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Introduction to MSK Radiology

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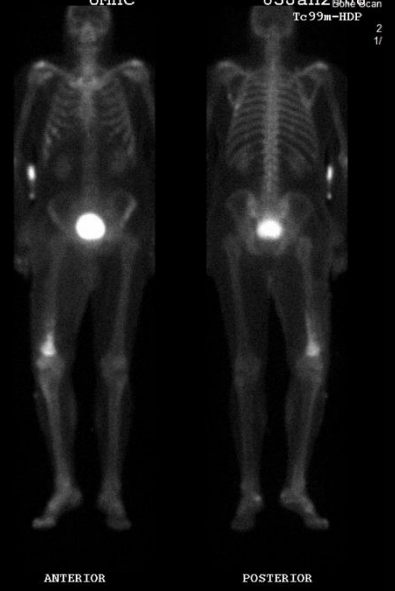
Outline

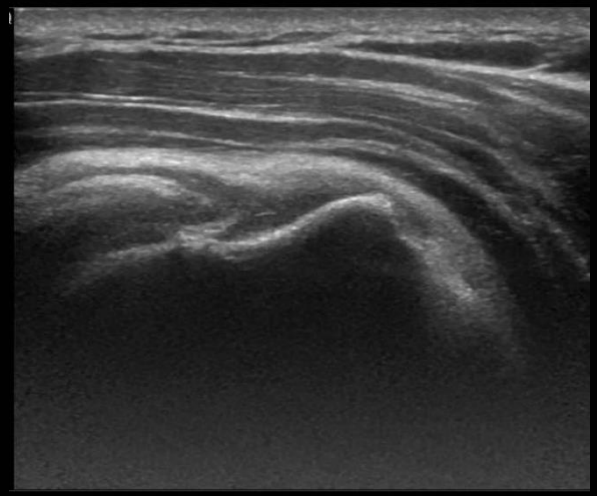
- Imaging modalities and their uses in MSK
  - Strengths, weakness, and pitfalls
- Fracture fundamentals
- Arthritis imaging
- Osteomyelitis
- Sports injury
- Musculoskeletal malignancy

- Disclosures: None

Available imaging modalities

- X-ray
- CT
- MRI
- Bone scintigraphy
- US





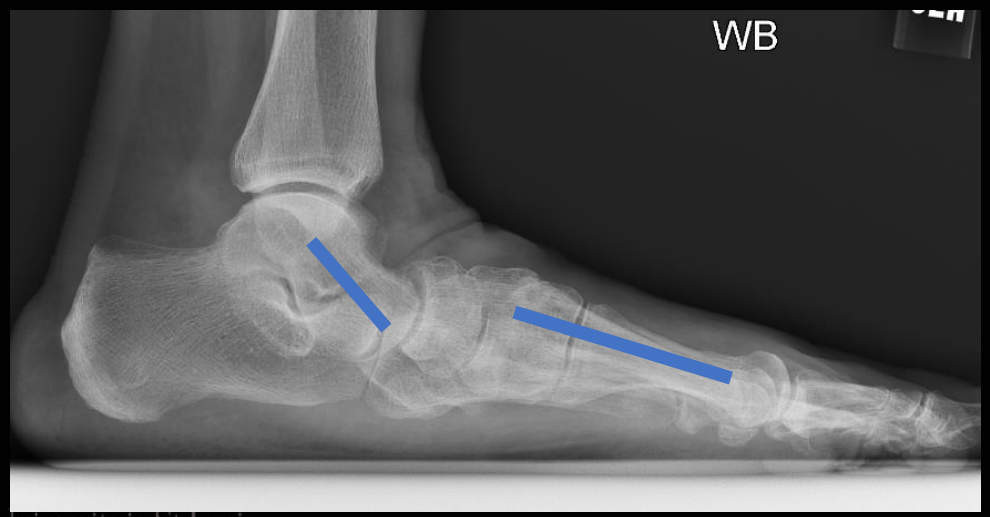
Radiographs

- Foundation of MSK radiology
  - All MSK workups should begin with radiographs
  - Please, read that one again.
- Critical information regarding:
  - Bone and joint alignment
  - Fractures and dislocations
  - Arthritis
  - Characterization of bone tumors, differential diagnosis
- In addition to being incredibly helpful, X-rays are also inexpensive, widely available, and portable

Radiographs

- Fundamentals:
  - Always obtain at least 2 views
  - Lower extremities should be weight bearing
  - Make sure the area of pain and adjacent joint are covered by the study
  - Review the images, don’t rely on the report
  - If in doubt please call and ask!

Radiographs: weight bearing alignment



Radiographs: stress views

Radiographs

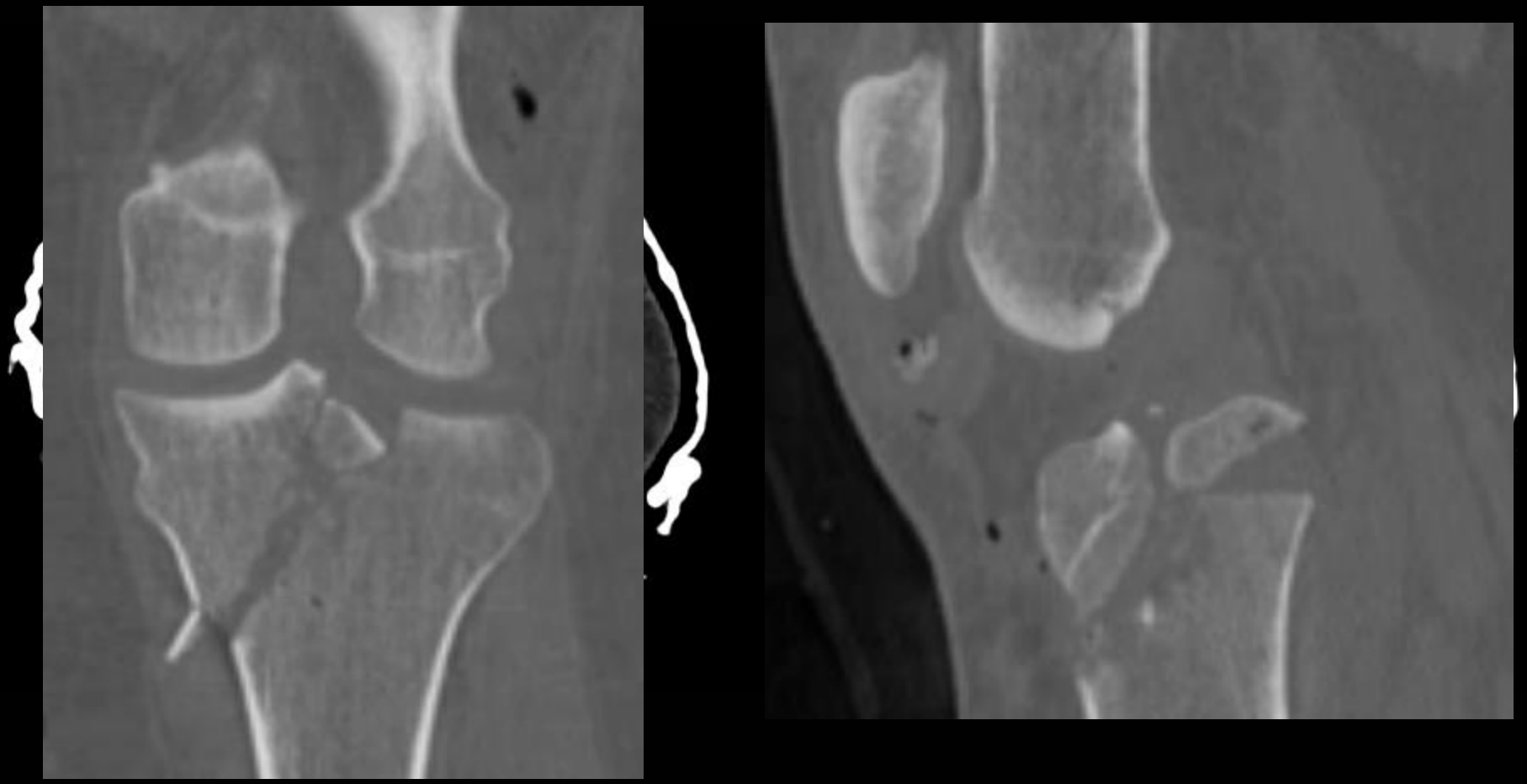
- Limitations:
  - Soft tissues not well evaluated
  - Non displaced fractures may be occult
  - Early disease – esp. infection and arthritis
  - Radiation
  - Marrow replacement is poorly seen unless the outer cortex is involved

CT

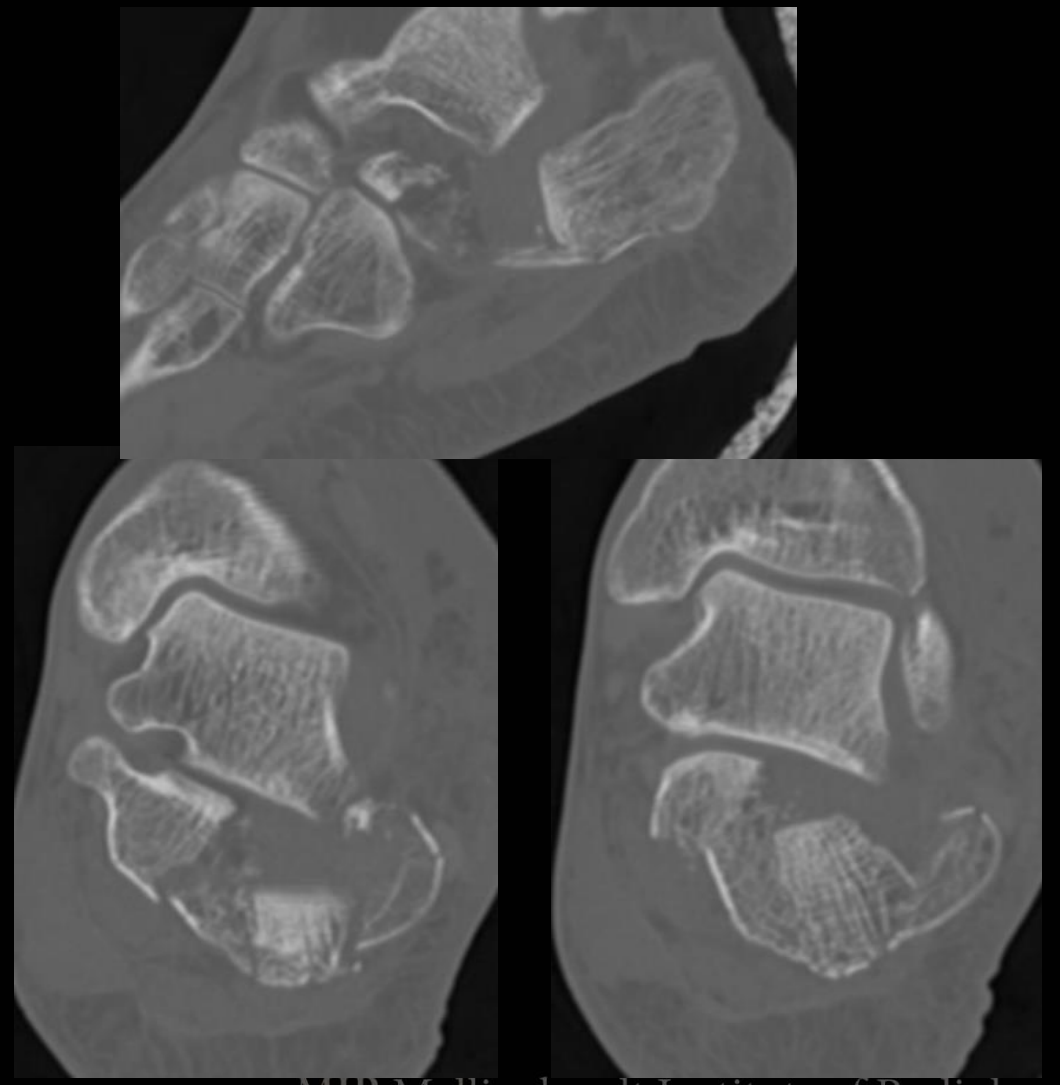
- Indications:
  - Complex fractures and orthopedic planning
  - MRI contraindications
  - Postoperative imaging
  - Soft tissue infection/fluid collections – less soft tissue contrast than MRI, but faster and can cover a larger area
- Advantages:
  - Fine bony detail, 2D and 3D reformats
- Primary disadvantage is radiation dose

CT: Polytrauma and complex fractures

CT: Polytrauma and complex fractures



CT: Polytrauma and complex fractures



MRI

- Indications:
  - Advanced bone and soft tissue imaging
  - Ligamentous injury, articular cartilage
  - Local staging of malignancy
  - Radiographically occult fractures
  - Bone and soft tissue infection
  - Many more!
- Advantage is wonderful soft tissue contrast
- Unfortunately disadvantages will need another slide

MRI

- Disadvantages:
  - Expensive
  - Contraindications (big magnet)
  - Single body region
  - Time (20 min to an hour or more)

- Aneurysm clip(s)
- Any metallic fragment or foreign body
- Coronary and peripheral artery stents
- Aortic stent graft
- Prosthetic heart valves and annuloplasty rings
- Cardiac occluder devices
- Vena cava filters and embolization coils
- Hemodynamic monitoring and temporary pacing devices, eg, Swan-Ganz catheter
- Hemodynamic support devices
- Cardiac pacemaker
- Implanted cardioverter-defibrillator (ICD)
- Retained transvenous pacemaker and defibrillator leads
- Electronic implant or device, eg, insulin pump or other infusion pump
- Permanent contraceptive devices, diaphragm, or pessary
- Cochlear, otologic, or other ear implant
- Neurostimulation system
- Shunt (spinal or intraventricular)
- Vascular access port and/or catheter
- Tissue expander (eg, breast)
- Joint replacement (eg, hip, knee, etc)
- Any type of prosthesis (eg, eye, penile, etc)
- Tattoo or permanent makeup
- Known claustrophobia
- Body piercing jewelry
- Hearing aid
- Renal insufficiency
- Known/possible pregnancy or breast feeding

MRI

- Basic physics:
  - Contrast in MR images depends on the number and magnetic properties of hydrogen atoms
  - Patient is placed in a magnetic field
  - Radiofrequency pulse is applied to spin protons out of phase to the applied magnetic field
  - There are two main measureable parameters of the nuclei as they line back up with the field
  - T1 and T2
  - Different scan parameters chosen to highlight different tissue properties

MRI

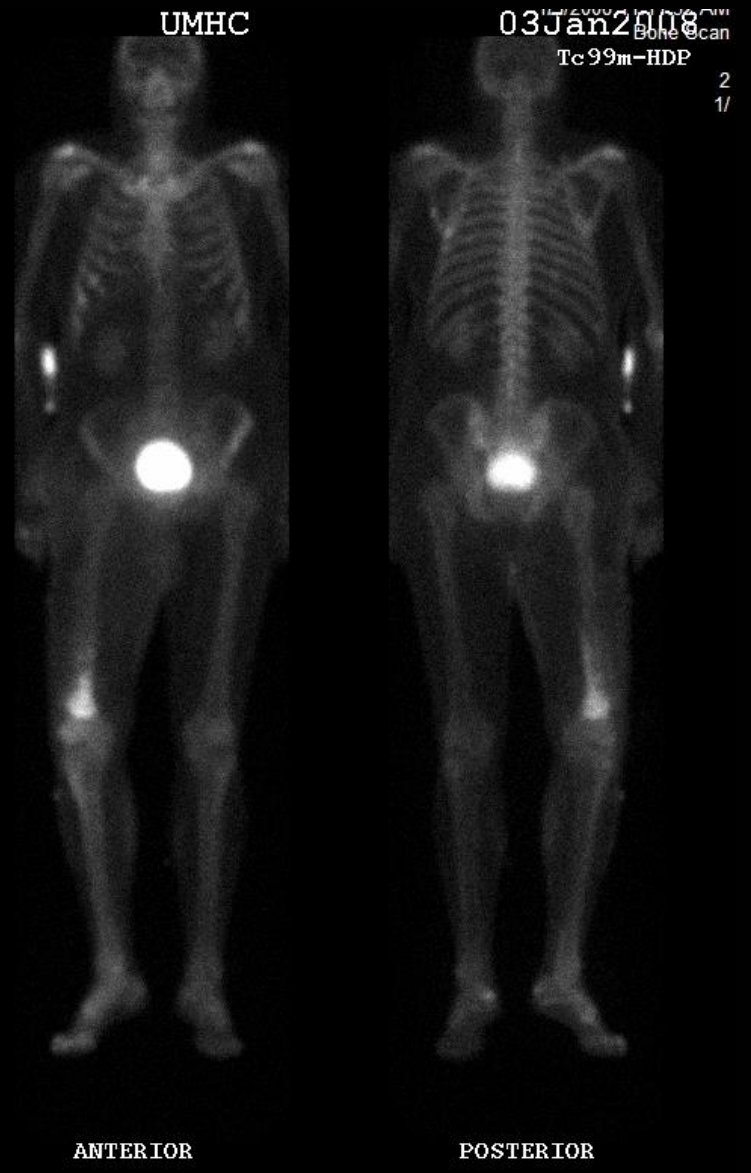
- T1 weighted images:
  - Without fat saturation subcutaneous fat and marrow fat will be bright
  - Fluid is dark
  - Muscle and most organs intermediate

MRI

- T2 weighted images:
  - Without fat saturation subcutaneous fat and marrow fat will be bright
  - Fluid is bright
  - Muscle and most organs intermediate
- Proton density:
  - Minimizes T1 and T2, mainly used for menisci and other MSK applications

