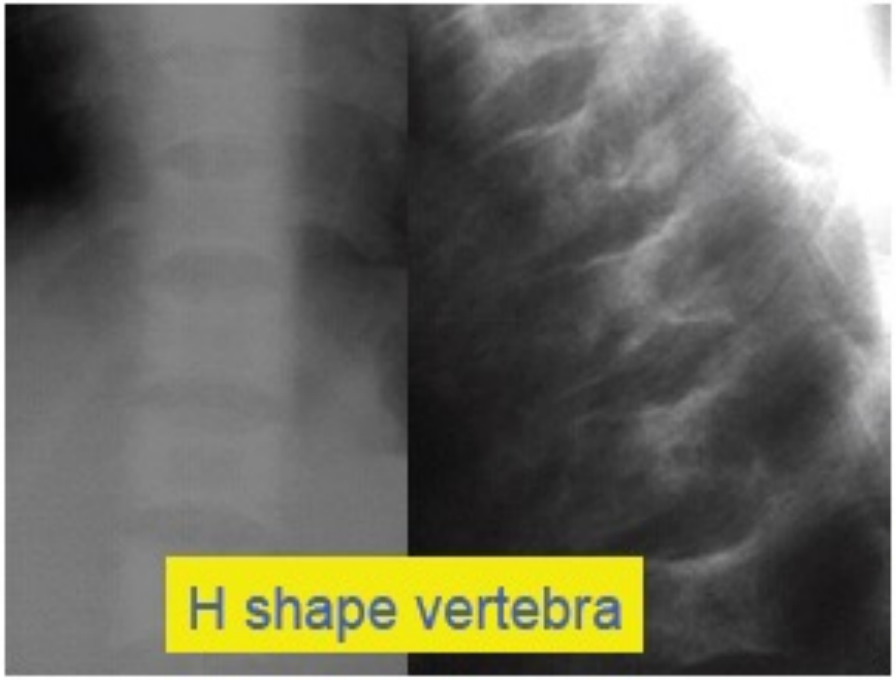
- Higher incidence in talus dislocation
- Other causes: fracture



Presence of the white or black irregular shadows in the middle of the talus - dead bone

SICKLE CELL DISEASE

- Deformity of RBC leads to vaso-occlusion and tissue death secondary to ischemia
- Marrow hyperplasia leads to increased lucency in bone while infarction, and possible myelofibrosis, lead to osteosclerosis



CAISSON'S DISEASE

- Decompression - nitrogen buble in the blood which block capillaries → necrosis

SPECIFIC NAME ACCORDING LOCATION:

Disease	Site
Legg-Calve-Perthes	Femoral head
Kohler's	Navicular
Freiberg's	Metatarsal
Kienbock's	Lunate
Osgood-Schlatter	Tibial tubercle
Sinding-Larson	Lower pole of patella
Sever's	Calcaneum
Scheuermann's	Ring-like epiphysis of vertebra

Legg-Calve-Perthes

FORM OF OSTEOCHONDRITIS DISEASES CAUSED BY AN INFARCT IN THE CAPITAL FEMORAL EPIPHYSIS

LEGG-CALVE-PERTHES' DISEASE

- Specific condition of unknown aetiology
- Represent avascular necrosis occurring without a recognized previous insult
- Age group: 4 and 9 years (boy:girl - 4:1)
- Present with painful limp
- Assct. anomalies including congenital heart disease, pyloric stcnosis, hernia, renal anomalies and undescended testes.
- Following ischaemia, the ossific nucleus of the epiphysis necrosed causing growth arrest. Overlying cartilage is thickened.
- The dead bone replaced by new bone.
- The previous nucleus shape of the necrotic nucleus does not return to normal and,
- Nucleus ends up flat in whole or in part

AVN OF METATARSAL HEAD (FREIBERG'S DISEASE)

- Freiberg first described this entity in 1914 as an infraction (incomplete fracture without displacement of the fragments)
- More commonly seen in females
- Usually in the second decade
- Unilateral involvement of the second metatarsal is the most common presentation
- May occur in the third and more rarely the fourth and fifth metatarsals