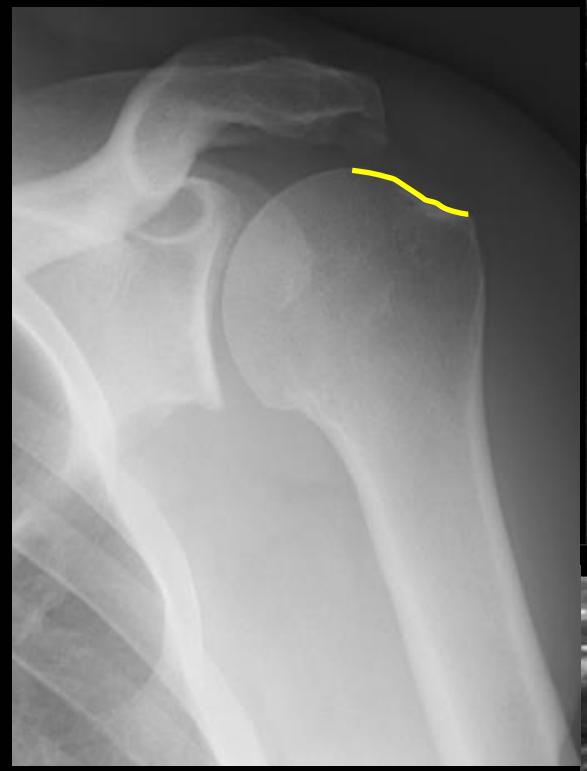
Scintigraphy (Bone Scan)

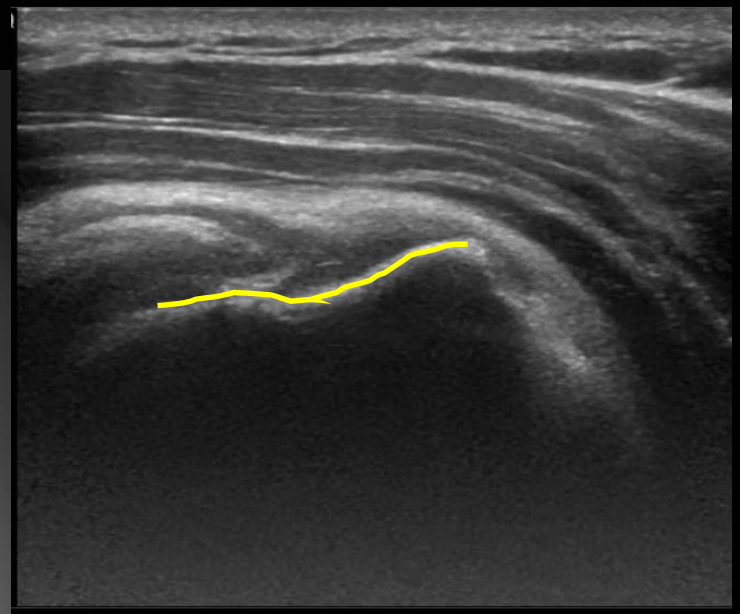
- Indications:
  - Cancer metastasis
  - Occult bone turnover: fracture or infection
- Advantages:
  - Very sensitive overview of the body, image the entire skeleton or an area of interest
- Limitations:
  - Lower resolution - SPECT/CT helps
  - Non-specific, need a second test
  - Soft tissues

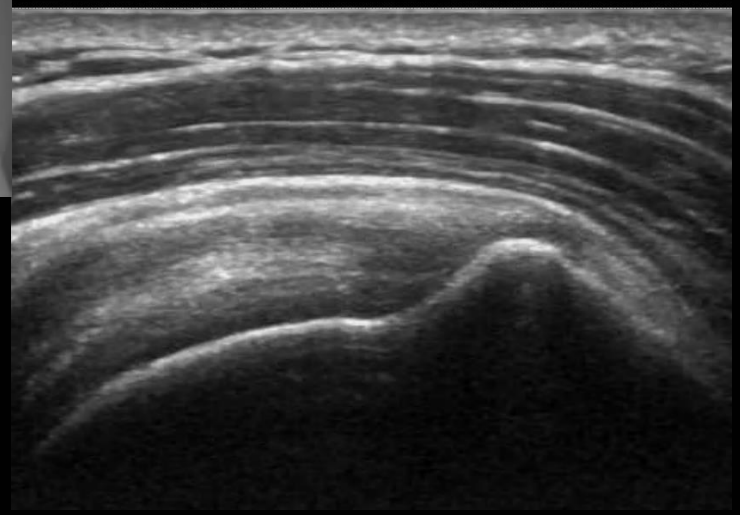


Ultrasound

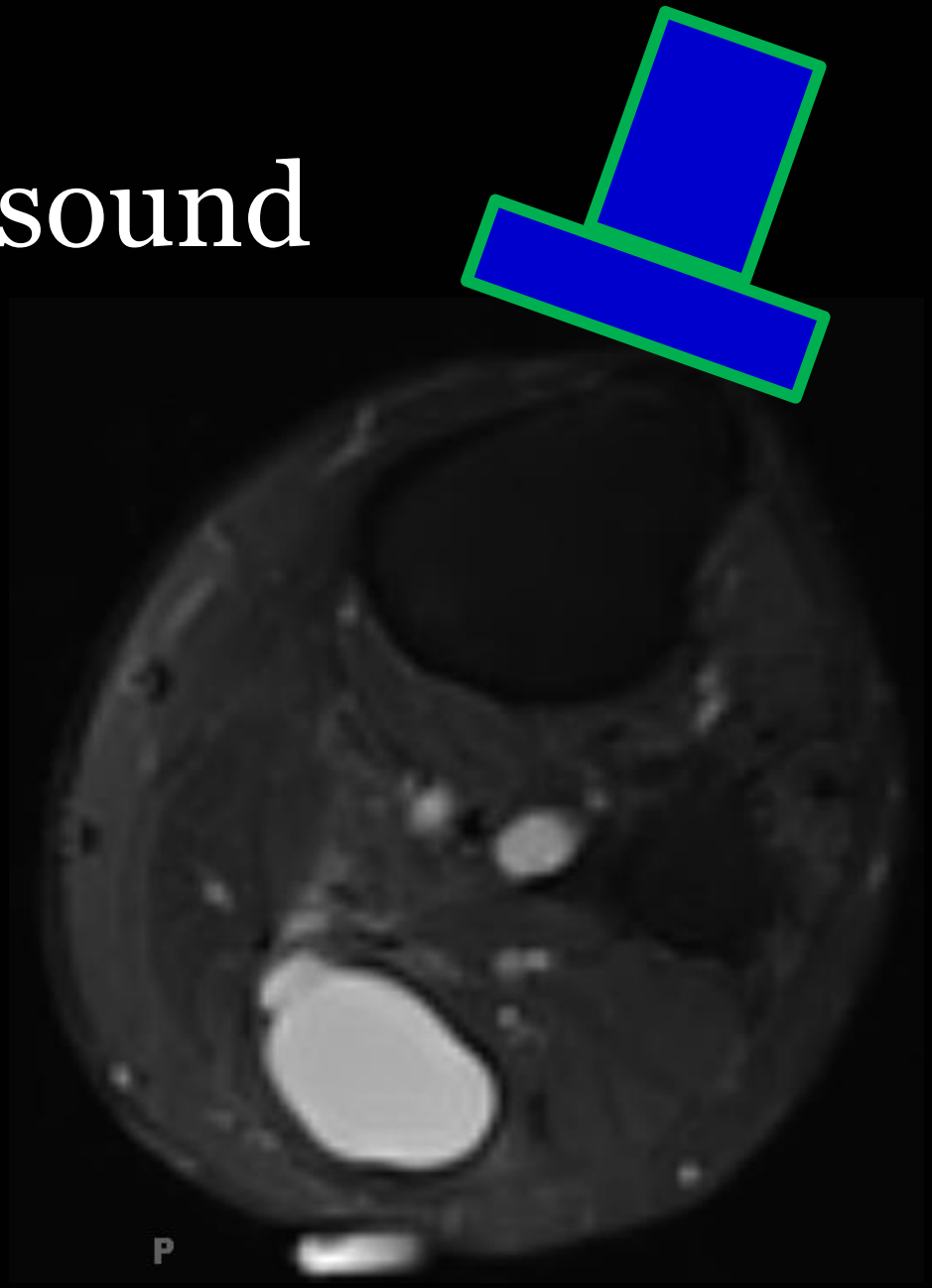
- Indications:
  - Soft tissue mass, fluid collection, tendon evaluation
  - Procedure guidance
- Advantages:
  - No radiation
  - Dynamic
- Disadvantages:
  - Superficial structures only
  - Extremely operator dependent

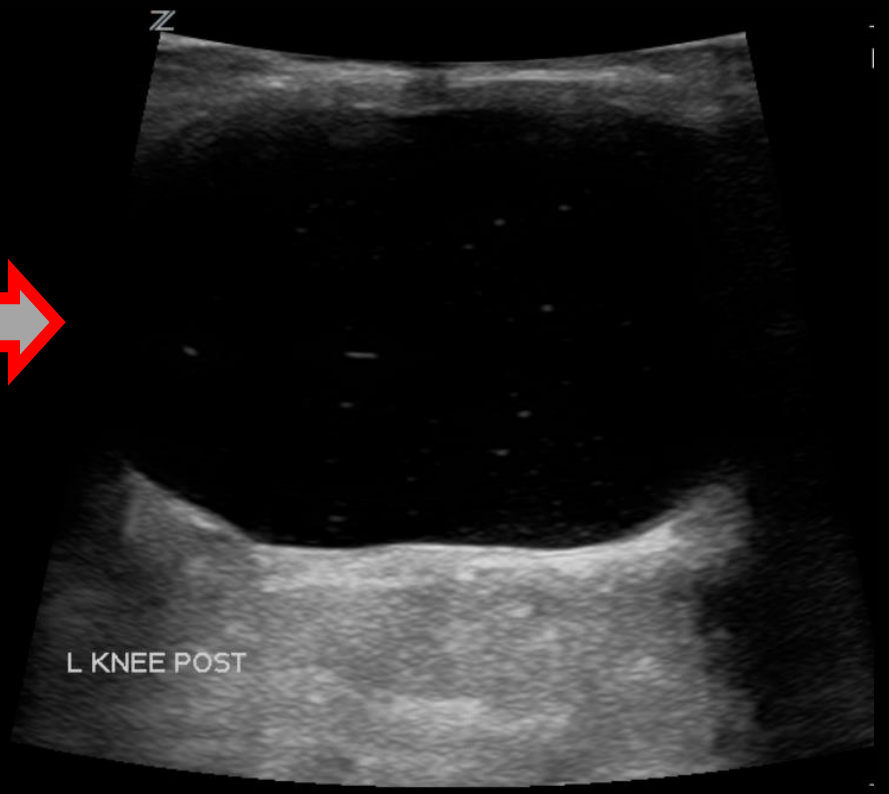




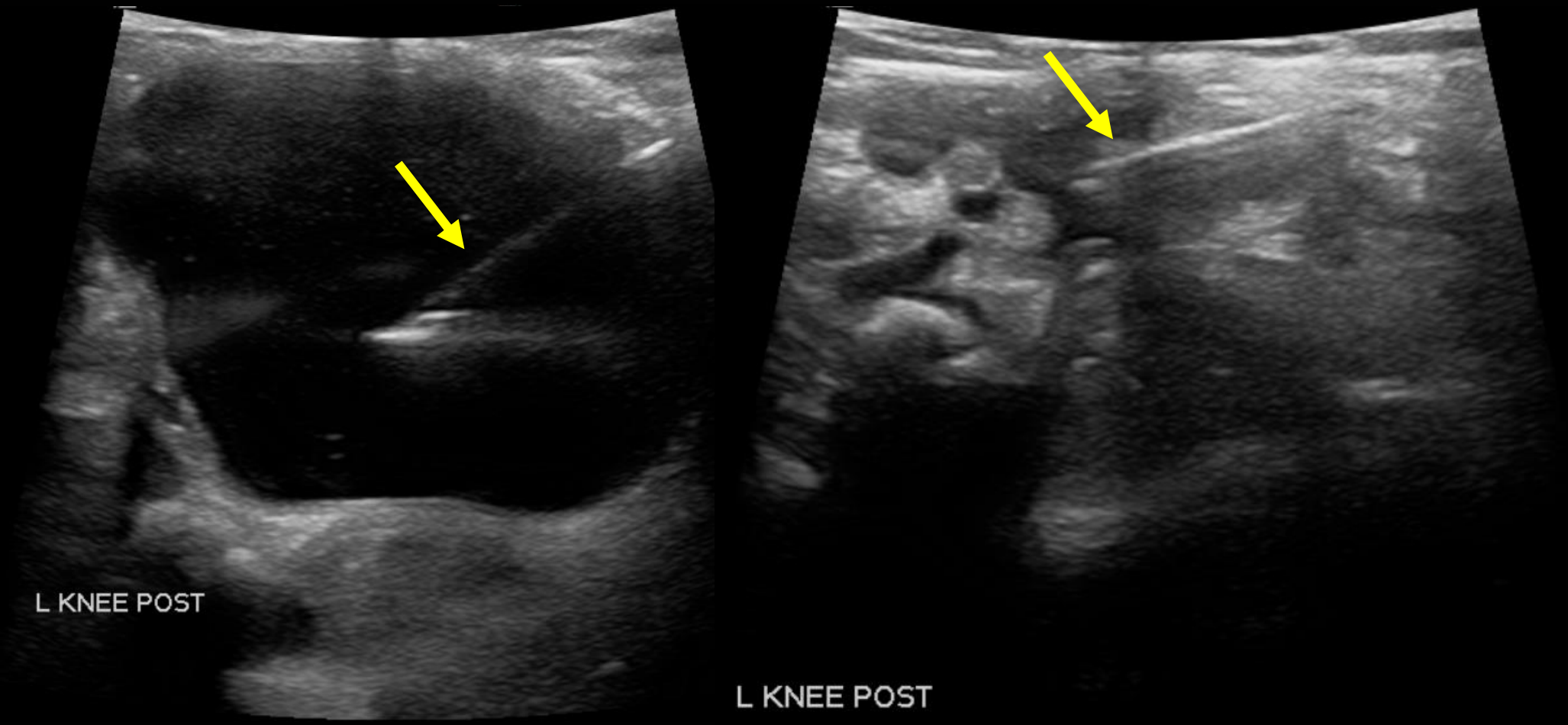


Ultrasound





Ultrasound



Trauma and fractures

- Radiographs are very sensitive
- Evaluation of fracture alignment and displacement
- At least 2 views
- Remember that fractures may be occult

Radiographic evaluation

- Ensure you have quality radiographs
  - Image quality
  - Correct coverage and correct body part!
- Establish a consistent pattern of evaluating the images

Radiographic evaluation

- Establish a consistent pattern of evaluating the images
  - Alignment
  - Bones
  - Cartilage spaces
  - Soft tissues
- Continuously develop and refine a mental checklist for each exam, body part, etc.

ABCs: Alignment

- General skeletal architecture
  - Size and # of bones
- General contour of bone
  - Smooth & continuous cortical lines
- Alignment of adjacent bones
  - Joint articulations

ABCs: Bones

- Bone Density
- Texture abnormalities
  - Trabeculae
- Local bone changes
  - Sclerosis, osteophytes

Fracture

- Cortical and medullary disruption

ABCs: Bones

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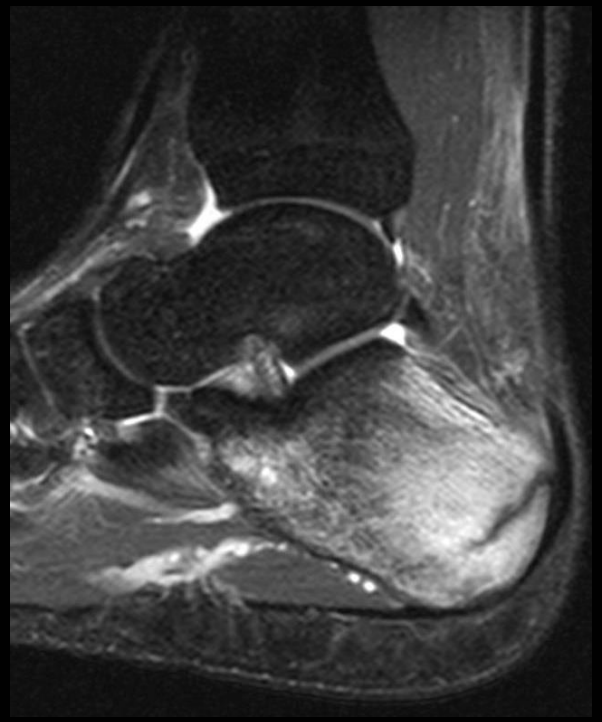
Fracture

- Cortical and medullary disruption



ABCs: Cartilage Space

- Joint space height

- Subchondral bone
  - Smooth surface, sclerosis, cysts

ABCs: Soft Tissue

- Muscles
- Fat pads/fat lines
- Swelling
- Periosteum
  - Periostitis (fx healing, tumor, infxn)
- Miscellaneous findings

Trauma and fractures

- Important to follow the cortical bone
- Smooth contours
- No unexpected overlap
- Location
- Displacement
- Intra-articular extension?

Trauma and fractures

- Weight bearing images of lower extremities are very helpful
- Lisfranc injury initially interpreted as normal without weight bearing

Non weight-bearing

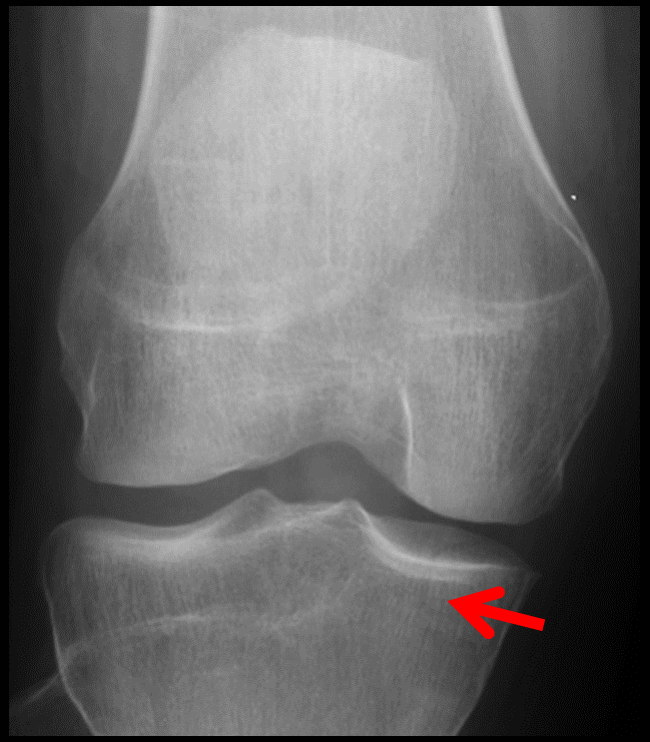
Weight-bearing

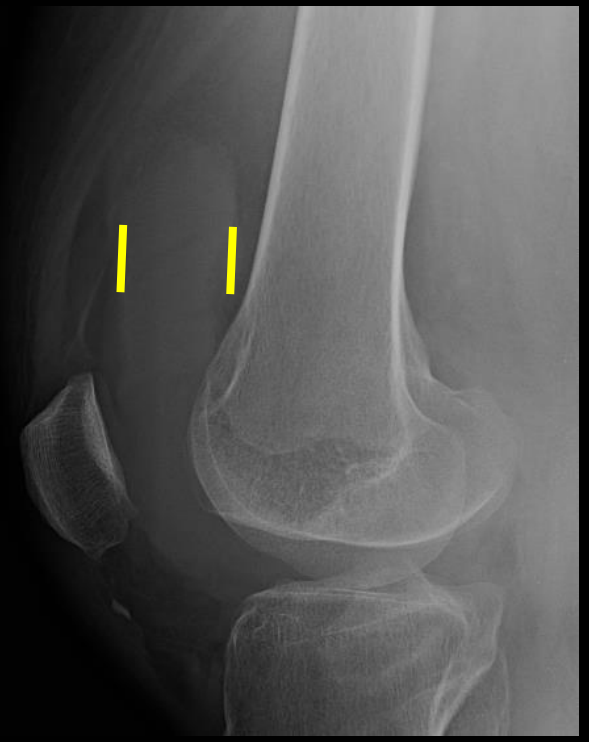
Trauma and fractures

- Soft tissues and joint effusions are important clues
- Knee and elbow
  - Effusion should raise concern for occult fracture in setting of trauma

Trauma and fractures

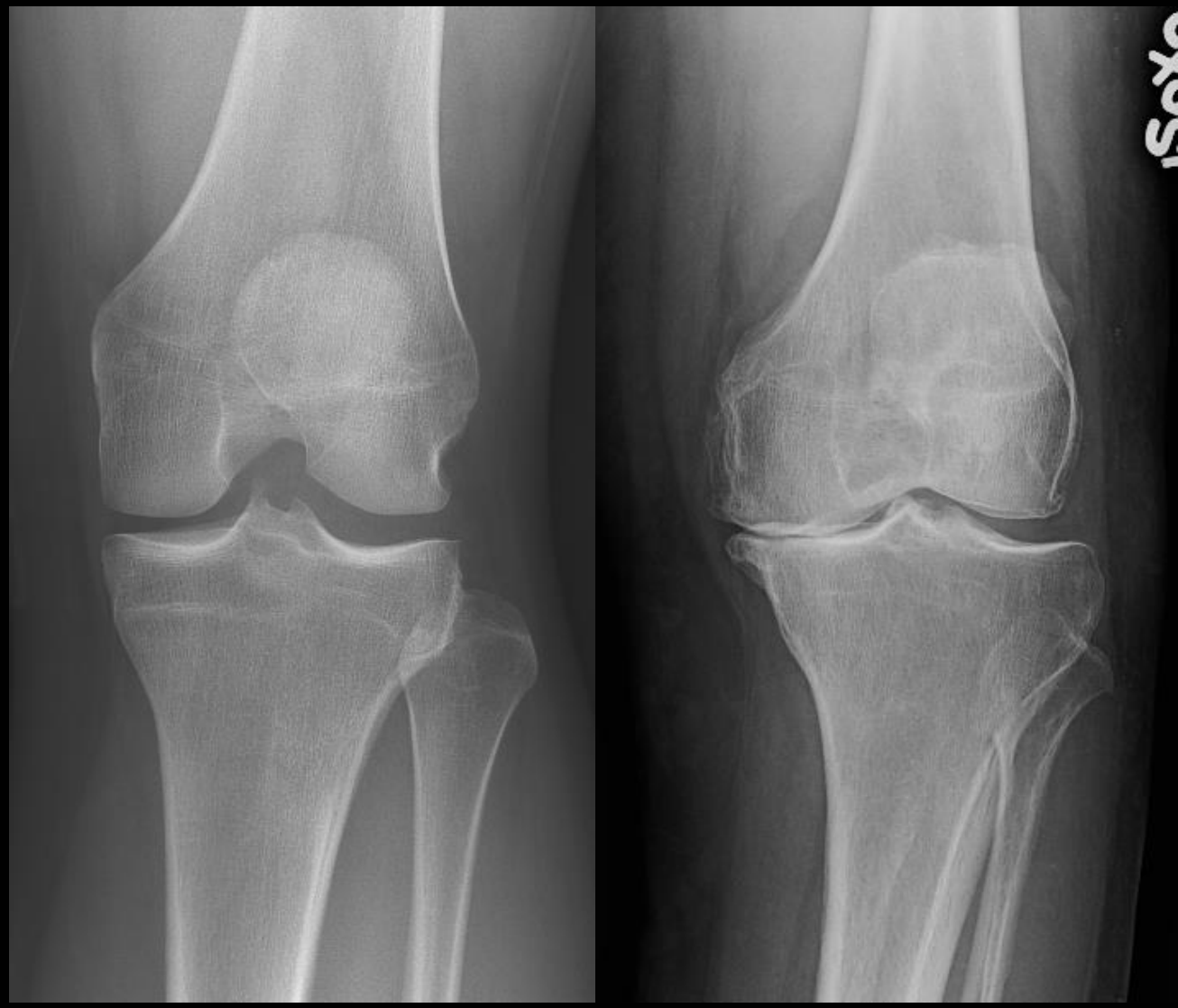
- Soft tissues and joint effusions are important clues
- Knee and elbow
  - Effusion should raise concern for occult fracture in setting of trauma
- Hip fracture:
  - Inability to bear weight should prompt further evaluation with MRI if radiographs are normal





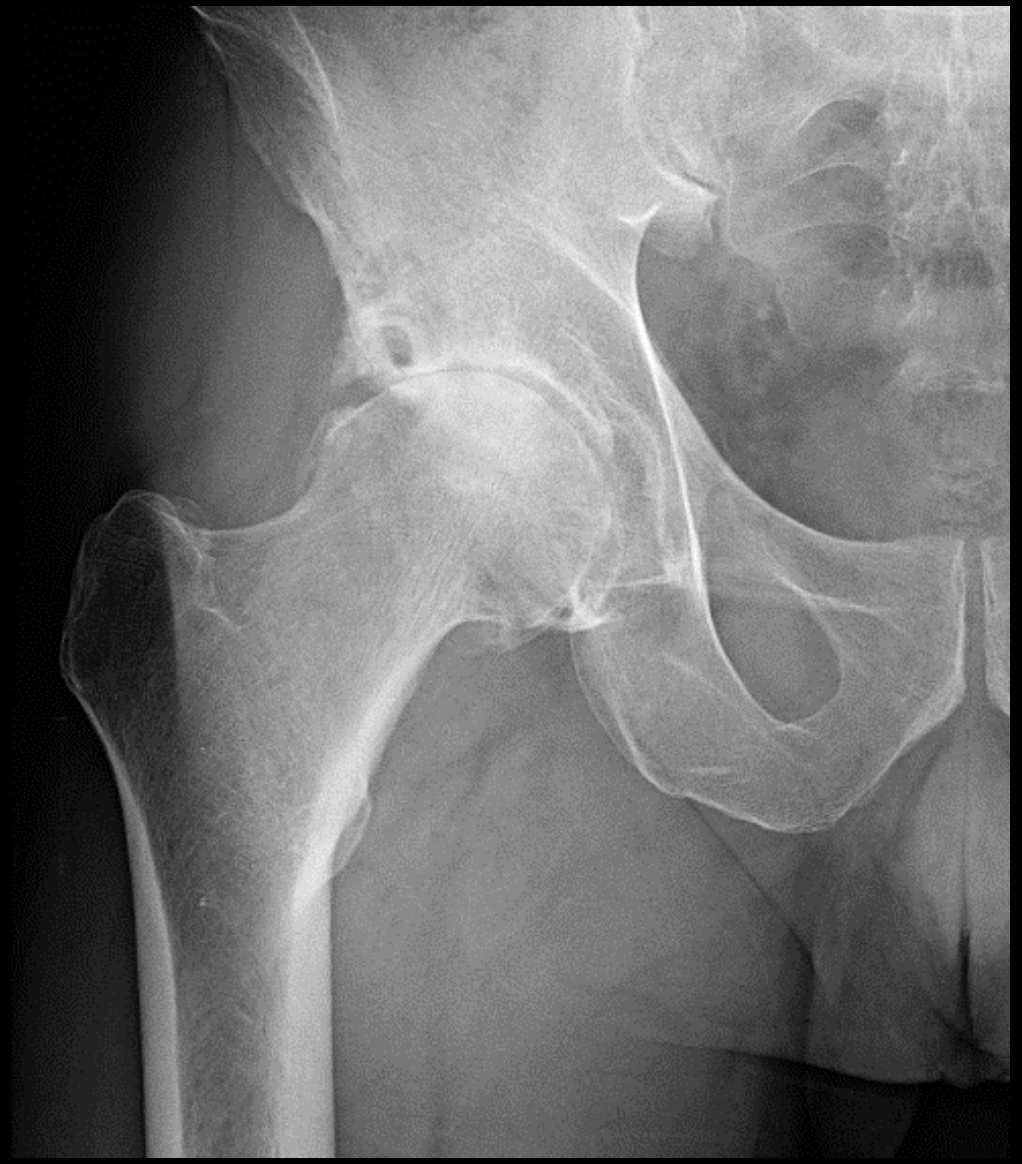
Arthritis Imaging

- Osteoarthritis
  - Articular cartilage damage
    - Non-uniform joint space narrowing
    - Subchondral sclerosis
    - Subchondral cysts
    - Osteophytes
  - Weight bearing and high use distribution



Osteoarthritis

- Most common cause of disability in older adults
- 50% of entire MSK disease burden
- Radiographically present in 30% of population >65 yo
- Worldwide estimates (>60 yo):
  - Men: 9.6%
  - Women 18.0%
- 80% with OA have movement limitation
- 25% with OA cannot perform ADLs

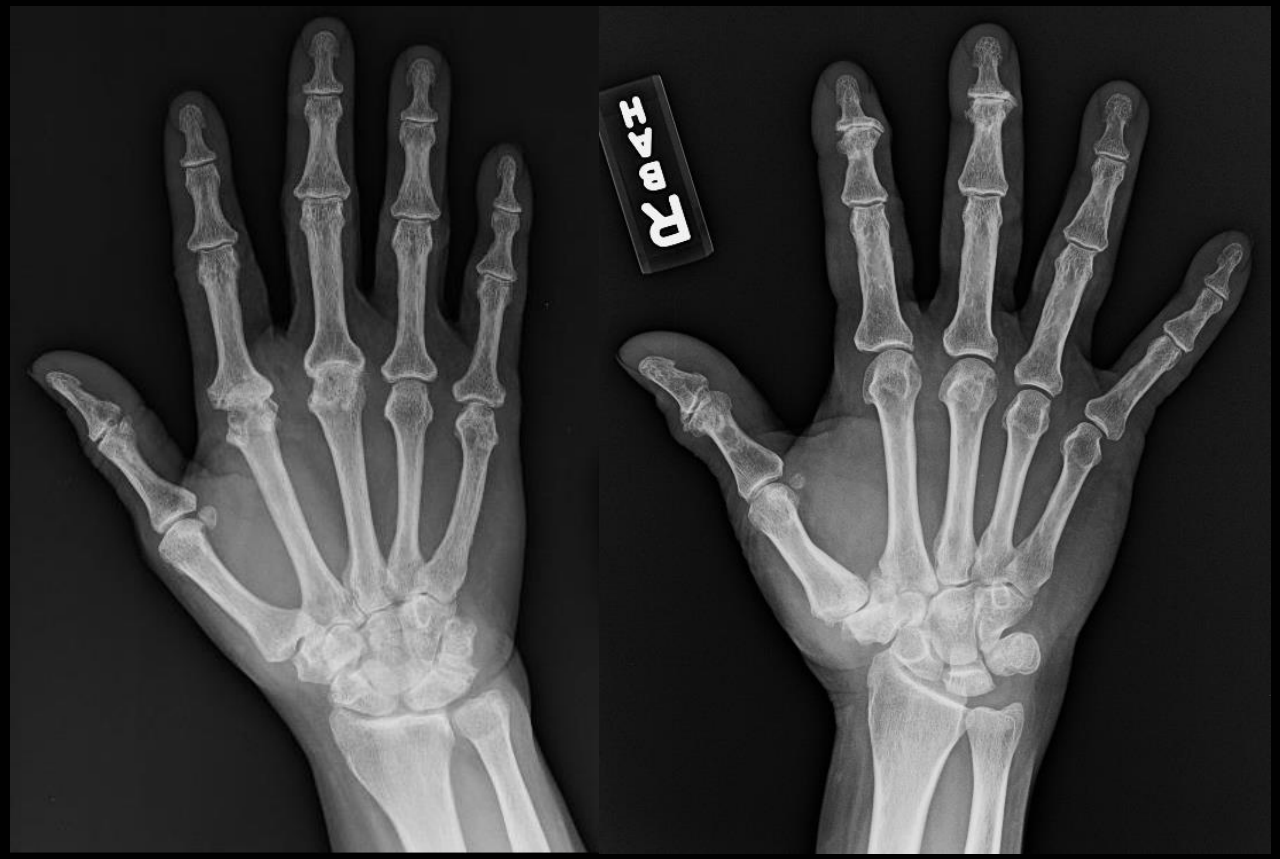


Osteoarthritis

- Radiographic severity correlates poorly with the patients current level of symptoms
- Bone marrow edema, synovitis, and associated insufficiency fractures may be better linked to symptoms

Arthritis Imaging

- Inflammatory arthritis
  - Rheumatoid arthritis and others
  - Immune dysregulation » activated synovium and pannus formation » cartilage and joint destruction
  - Uniform joint space narrowing
  - Bone erosion
  - Soft tissue swelling
  - Systemic disease



Clinical Diagnosis and Presentation

- Rheumatoid arthritis:
  - Persistent synovitis
  - Systemic inflammation
  - Autoantibodies
- 1% of adults, greatest prevalence women >65
- Clinical diagnosis based on 2010 classification criteria

Clinical Diagnosis and Presentation

- Prior 1987 criteria not helpful for early diagnosis and intervention
- Goal to prevent chronic erosive disease
- Diagnosis based on clinical findings, history, and lab values
- Sens and spec range from 50-97%
- Goal is to initiate therapy, no clear recommendation for initial imaging

- Clinical synovitis
  - Number of total joints
  - Small joint involvement
- Serologic results
  - Rheumatoid factor
  - ACPA
- Duration of symptoms
  - >6 weeks

ACPA: anti-citrullinated protein antibodies

New role(s) of imaging

- Radiographs helpful to establish a patients baseline
- Helpful also to investigate chronic disease of uncertain etiology
- MRI and US
  - Shown in multiple studies to improve clinical detection of active synovitis involving joints
  - When used in conjunction with clinical information can upstage the patient, increasing confidence of diagnosis of inflammatory arthritis
  - Also helpful in detecting subclinical inflammation which can guide changes in dose or therapy

Tamai M **Ann Rheum Dis** 2014;73(12):2219–2220

Rheumatoid arthritis

- Radiographic findings:
  - Soft tissue swelling
  - Juxta-articular osteopenia
  - Uniform joint space narrowing
  - Marginal erosions
- Distribution:
  - PIP, MCP
  - Carpus and ulnar styloid
  - Generally symmetric in distribution
  - Sparing of DIP (often superimposed OA)

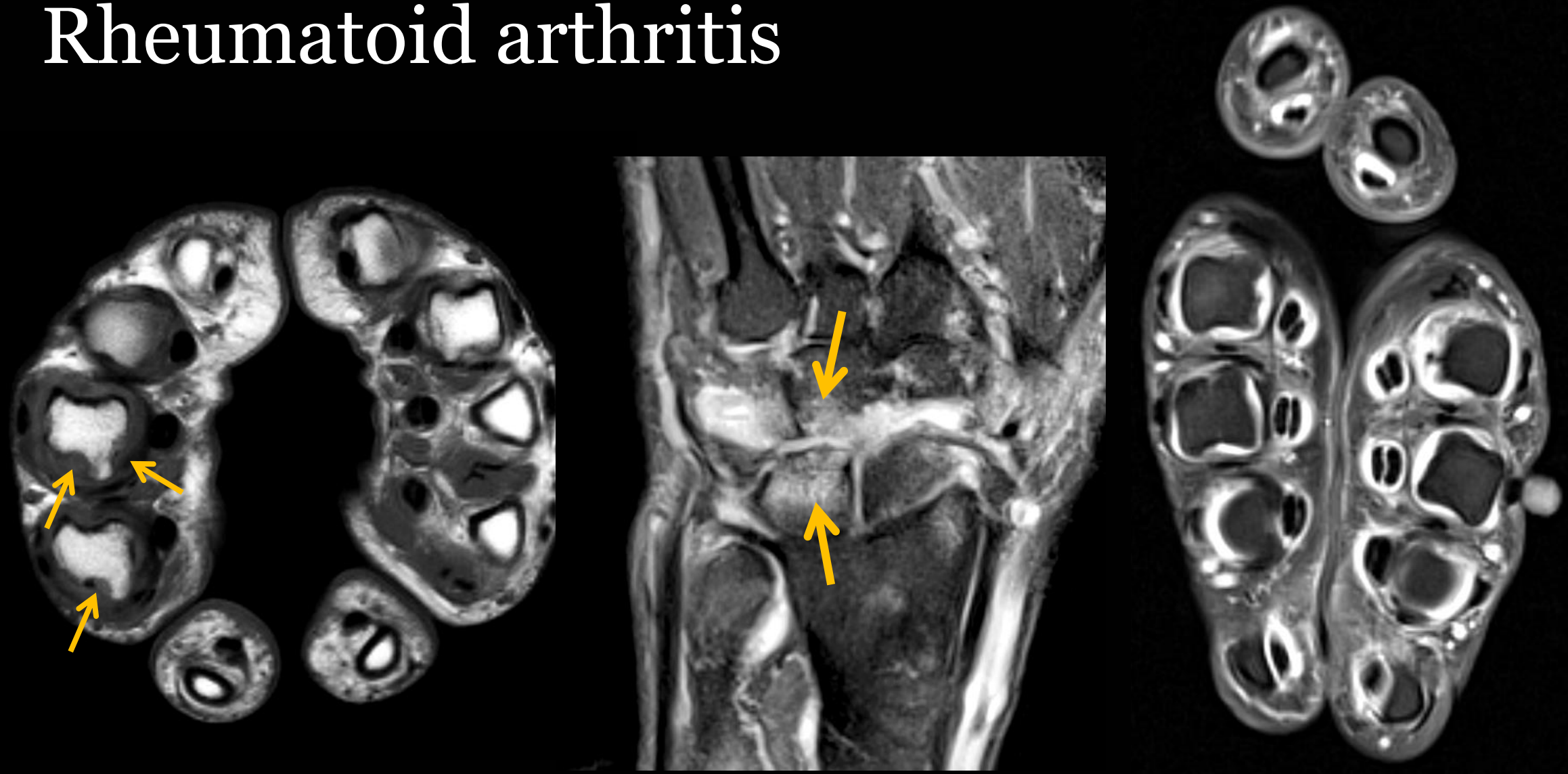
Rheumatoid arthritis

- Feet:
  - Similar to hands, subtalar joint and ankle
- Shoulder:
  - Superolateral marginal erosions
  - Distal clavicle erosions
  - High incidence of rotator cuff tears and cuff arthropathy
- Hip:
  - Uniform, concentric loss
  - Acetabular protrusio