AVN OF VERTEBRAL APOPHYSIS (SCHEUERMANN'S DISEASE)

- Originally described by Scheuermann
- There was wedging of vertebral bodies, in association with other changes: intervertebral disc space narrowing, Schmorl's nodes, and deformity
- Occurs in children and is quite common (up to 25% in some studies)
- Usually becomes apparent at school with the advent of some deformity (kyphosis)
- Can be accompanied by backache and stiffness

AVN OF NAVICULAR (KOHLER'S DISEASE)

- Described in 1908 by Kohler
- Radiographic findings of flattening, sclerosis and irregular rarefaction
- More common in boys
- Age of onset: 5yo in boys and 4yo in girls
- Diagnosis of Kohler's disease should only be made when symptoms are present

1. Nuclear medicine in osteomyelitis

A. Gallium scan is positive only after the MDP scan is positive
B. Gallium is very useful in chronic osteomyelitis
C. Cold spot exclude osteomyelitis
D. False negetive rate higher in children
E. Cellulitis cannot be differentiated from osteomyelitis

1. Nuclear medicine in osteomyelitis

- FTFTF

2. Lesion producing the same appearance as osteomyelitis in bone scan

A. Paget's disease
B. Septic arthritis
C. Diabetic neuropathy
D. Tumors
E. Post traumatic

2. Lesion producing the same appearance as osteomyelitis in bone scan

- TTTTT

3. White cell scan in osteomyelitis

A. Initial cold area becomes hot in vertebra
B. In 111 labelled leucocytes is the best for acute infection
C. Tc 99m labelled leucocytes preferred for extremities
D. WBC scan is better than gallium scans
E. Uptake is increased in 24 hours

3. White cell scan in osteomyelitis

- FTTTT

4. Bone scan

A. Osteomyelitis may be cold
B. Myocardial infarction is hot
C. Lytic phase of Paget's disease is cold
D. 10% of metastases appear cold
E. Fibrous dysplasia is cold

4. Bone scan

- TTFTT

6. Bone scan – increased uptake is seen

A. Carcinoma of breast
B. Calcium containing gallstones
C. In the kidney in the presence of right to left shunt
D. Soft tissue in myositis ossificans
E. Asbestos is related pleural disease

6. Bone scan – increased uptake is seen

- TFTTT

7. Indication for bone scan

A. Shin splint
B. Spondylolysis
C. Plantar fasciitis
D. Paget's disease
E. Stress fracture

7. Indication for bone scan

- TTTTT

8. Bone scan

A. Within 2-6 hours after administration, there is uptake of 50% of isotope by skeletal system
B. Optimal images are obtained 10 hours after administration
C. The dose is 50mCi
D. Absorption occurs to the organic phase of the bone
E. New bone formation is the important factor deciding the isotope uptake

8. Bone scan

- TFFTT

10. Bone scintigraphy

A. Local extent of primary tumor can be demonstrated accurately
B. Stress fracture can be demonstrated in the presence of a normal x ray
C. More than 70% of isotope is taken up by kidney
D. In Paget's disease, osteoporosis circumscripta is cold
E. In fracture femur, absence of uptake indicates lack of blood supply

10. Bone scintigraphy

- FTFTF

11. Positive bone scan in 19 year old male with severe pain in the leg may be due to

A. Stress fracture
B. Osteoid osteoma
C. Arterial compression
D. Chrondromalacia patellae
E. Brodie's abscess

11. Positive bone scan in 19 year old male with severe pain in the leg may be due to

- TTFFT

12. Increased uptake in bone scan

A. Normal breast
B. Normal thymus
C. Subphrenic abscess
D. Acute myocardial infarction
E. myeloma

12. Increased uptake in bone scan

- TFTTF

13. Bone scan

A. Blood pool images are obtained at 30 minutes after administration of isotope
B. Increased uptake is seen with increased flow
C. No renal excretion occurs with markedly increased uptake from any cause
D. Sweat produces high uptake in axilla
E. Tooth extraction causes high uptake