Rheumatoid arthritis

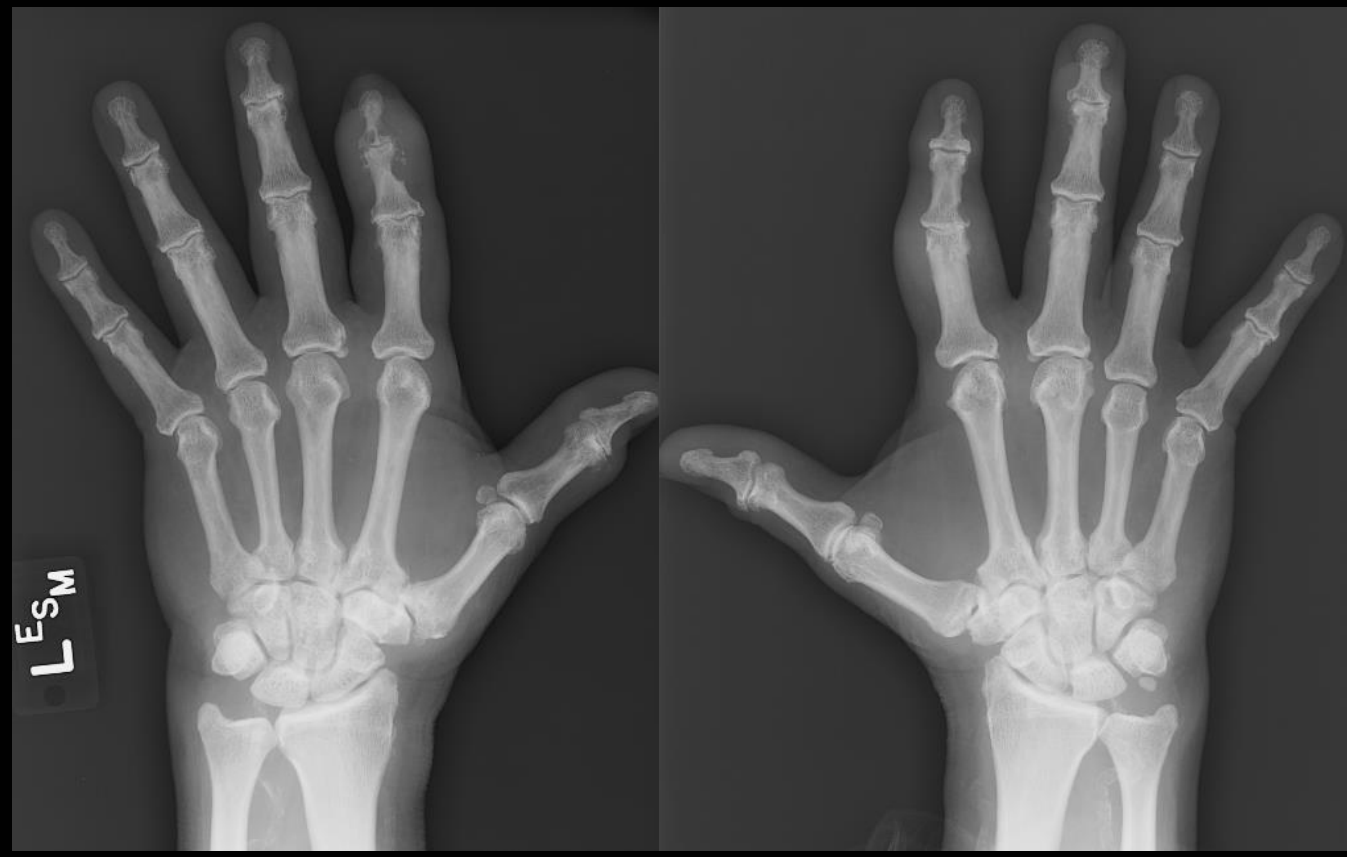
- Spine:
  - Cervical spine most frequently involved
  - Erosion of the dens
  - Atlantoaxial subluxation
  - Atlantoaxial impaction
  - Compression fractures
    - Osteoporosis and steroids
- Cardiovascular
  - Lung and vascular involvement, doubled average risk of CVA and coronary dz
- Increased incidence of lymphoma controlled for medication risk

Rheumatoid arthritis



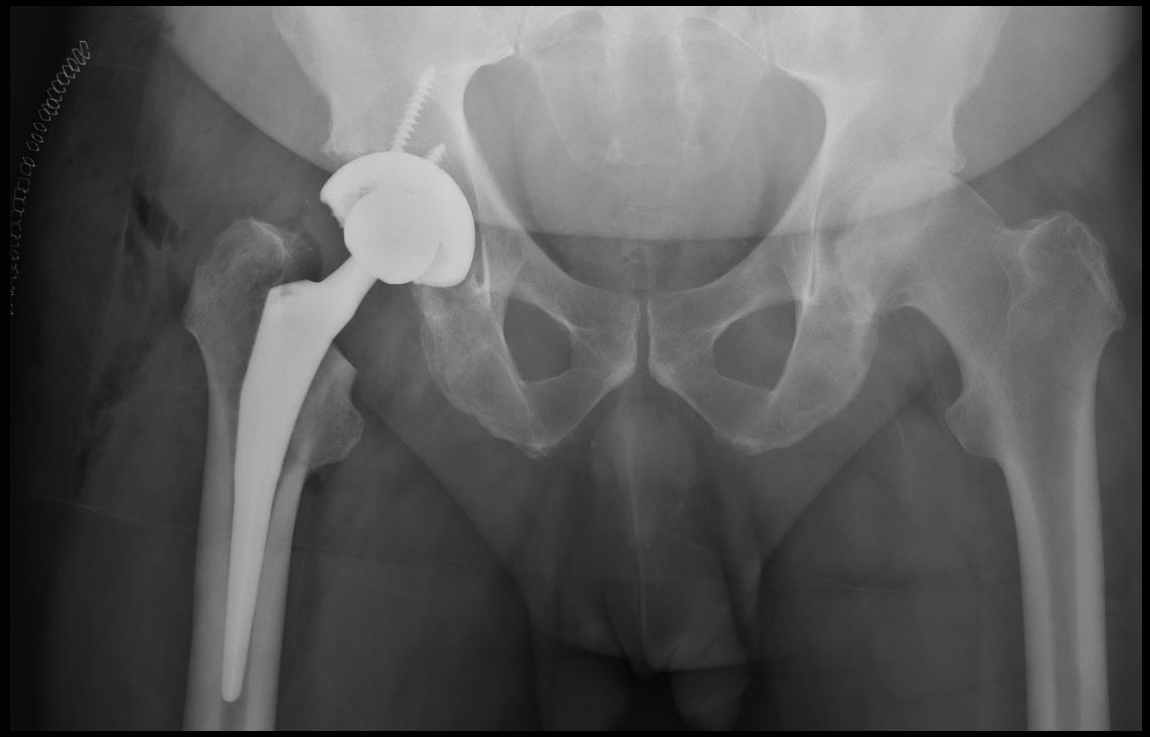
Arthritis Imaging

- Gout
  - Common crystalline arthropathy
  - Assoc. with metabolic, cardiovascular, and renal morbidity
  - Monosodium urate
  - DECT can be used to detect and quantify
  - Well defined erosions with overhanging edges
  - Soft tissue tophus may calcify
  - Radiographic findings typically not seen for years



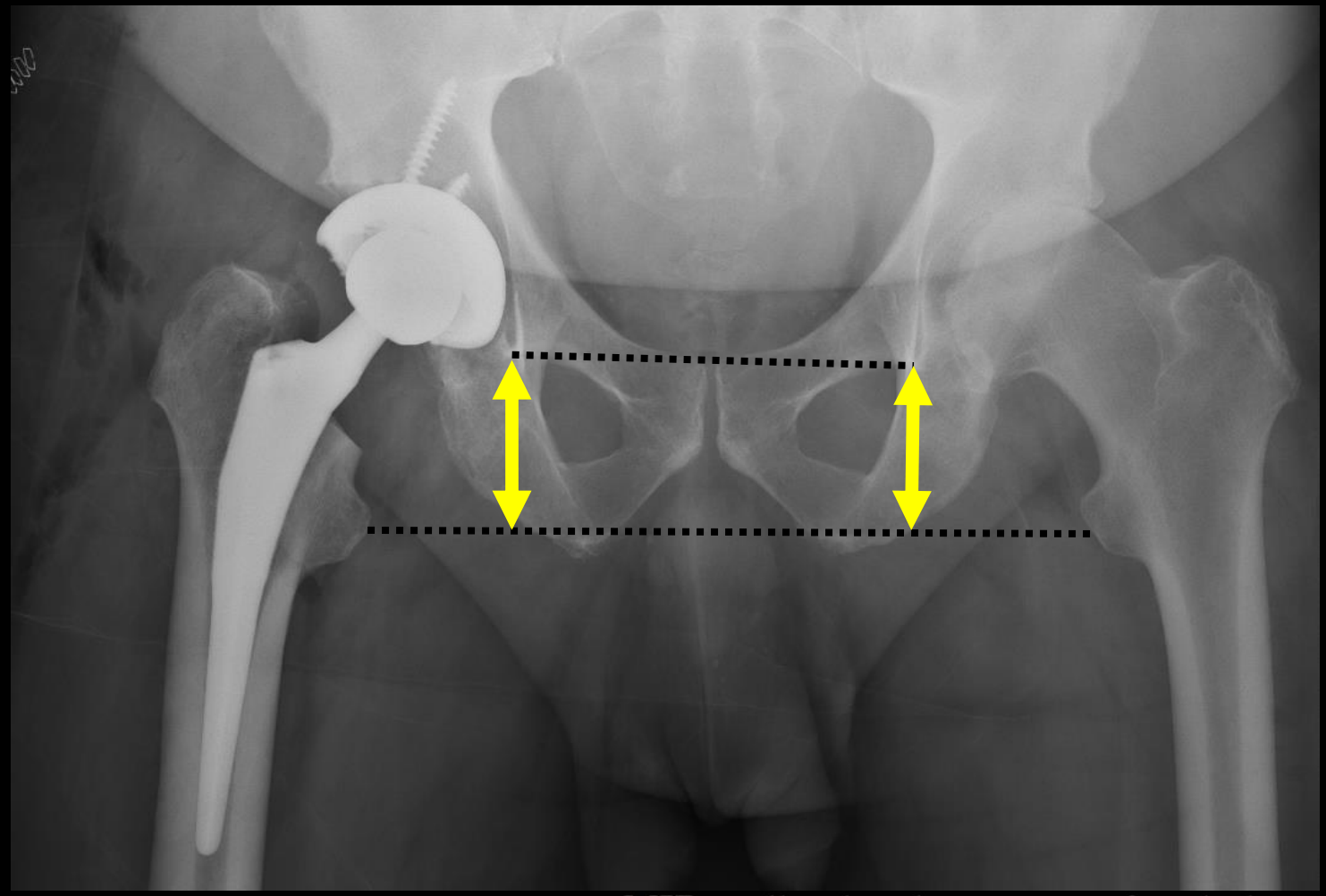
Joint Arthroplasty

- Over 370,000 hip replacements per year in US (2014 data)
- Expected to increase to ~630,000 by 2030
- ~60-70,000 revisions per year
- This is less than knee arthroplasty ~850k/yr in US
- Shoulder, ankle, etc.



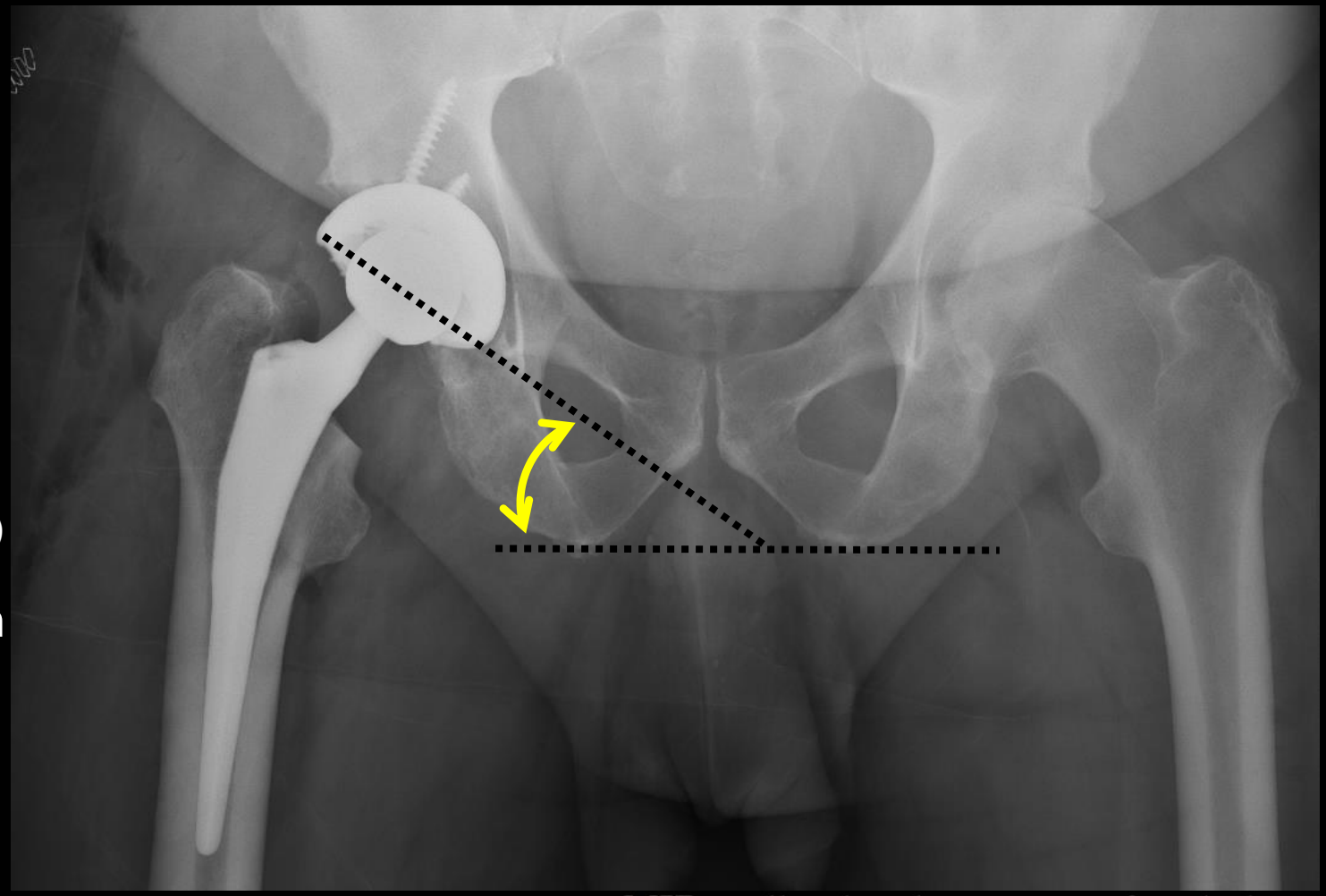
Initial Radiographic Assessment

- Evaluate:
  - Leg length
    - Distance between acetabular teardrop and center of lesser trochanter
    - No clear “acceptable” value, less than 1cm difference not usually symptomatic
  - Lateral acetabular inclination
  - Femoral component position
  - Centers of rotation
  - Acetabular anteversion



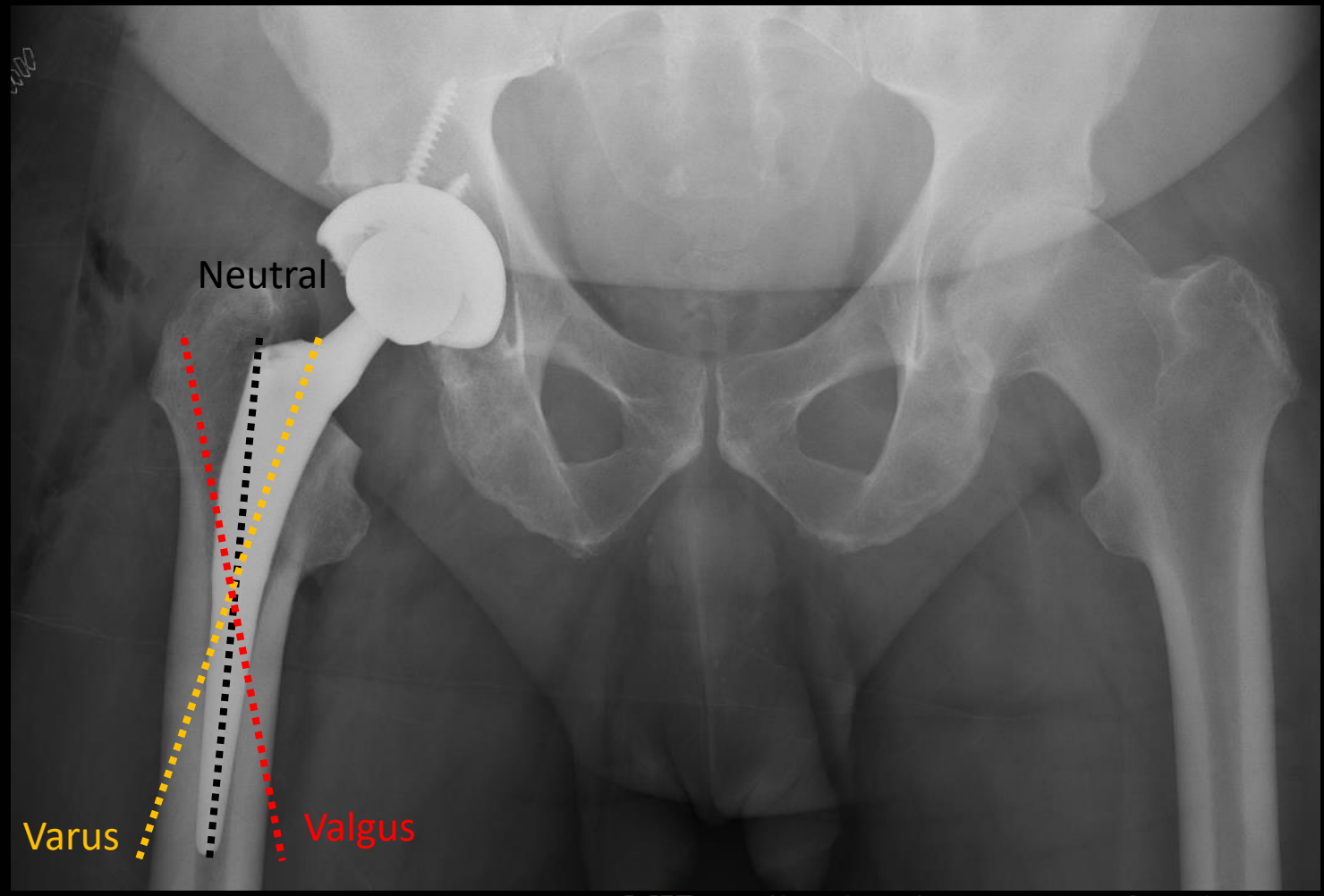
Initial Radiographic Assessment

- Evaluate:
  - Leg length
  - Lateral acetabular inclination
    - Lateral edge of cup to transischial tuberosity line
    - Normal 30-50 degrees
    - Lesser angulation (horizontal) is stable but decreased abduction
    - Greater angulation (vertical) increases risk of dislocation
  - Femoral component position
  - Centers of rotation
  - Acetabular anteversion



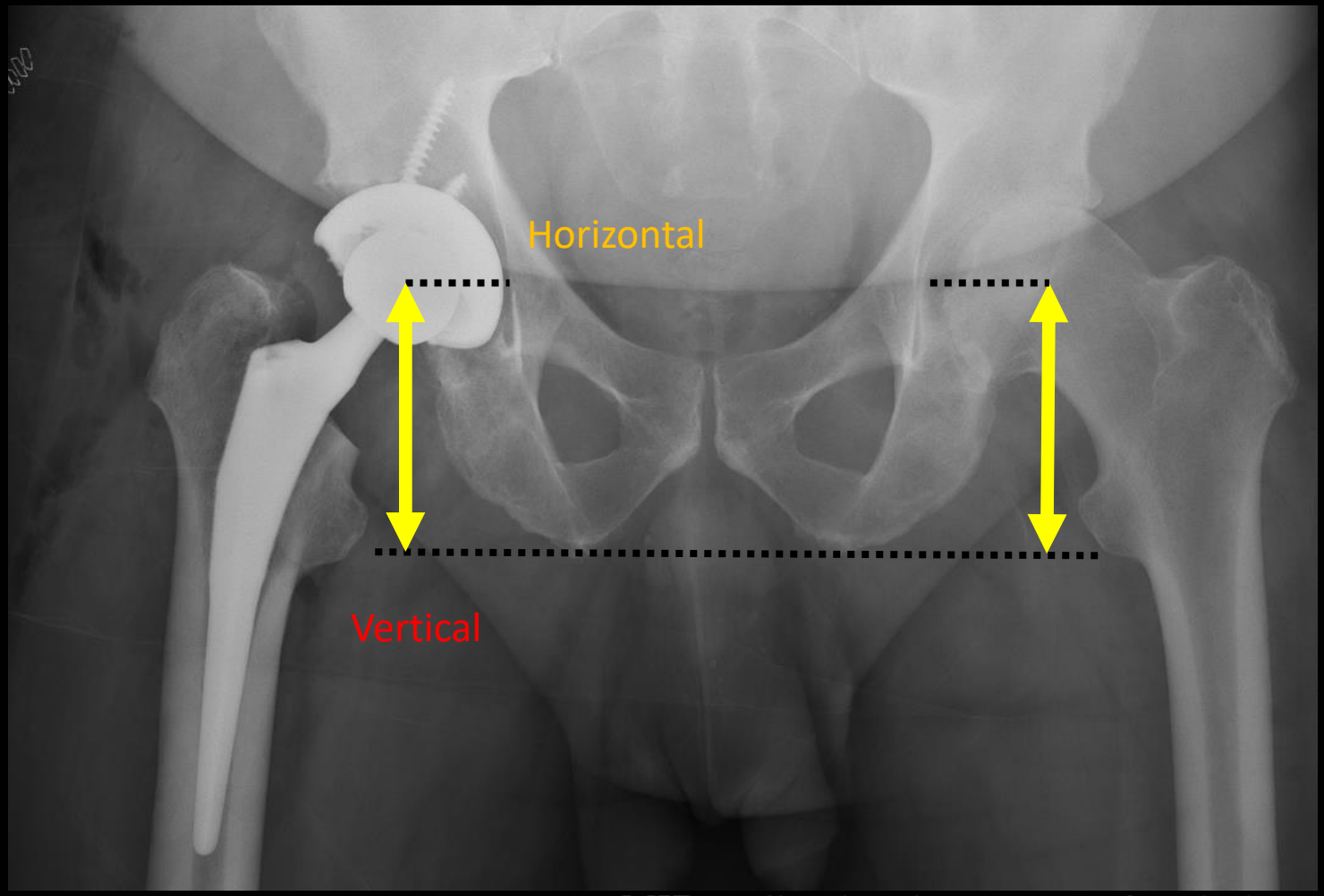
Initial Radiographic Assessment

- Evaluate:
  - Leg length
  - Lateral acetabular inclination
  - Femoral component position
    - Stem neutral within shaft
    - Tip center
    - Shoulders of stem appropriately positioned in femur
    - Failure and femoral fracture associated with varus
  - Centers of rotation
  - Acetabular anteversion



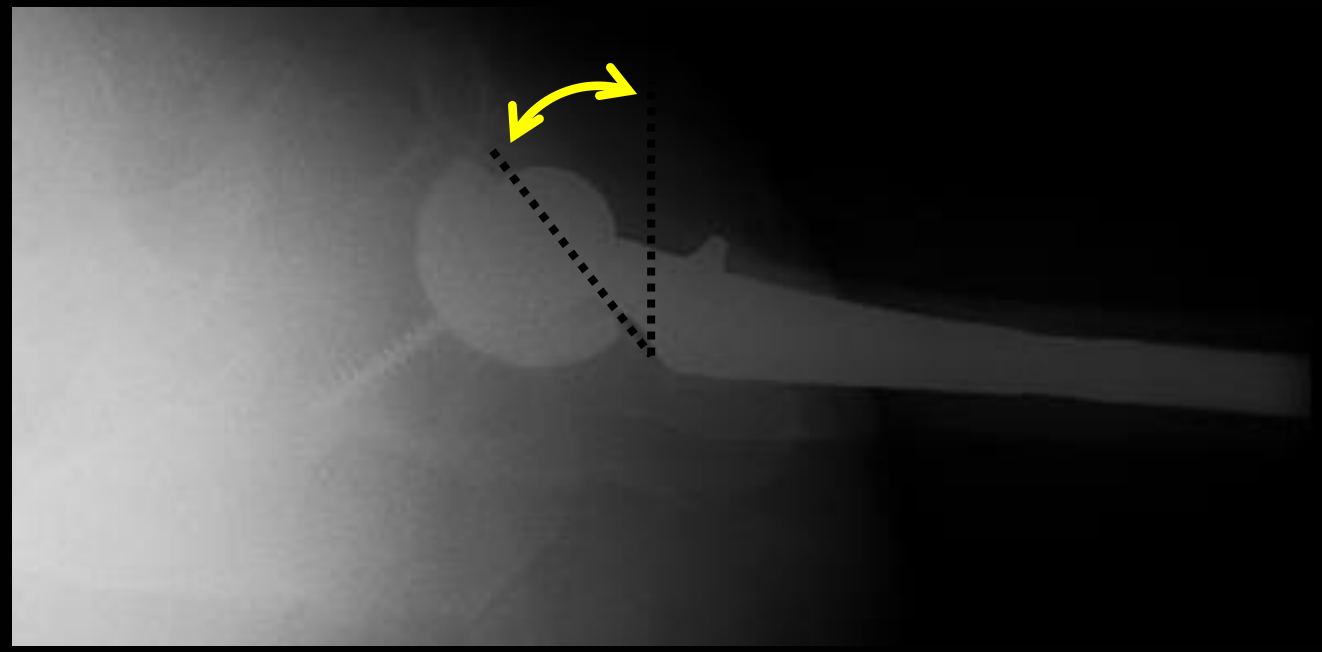
Initial Radiographic Assessment

- Evaluate:
  - Leg length
  - Lateral acetabular inclination
  - Femoral component position
  - Centers of rotation
    - Vertical: Center of head to transischial tuberosity line
    - Horizontal: Center of head to teardrop
    - Should be equal to other hip
  - Acetabular anteversion



Initial Radiographic Assessment

- Evaluate:
  - Leg length
  - Lateral acetabular inclination
  - Femoral component position
  - Centers of rotation
  - Acetabular anteversion
    - Lateral radiograph angle formed by face of acetabulum to vertical
    - Normal 5-25 degrees



Survival and Revision

- Estimated arthroplasty survival rates are approximately 94% at 5 years and 87% at 10 years
- ~60-70,000 revisions in the US per year
- Roughly 10-15% of surgeries are revisions

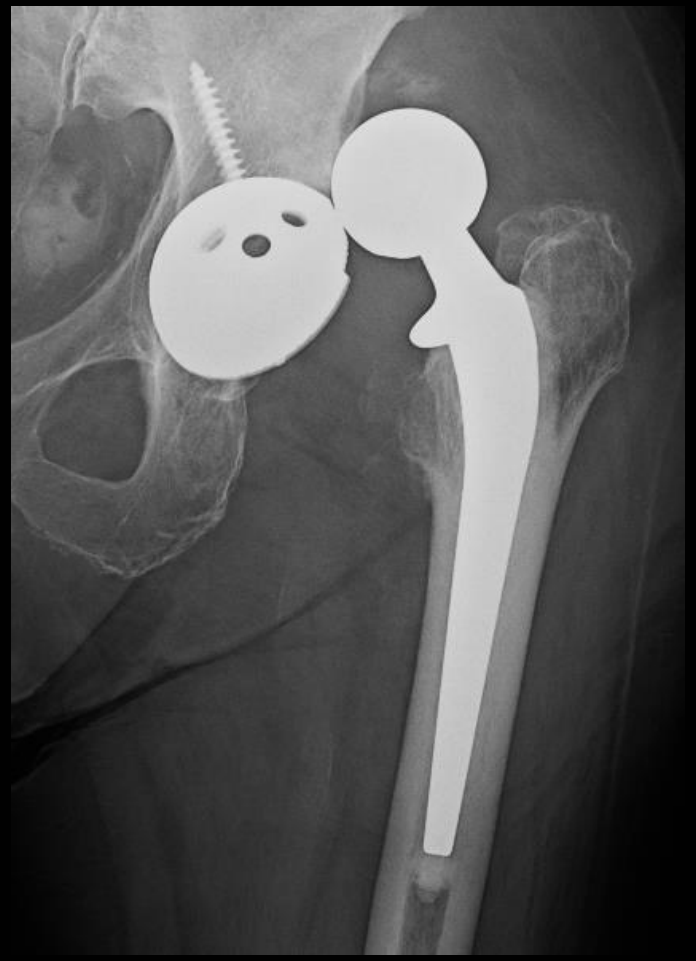
Labek G, Thaler M, Janda W, Agreiter M, Stöckl B. Revision rates after total joint replacement: cumulative results from worldwide joint register datasets. *J Bone Joint Surg Br* 2011; 93:293–297

Complications

- Early:
  - Periprosthetic fracture at placement
  - Instability
  - Infection
- Later:
  - Osteolysis and aseptic loosening
  - Instability
  - Fracture
  - Infection
  - Component failure
  - Soft tissue abnormalities

Complications

- Instability
- Many risk factors:
  - Patient's age, sex, compliance with activity restrictions
  - Surgical approach, technique, prosthesis design and placement
- < 3 months: in direction of surgical approach with initial weight bearing – lax pseudocapsule
  - Often reduced non operatively
- 3 months to 5 years can be related to component malposition – vertical acetabulum
- After 5 years surrounding soft tissue laxity is a contributing factor
- Instability beyond early perioperative period may require revision and/or operative reduction



Complications

- Options for recurrent dislocations
  - Change acetabular position
    - Decrease lateral inclination
  - Constrained liner
  - Upsize femoral head
- In this example the acetabular inclination decreased upon revision, and a constrained liner was added

Complications

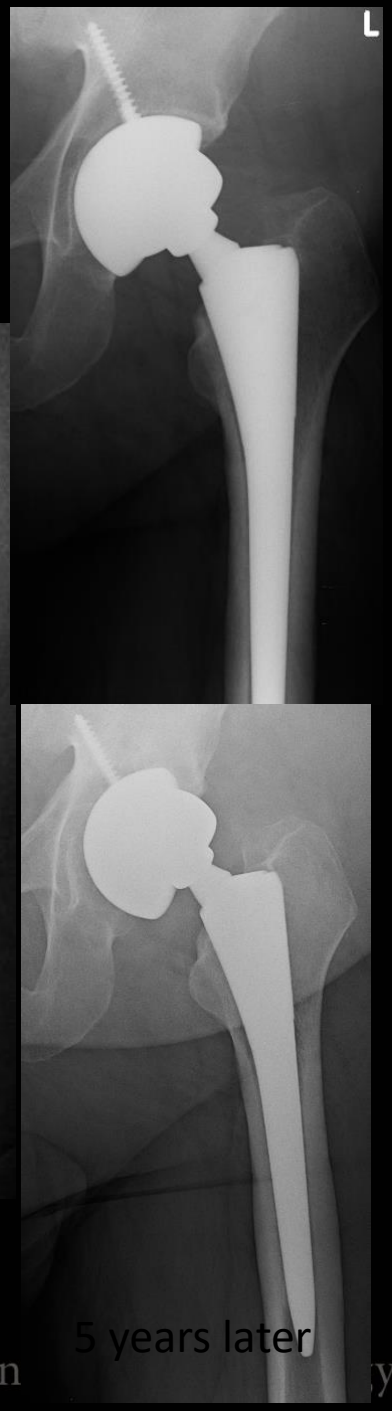
- Aseptic loosening:
- Loosening of an implant is the failure of the bond between the implant and the bone
- The prosthesis can then move and shift leading to pain and failure
- Aseptic loosening is loss of fixation in the absence of infection
- May be caused by inadequate initial fixation, mechanical loss of fixation over time, or biologic loss of fixation due to osteolysis

Complications

- Osteolysis
- Most common cause of arthroplasty failure after 5 years
- Biologic process initiated by macrophages resulting in a foreign body reaction
- May be a reaction to particles of bone cement, polyethylene, metals and ceramics
- First occurs where joint fluid containing these particles has access to bone, progresses like a membrane around the implant
- Shows up as lucency around the implant

Complications

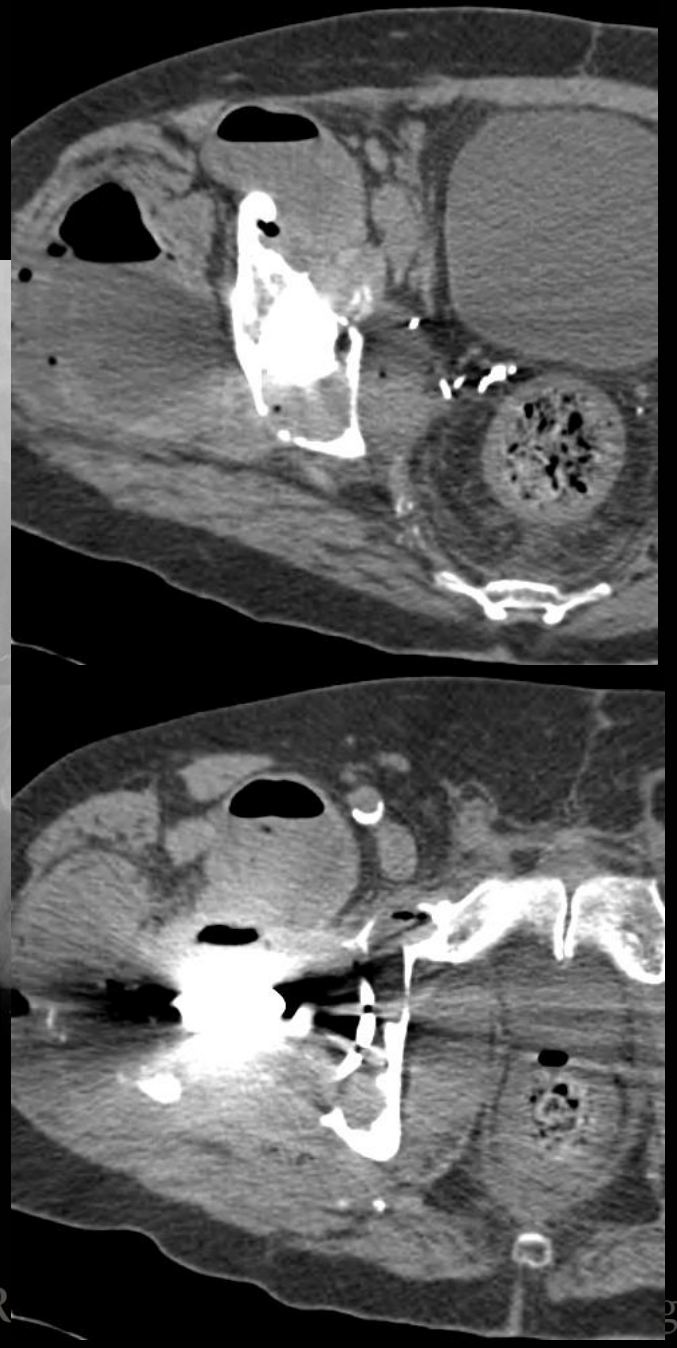
- Radiographic findings:
- Lucency at bone interface greater than 2 mm or progressive widening
- Loosening of the stem may result in subsidence into the femur > 1cm or progression after 1 year
- Loosening and osteolysis can involve the acetabular cup as well as the femur
- Component movement