13. Bone scan

- TTFTT

14. Bone scan with abnormal uptake in thorax

A. Carcinoma of beast
B. Asbestos plaque
C. Alveolar microlithiasis
D. Chrondrosarcoma
E. pneumonia

14. Bone scan with abnormal uptake in thorax

- TTTTF

15. Abnormal bone scan uptake in kidneys

A. Renal vein thrombosis
B. Acute tubular necrosis
C. Pyelonephritis
D. Obstruction
E. Iron overload

15. Abnormal bone scan uptake in kidneys

- TTTTT

16. Increased uptake in bone scan is seen

A. Rhabdomyolysis
B. Bismuth injection
C. Subdural haematoma
D. Hyperparathyroidism
E. Lymphedema

16. Increased uptake in bone scan is seen

- TFTTT

17. Bilateral symmetric increased uptake in the diaphysis

A. Hyperthrophic pulmonary osteoarthropathy
B. Fluorosis
C. Hypothyrodism
D. Shin splint
E. Engelmann's disease

17. Bilateral symmetric increased uptake in the diaphysis

- TFFTT

18. Long segmental uptake in diaphysis

A. Paget's
B. Osteogenesis imperfecta
C. Melorheostosis
D. Arterial injection
E. Fibrous dysplasia

18. Long segmental uptake in diaphysis

- TTTTT

19. Features of super scan

A. Abnormal uptake in kidneys
B. Prominent uptake in the axial and appendicular skeletal
C. Visualisation of femoral cortices
D. Increased metaphyseal activity
E. Increased bone to soft tissue ratio

19. Features of super scan

- FFTTT

20. Causes of superscan

A. Hyperthyroidism
B. Hypoparathyroidism
C. Osteoporosis
D. Osteomalacia
E. Renal osteodystrophy

20. Cause of superscan

- FFFTT

21. Increased uptake in bone scan is seen in

A. Cerebral infarction
B. Unstable angina pectoris
C. Kidneys in gentamicin uptake
D. Cirrhosis
E. Accessory spleen

21. Increased uptake in bone scan is seen in

- TTTFF

Malignancy

A. In multiple myeloma the MDP bone scan is usually abnormal
B. Increased MDP bone scan uptake into metastatic deposits 2 months after chemotherapy indicates failure of response and progression of disease
C. A solitary rib hot spot in a cancer patient usually represent benign disease
D. A rib hot spot which is present over a year is likely to represent a simple healing fracture
E. A solitary area of abnormal uptake is a patient with a known primary cancer with normal plain film appearances is likely to be benign

Malignancy

- TFFFT

Bone scanning in malignancy

A. A malignant superscan requires more time to acquire the image
B. It is possible to distinguish a malignant superscan from one of metabolic bone disease
C. A superscan characteristically shows increased bone and renal uptake of MDP
D. Uptake of MDP into malignant bone disease relies solely on osteoblastic activity
E. It is not possible to distinguish benign from malignant vertebral collapse

Bone scanning in malignancy

- FTFFT

Bone scan in Paget's disease

A. A bone scan may be normal in Paget's disease
B. A bone scan is a method of choice to detect sarcomatous change in Paget's disease
C. Paget's very rarely only involves a single bone
D. The appearance of new lesions in a patient with established Paget's disease is a common recognized finding
E. A bone scan is the method of choice in assessing response to therapy in Paget's disease

Bone scan in Paget’s disease

- TFFFF

Bone scan in malignant disease

A. Patients with a known primary cancer and single skeletal hot spot have a roughly equal chance that it is benign or malignant
B. Patients with a known primary cancer and a single vertebral hot spot are unlikely to have malignant disease
C. A bone scan is a useful routine staging procedure of prostate carcinoma
D. A bone scan is a useful routine staging procedure for all patients with carcinoma of the cervix
E. A bone scan is a useful routine staging procedure for patients with stage III and IV breast carcinoma