5 years later

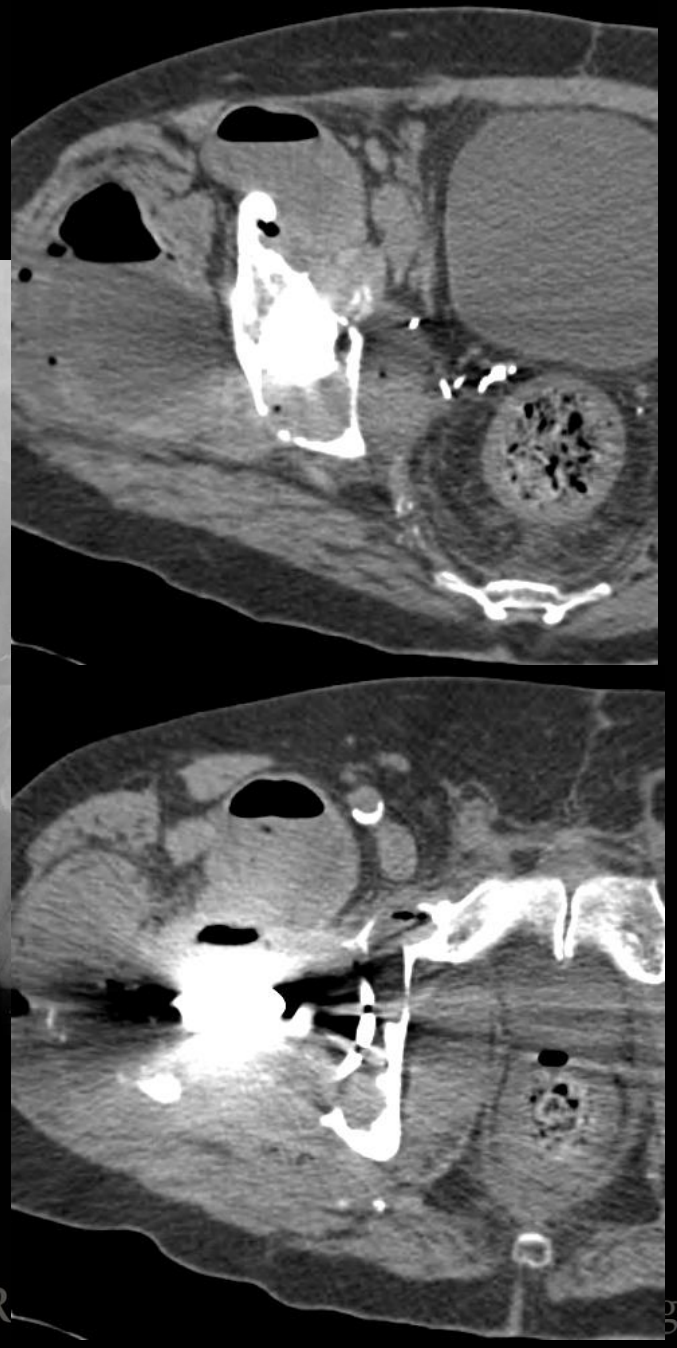
Complications

- Infection
- Rates are ~1-2%
- Higher after revision
- Aspiration of joint, labs (crp, sed rate, WBC)
- Often prolonged course
- Treated with staged revision
  - Explant infected arthroplasty
  - Antibiotic impregnated cement spacer arthroplasty
  - 6 weeks to 3 months of IV antibiotics
  - Revision



Complications

- Radiographic features of infection:
- Wide irregular periprosthetic lucency, bone destruction, fluid collections, sinus tracts, periosteal reaction
- Can look like aseptic loosening
- Time course of progression can be helpful, infection may progress more rapidly



Septic Arthritis

- Typically localized to a single joint
- Radiographic features compatible with inflammatory arthritis:
  - Osteopenia and erosion
  - Soft tissue swelling
  - Uniform joint space narrowing
- Remember initially joint space may to normal to increased (effusion) without osseous destruction or erosion
- Acute mono-articular arthritis should lead to joint aspiration

Osteomyelitis

- Radiographs are always first test
- If positive obviates need for more tests
- Helps to choose next test
- Insensitive to early (first 10-20 days) disease

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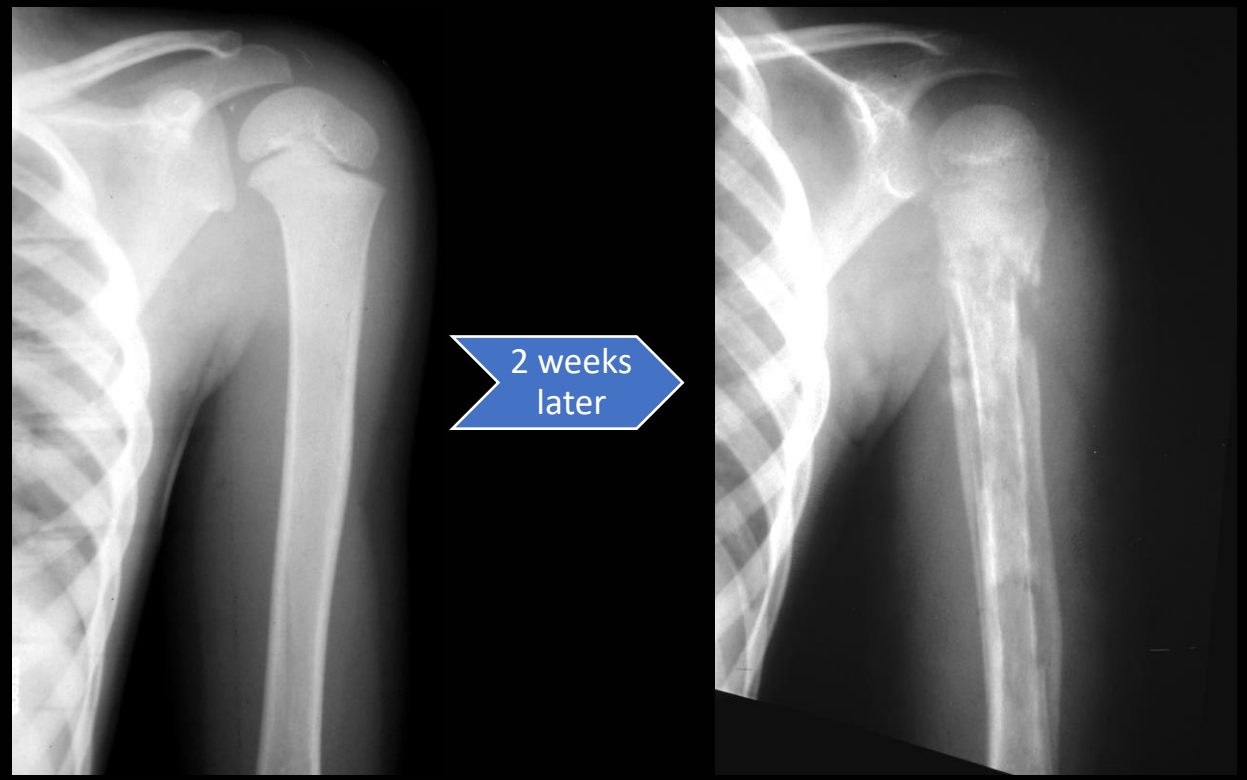
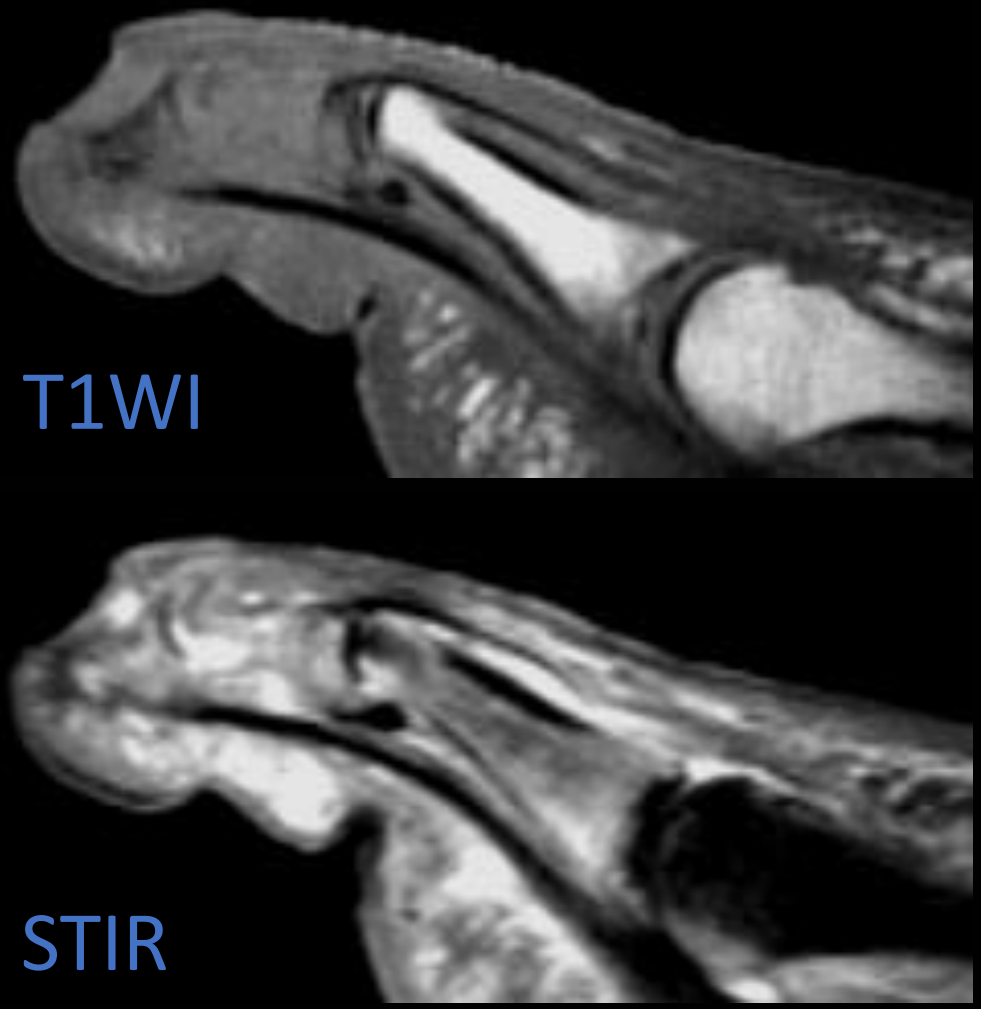


Osteomyelitis

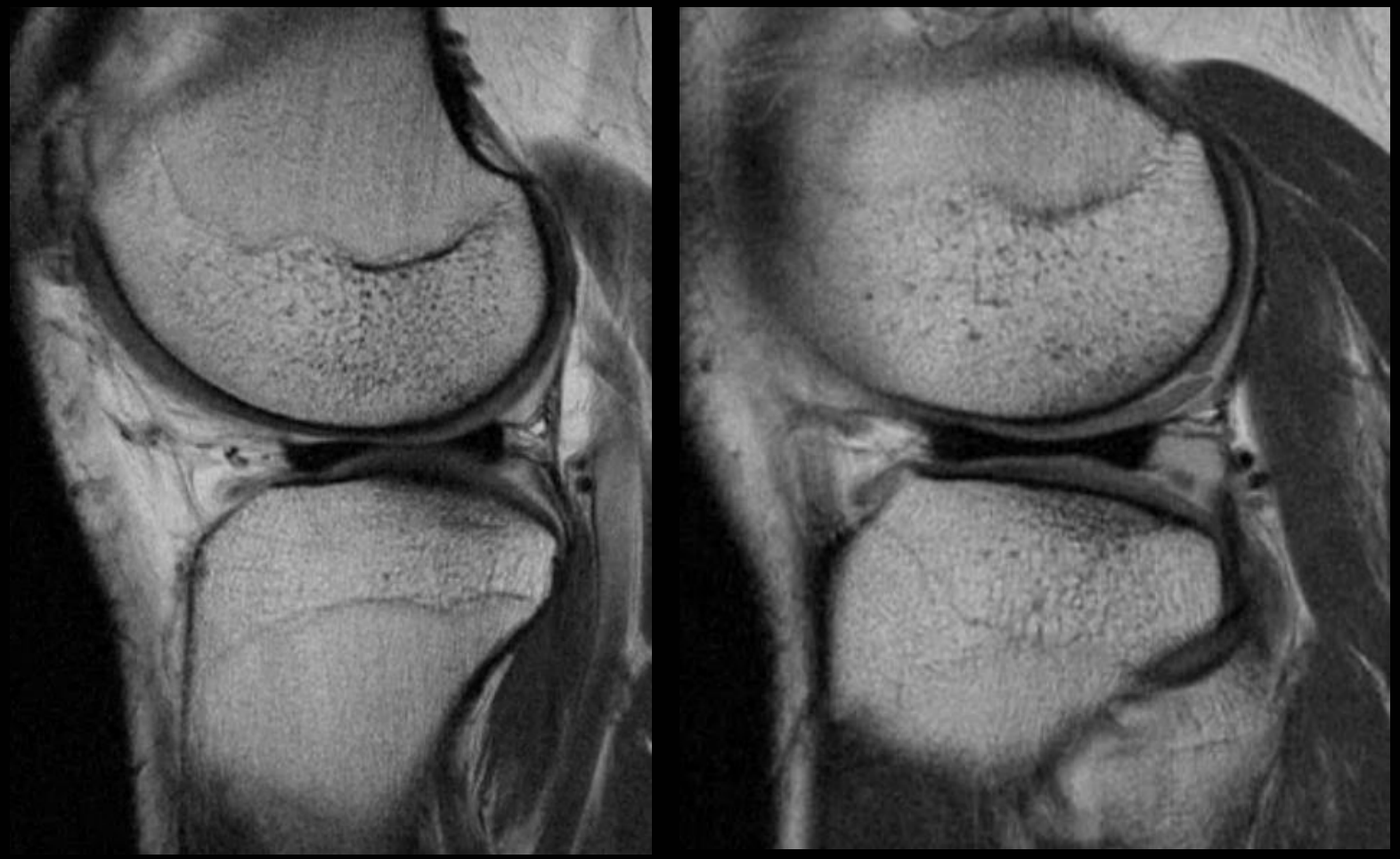
- MRI is very sensitive and specific
  - Contrast helpful for soft tissue abscess and non viable tissue
- Bone scan is sensitive but less specific
- CT has difficulty determining acute vs chronic disease



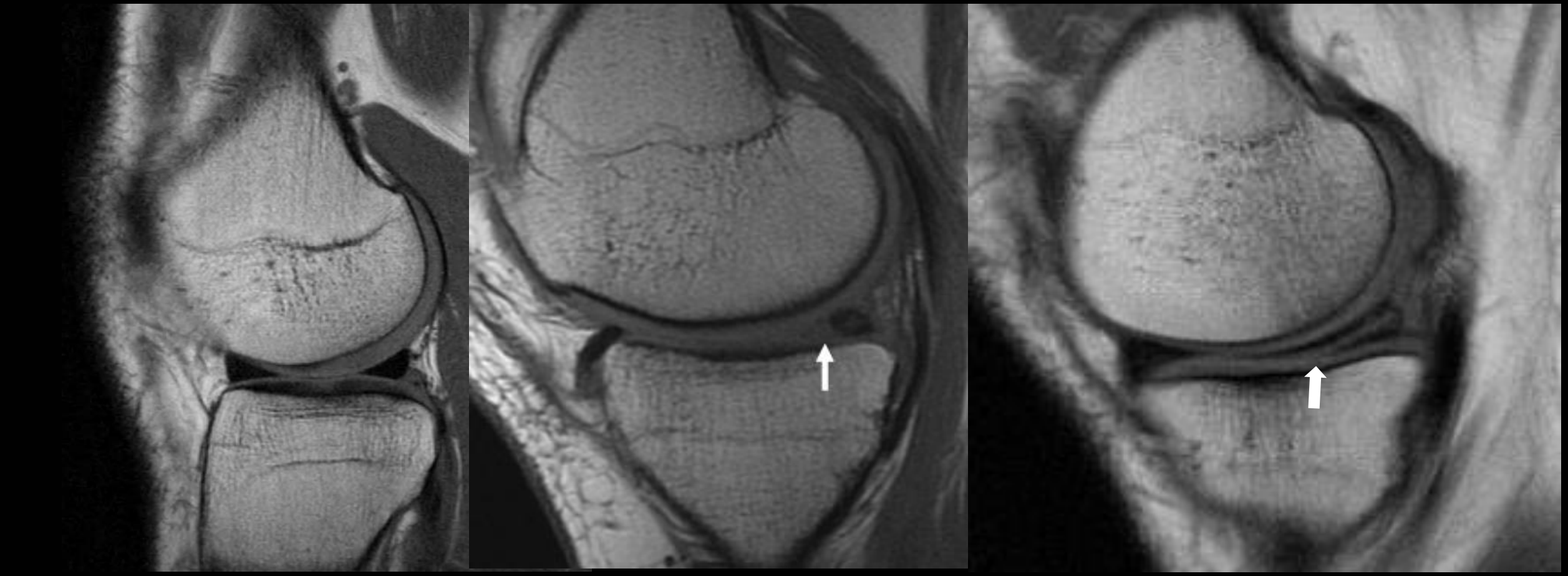
Sports and tendon injury

- MRI is generally the imaging modality of choice for diagnosis of tendon and ligamentous injury
  - Cruciate and collateral ligaments of the knee
  - Rotator cuff tendons in the shoulder
  - Ankle ligaments and Achilles tendon
  - Glenoid and acetabular labrum
  - Etc.

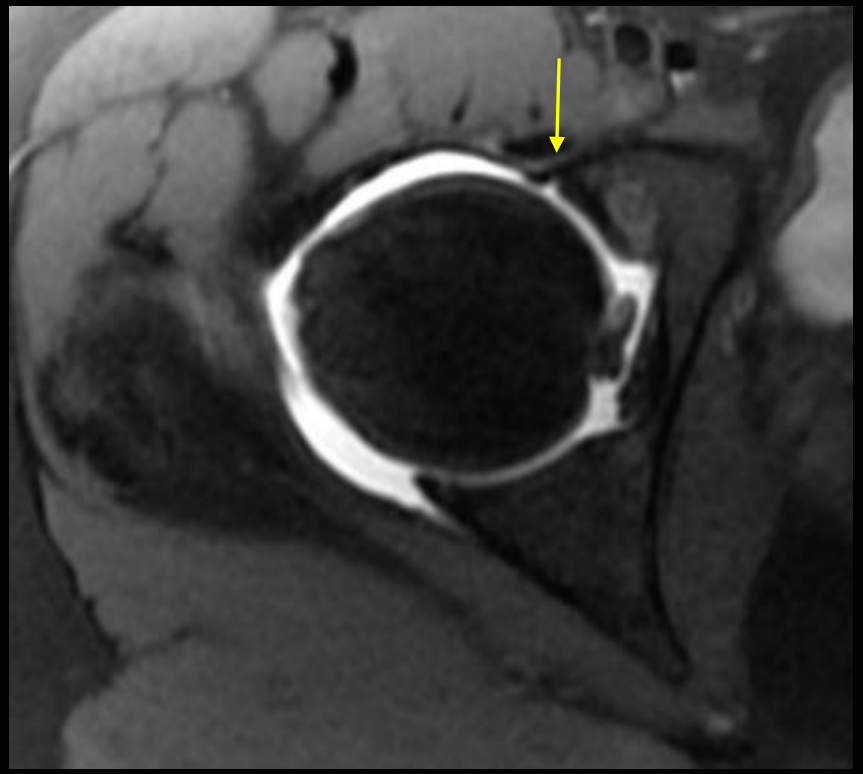
Sports and tendon injury: Articular Cartilage



Sports and tendon injury: Meniscus

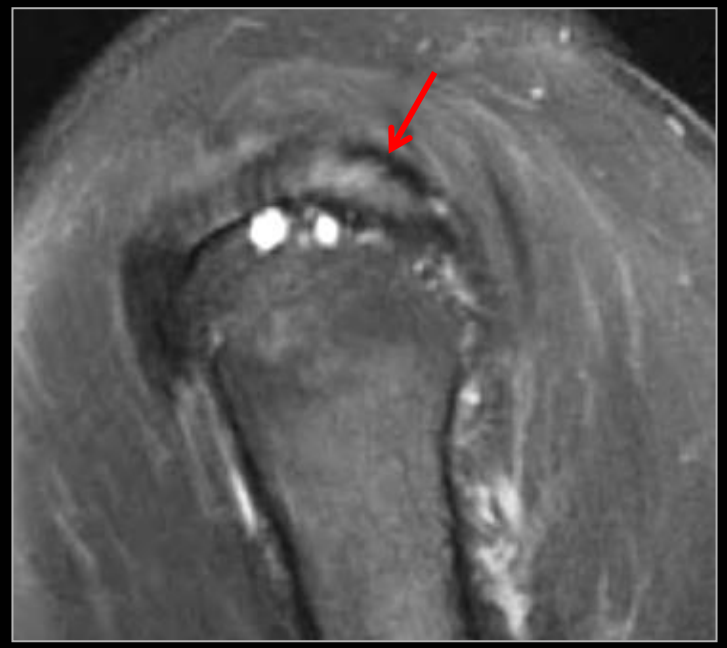


Sports and tendon injury: Labrum



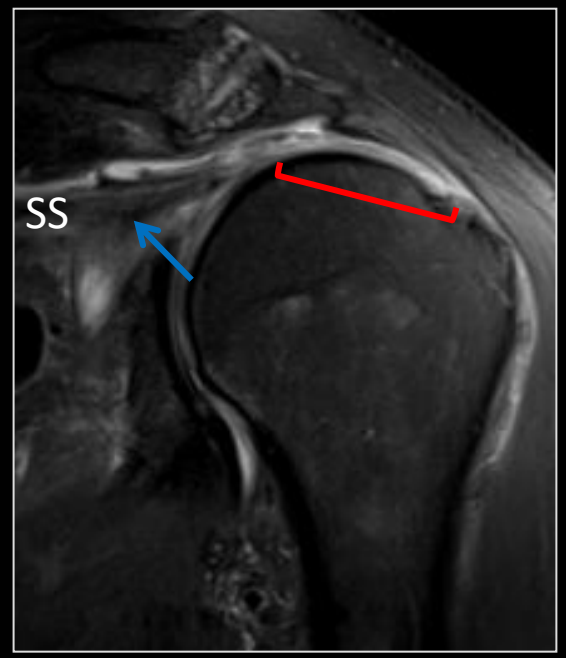
Rotator Cuff

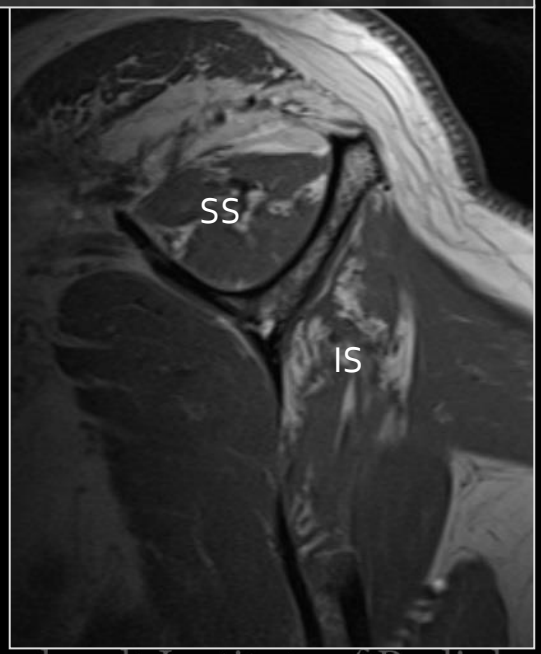
- Tendinopathy
  - Loss of uniform thickness
  - T2 hyperintensity less than fluid
  - Can be hypertrophic or atrophic



Rotator Cuff

- Full thickness rotator cuff tears
  - Discontinuity with fluid signal in tendon gap
  - Retraction of myotendinous junction
  - Subacromial-Subdeltoid bursal fluid (or contrast)
  - Muscle edema/atrophy



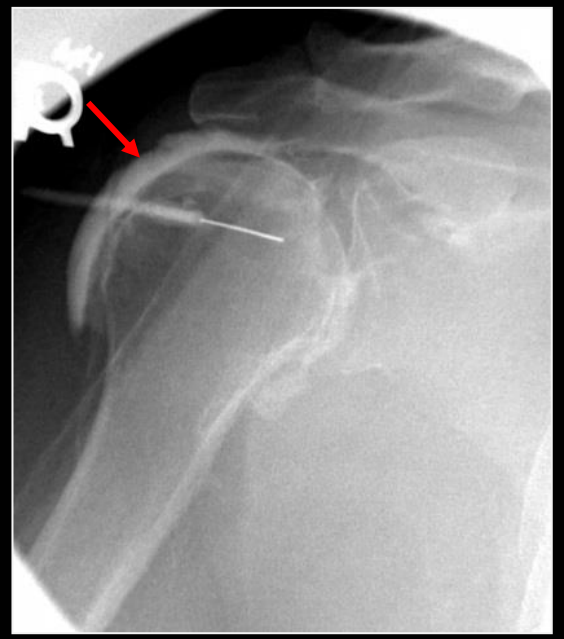


Rotator Cuff

- Full thickness rotator cuff tear

Findings:

- Contrast escaping into subacromial-subdeltoid bursa
- Retracted supraspinatus and infraspinatus tendons are markedly tendinopathic
- Retraction of the myotendinous junction medial to glenoid

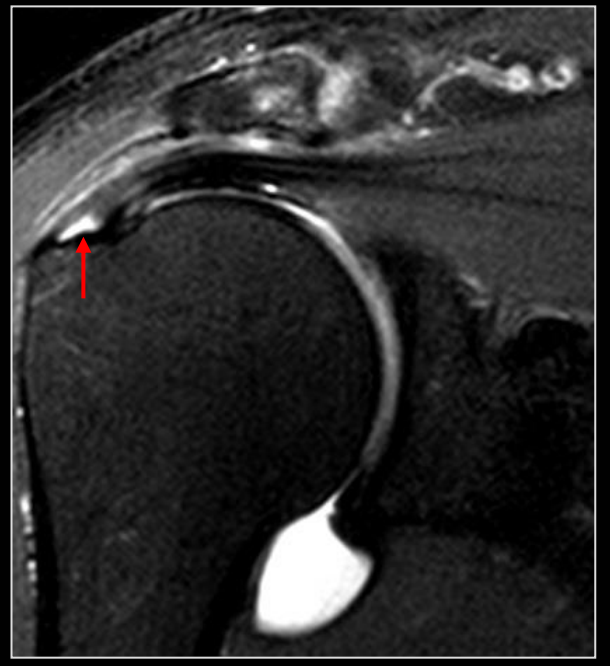


Rotator Cuff

- Partial thickness rotator cuff tears
  - Tear location and depth are important prognostic factors

Articular sided

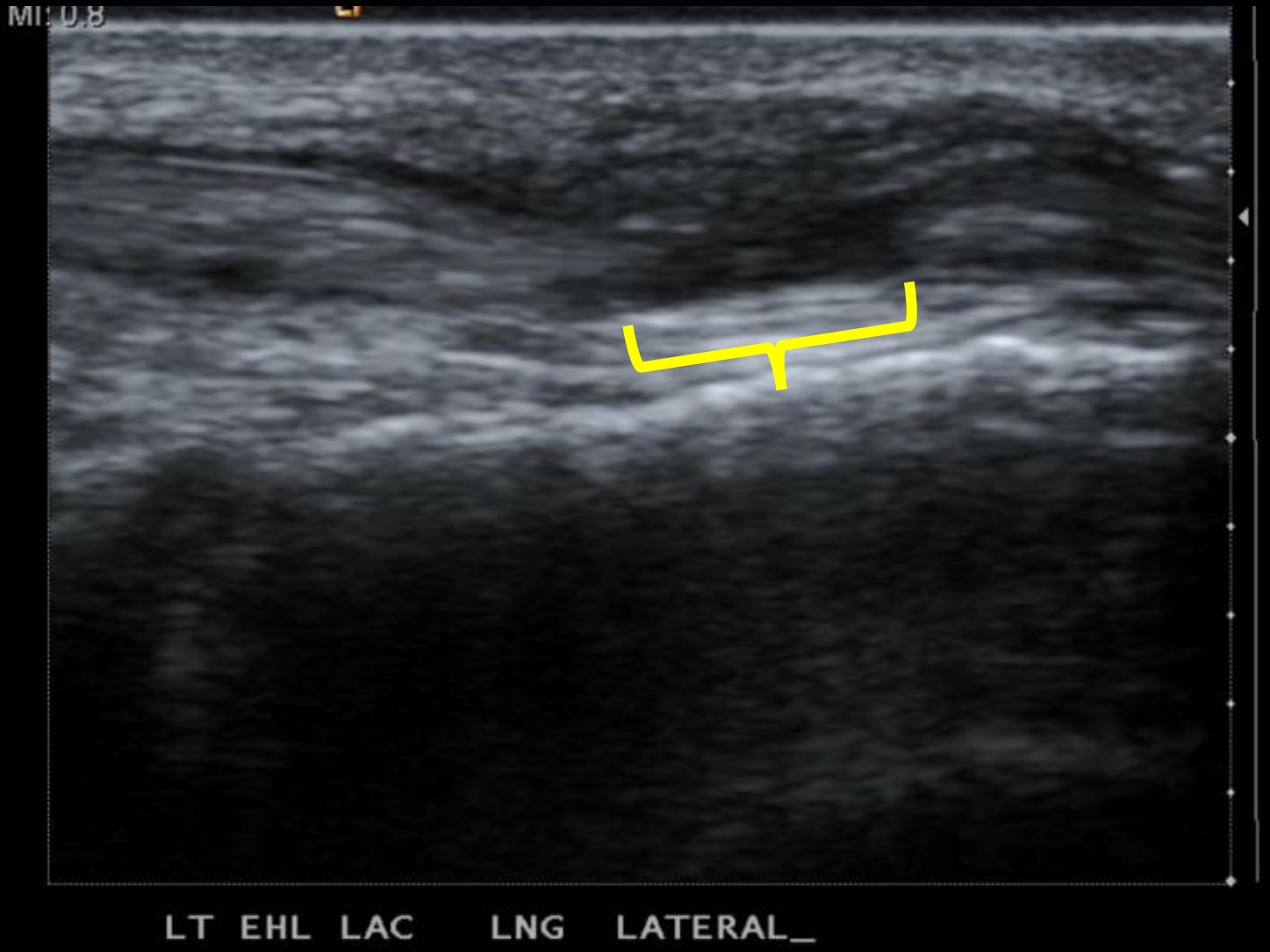
Intrasubstance



Bursal sided

Sports and tendon injury

- Clinical Case
- 19 yo female
- Dropped picture frame on the top of foot
- Cannot extend great toe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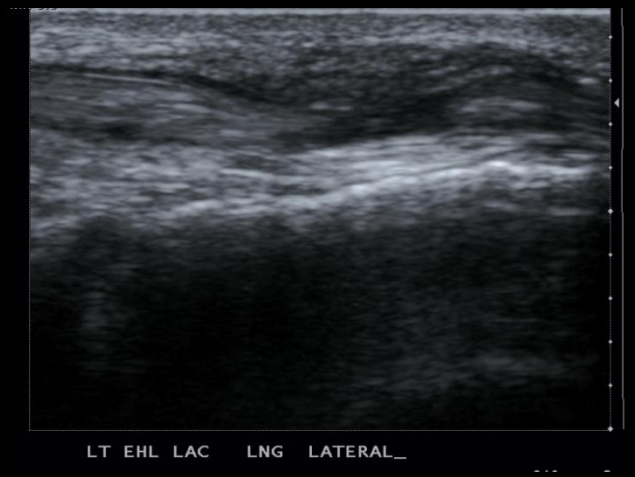
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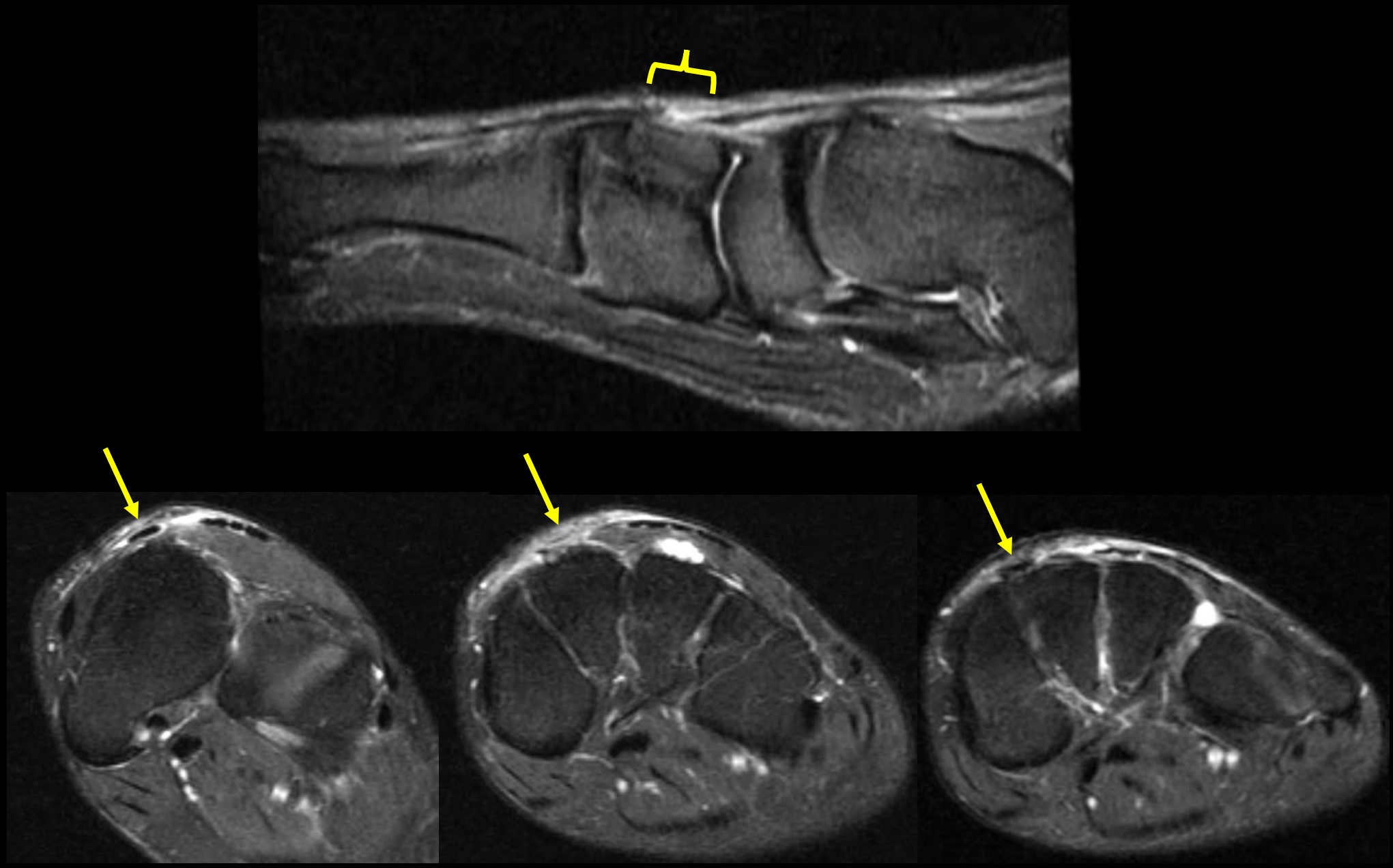
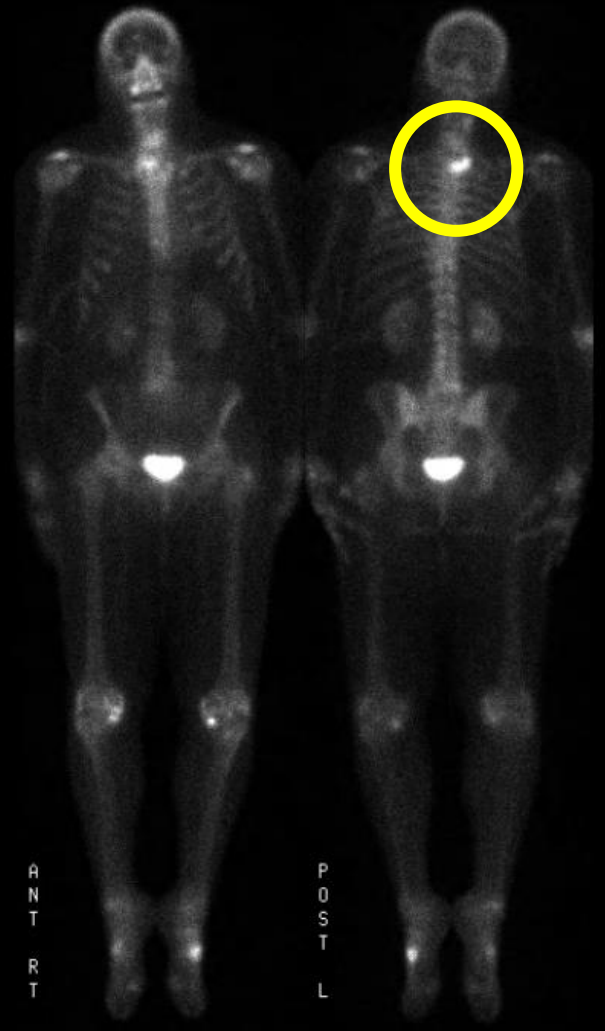