Bone scan in malignant disease

- TFTFT

Bone scan in trauma

A. Tibial stress fractures are indistinguishable from shin splint on bone scan
B. Compartmental syndromes are indistinguishable from shin splint on bone scan
C. Reflex sympathetic dystrophy syndrome may show reduced uptake of MDP
D. 50% of non pathological rib fractures heal by one year
E. In talar coalition increased activity is usually at the site of coalition

Bone scan in trauma

- FFTFF

Bone scan in avascular necrosis

A. Septic arthritis of the hip in children may cause absent uptake of MDP into the femoral head
B. Osteomyelitis and bone infarction are easily distinguishable in sickle cell disease
C. Decreased MDP accumulation lasts for about 6 weeks following bone infarction in sickle cell disease
D. In chronic Perthes disease bone scan has a sensitivity and specificity of over 90%
E. Bone scan a few weeks following femora; neck fracture that is associated with higher uptake in the femoral neck indicates a favorable prognosis

Bone scan in avascular necrosis

- TFFFT

Bone scan in infection

A. Labeled WBC scanning is the method of choice in diagnosing osteomyelitis in HIV patients
B. Tc-99m HMPAO labeled WBC are preferable to In-111 labeled in detection of acute osteomyelitis of extremities
C. Tc-99m HMPAO labeled are the method of choice in diagnosing infection in children
D. It is not possible to carry out WBC scanning in severely neutropenic patients
E. WBC scanning is the method of choice in differentiating acute infarct from osteomyelitis in sickle cell disease

Bone scan in infection

- FTTFF

Increased uptake of MDP is seen in

A. Bone island
B. Osteopoikilosis
C. Fibrous dysplasia
D. Melorheostosis
E. Eosinophilic granuloma

Increased uptake of MDP is seen in

- FFTTT

Primary bone tumors

A. Vertebral hemangiomata may cause reduced or increased uptake of MDP into a vertebral body
B. It is possible to differentiate benign from malignant bone tumors from the degree of uptake of MDP
C. Bone scan is a good method for assessing the extent of involvement of a bone in osteogenic sarcoma
D. Bone scan is a reliable method of detecting soft tissue metastasis e.g.. lung in osteogenic sarcoma
E. Bone scan is a useful preliminary staging procedure in Ewing's sarcoma

Primary bone tumors

- TFFFT

Metabolic bone disease

A. The tie sign is a recognized feature
B. Reduced uptake of MDP into the diaphyses of long bones is a recognized feature
C. Osteomalacia causes a reduction in uptake of MDP as there is reduction of bone mass
D. Aluminum osteomalacia in hemodialysis patients causes a metabolic superscan in advanced disease
E. Treatment with biphosphonates may cause a reduction in MDP uptake into the skeleton

Metabolic bone disease

- TFFFT

Infection

A. Both infection and loosening of a hip prosthesis will show both increased vascularity and uptake on delayed images
B. Increased activity in relation to a knee prosthesis one year after surgery nearly always signifies infection or loosening
C. Cellulitis in the limb may cause increased uptake into bone on a bone scan
D. Uptake of Gallium into a bone at the site of increased uptake on a bone scan nearly always signifies infection
E. Bone scan are less sensitive in detecting osteomyelitis in neonates because of their small size

Infection

- FFTFF

Photon deficient bone scan lesions may be found in

A. Metastatic disease
B. Legg-Calve-Perthes disease
C. Infarct of sickle cell disease

Photon deficient bone scan lesions may be found in

- TTT

Pulmonary, gastric, and enhanced kidney activity on a bone scan is often seen in patients with

A. Myelosclerosis
B. Histocytosis
C. Metastases from osteogenic sarcoma
D. Hyperparathyroidism
E. Hyperthyroidism

Pulmonary, gastric, and enhanced kidney activity on a bone scan is often seen in patients with

- FFFTF

Spleenic uptake in bone scan is most often seen in

A. Cirrhosis with portal hypertension
B. Hypersplenism
C. Sickle cell disease
D. Lymphoma
E. Splenic abscess

Spleenic uptake in bone scan is most often seen in

- FFTFF