Musculoskeletal malignancy

- Primary bone and soft tissue sarcomas are uncommon
- Metastatic disease is the most common bone tumor
- Large autopsy studies estimate the incidence of skeletal metastases in the patient with an extra-skeletal malignancy ranges from 20-35%
- Metastatic lesions are biopsied 35x more frequently than primary tumors
- The American Cancer Society 2019 estimates only (0.2%) of bone and joint cancer are primary bone tumors…bone tumors are RARE

Musculoskeletal malignancy

- Staging of metastatic disease
- Bone scintigraphy



Musculoskeletal malignancy

- Staging of metastatic disease
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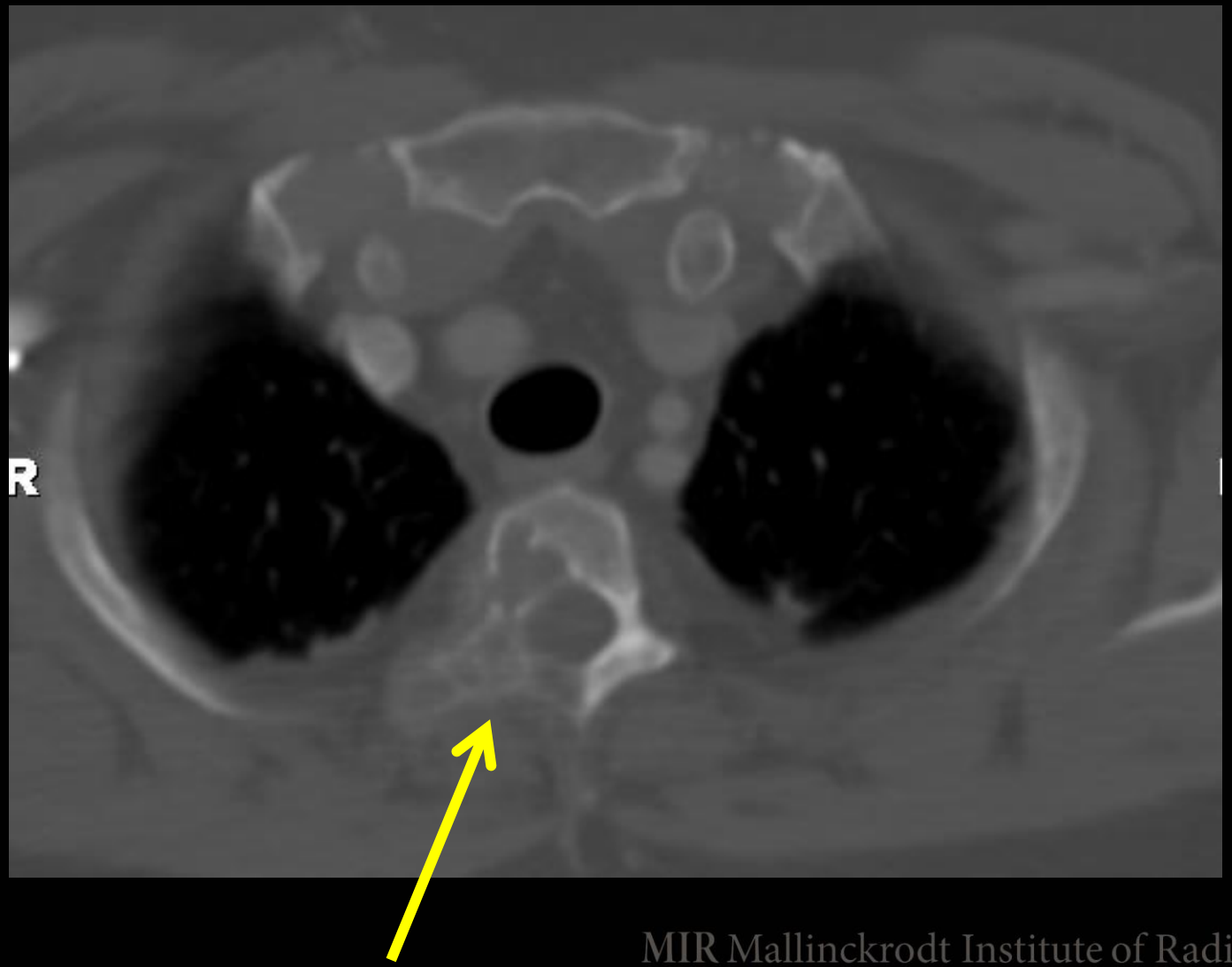


Musculoskeletal malignancy

- Staging of metastatic disease
- Bone scintigraphy

Bone Tumor Age Predilection

Age (years)	Benign	Malignant
<20	• Fibrous cortical defect • Nonossifying fibroma • Simple bone cyst • Chondroblastoma • Osteoid osteoma • Osteofibrous dysplasia • Fibrous dysplasia • Chondromyxoid fibroma • Enchondroma	• Leukemia • Lymphoma • Ewing sarcoma • Osteosarcoma (conventional, periosteal, telangiectatic) • Metastatic disease (neuroblastoma, retinoblastoma, rhabdomyosarcoma)
20-40	• Enchondroma • Giant cell tumor • Osteoblastoma • Osteoid osteoma • Chondromyxoid fibroma • Fibrous dysplasia	• Osteosarcoma (parosteal) • Adamantinoma
>40	• Fibrous dysplasia • Paget disease	• Metastases • Myeloma • NH lymphoma • Malignant fibrous histiocytoma (MFH) • Osteosarcoma (2/2 Paget and radiation)

Adapted from Miller, *Radiology*

Tumor Margin Analysis

- The margin of the tumor with the native bone is an indicator of the growth rate of the tumor
- It is the **most important feature** in differentiating an aggressive lesion from a nonaggressive lesion

UBC (Unicameral bone cyst)

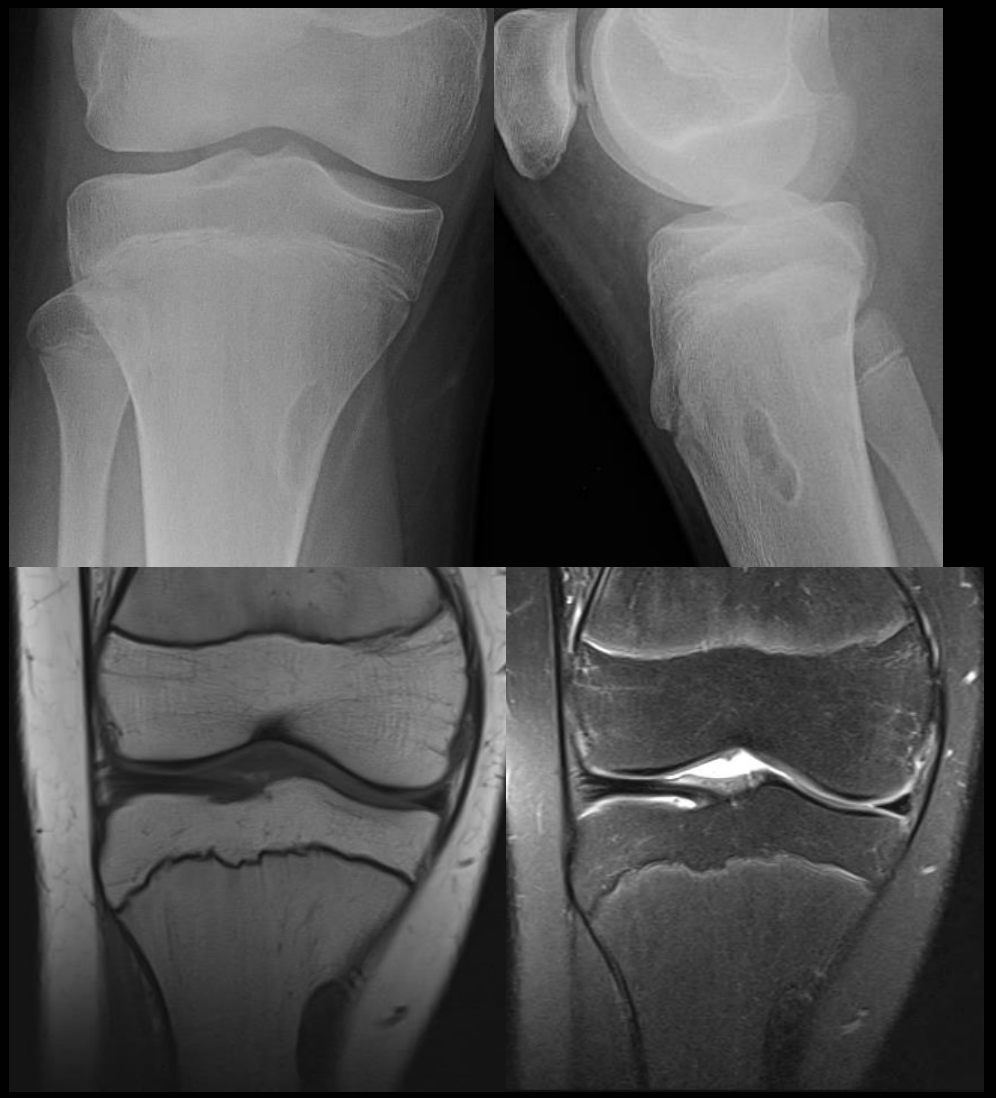
- Imaging Characteristics:
  - Geographic lesion with a narrow sclerotic margin (IA)
  - Central metaphyseal (can migrate into the diaphysis)
  - Mild expansion and remodeling
  - Can be multilocular
  - Pathologic fracture is common (can see the “fallen fragment sign”)

ABC (Aneurysmal bone cyst)

- Imaging Characteristics:
  - Only osseous neoplasm named for its radiologic appearance
  - Metaphyseal (80-90%), eccentric medullary geographic
  - Expansile remodeling (“blown-out” or “ballooned”) with an uneven distribution which can create one aggressive margin
  - CT/MRI shows an intact periosteal membrane as well as fluid/fluid levels (nonspecific)—solid components suggests the ABC is secondary
  - MRI enhancement is thin peripheral and septal
- Secondary ABC (at least one third) in:
  - GCT (#1), Chondroblastoma, CMF, NOF, fibrous dysplasia, UBC; chondrosarcoma, telangectatic osteosarcoma, hemangioendothelioma

Non-ossifying fibroma

- Imaging Characteristics:
  - Metaphyseal origin (can migrate to the diaphysis)
  - Eccentric cortically-based lesion
  - Longitudinal growth pattern
  - Lobulated contour
  - Expansile remodeling with trabeculation is possible
  - Cortex may appear focally permeated, but no soft tissue mass is present
  - Rim of sclerosis is typical
  - MR: usually intermediate to low T1 signal but can be high or low signal on T2
- Additional Features:
  - Pathologic fracture is more likely with lesions > 3cm and/or >50% of bone width
  - Multiple are associate with: NF-1, Jaffe-Campanacci syndrome (with café au lait spots)



Fibrous Dysplasia

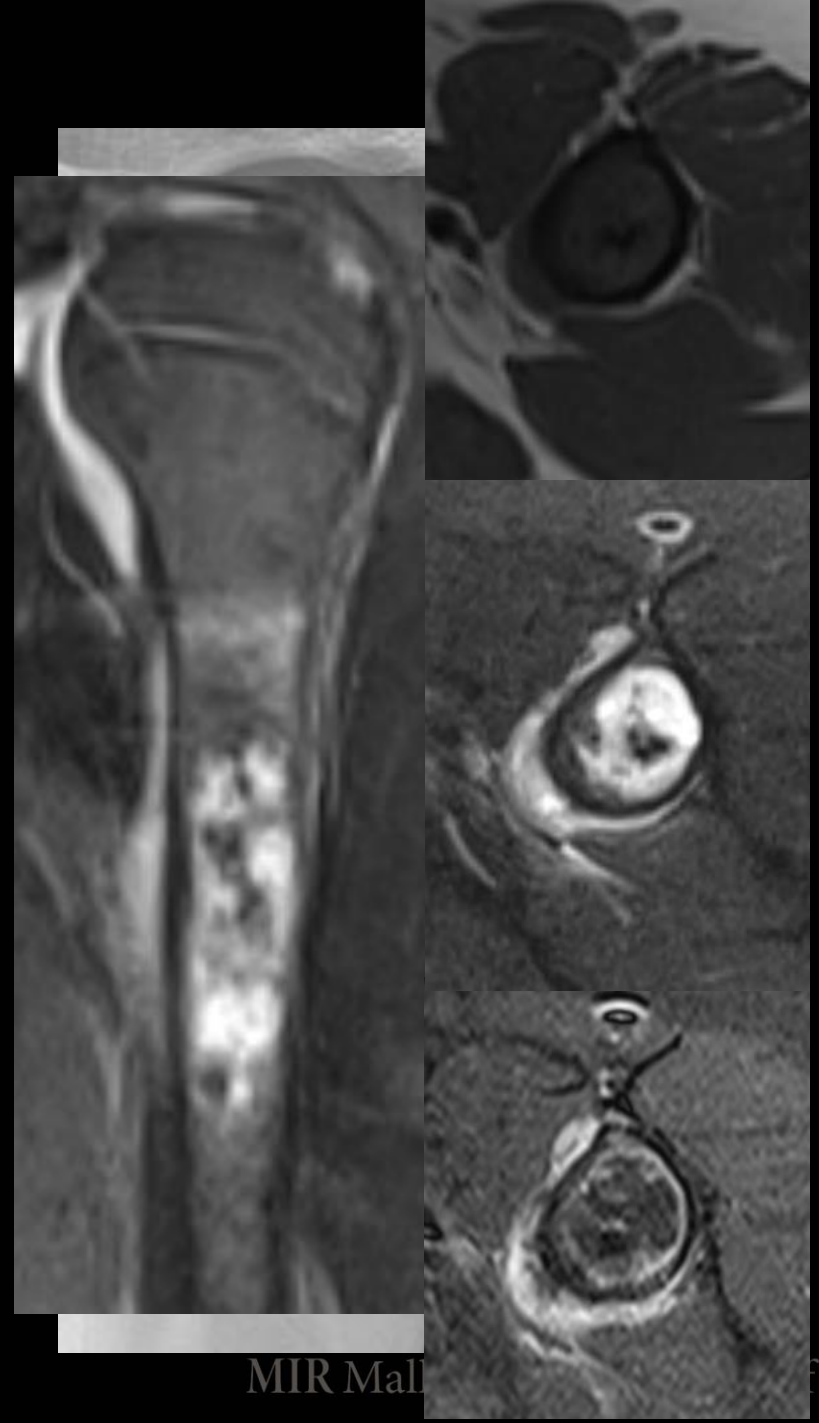
- Imaging Characteristics:
  - Medullary diaphyseal lesions
  - Radiolucent woven bone produces a “ground glass” appearance, but mineralization can be variable from lesion to lesion and within a lesion
  - Lucent components suggest ABC/cyst component
  - Expansile remodeling
  - Usually well defined with a sclerotic rim (monostocic lesion)
  - “Long lesion in a long bone”
  - MR: variable T2 signal

Osteosarcoma

- Imaging Characteristics:
  - Intramedullary high grade
  - Aggressive, typically mixed lytic and sclerotic
  - + soft tissue mass (80%)
  - + periosteal reaction (80%)
  - Osteoid matrix (90%)
  - Extends across the epiphyseal plate (75-90%)
- MRI is necessary for staging and preoperative planning

Chondrosarcoma

- Imaging Characteristics:
  - Geographic IB-IC to permeative
  - Often incomplete sclerotic margins
  - Deep endosteal scalloping
  - Cortical thickening/periosteal reaction often present
  - Expansile remodeling
  - Soft tissue mass in 20-76%
  - Chondroid matrix (78% by radiographs, 94% by CT)
  - MR: low T1, high T2; peripheral/septal enhancement



Metastatic disease

43 year-old woman

Multiple ill defined lytic lesions

Metastatic breast cancer

Key Points

- Always start with X-rays
  - At least 2 views
- Radiographs may be normal despite non displaced fracture or early disease
- Understand the advantages and disadvantages of different modalities and common indications
- Remember that MRI examinations are wonderful, but expensive, slow, and have numerous contraindications

Thank you!

- Questions?