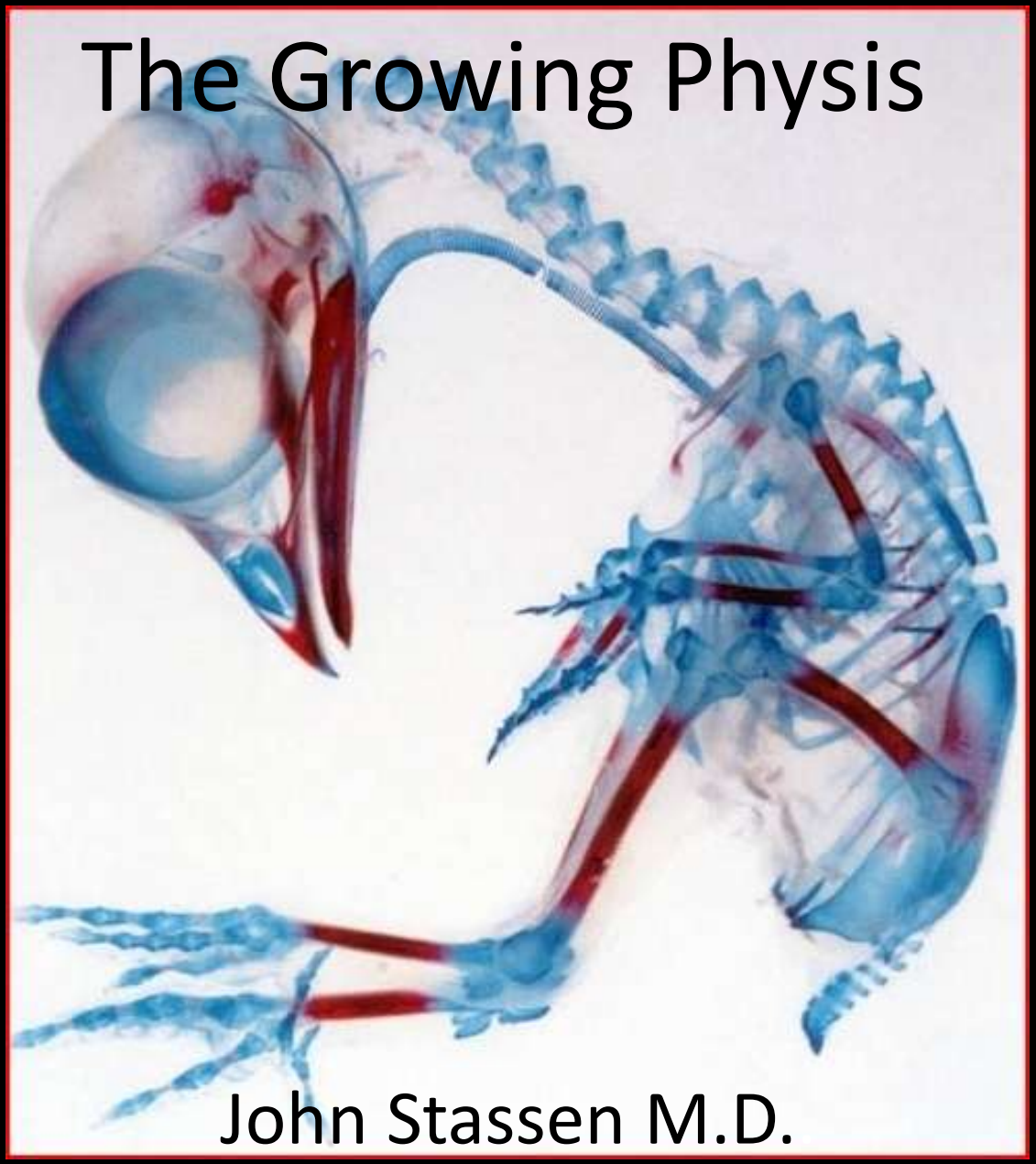
The Growing Physis



John Stassen M.D.

Objectives

- Anatomy and physiology of the growth plate
- Pathology
  - Trauma
    - Acute
    - Repetitive
  - Infection
  - Potpourri

Types of Bone Growth

- Membranous
  - Increases diameter of long bones
  - Flat bones
    - Scapula
    - Skull
    - Most of the pelvis and clavicle
- Endochondral

Endochondral bone formation

- Cartilaginous templates established
  - Bone formation ensues from ossification centers that form in the center of long bones and proceed as a wave extending toward the two ends
- Begins in the primary ossification centers during embryonic development
  - Recapitulated during post-natal skeletal growth at the epiphyseal growth plates
- Four zones
  - Resting/undifferentiated:
    - supplies bone with chondrocytes formed in perichondrium
  - Proliferative:
    - length provided “stack of coins” appearance to chondrocytes
  - Hypertrophic:
    - Chondrocytes swell and eventually die (weakest zone secondary to diminished chondroid matrix)
  - Ossification

Endochondral bone formation

- Maturing chondrocytes secrete a matrix
  - Chondroitin-sulfate proteoglycans
  - Type II collagen
  - Other matrix components
- Cells hypertrophy and subsequently express type X collagen and alkaline phosphatase
- Apoptosis as matrix is mineralized and replaced by trabecular bone

PHYSIS

- “The physis is the area from which all grows, it’s like the Force” Dwek
- "Life creates it, makes it grow. Its energy surrounds us and binds us” Yoda

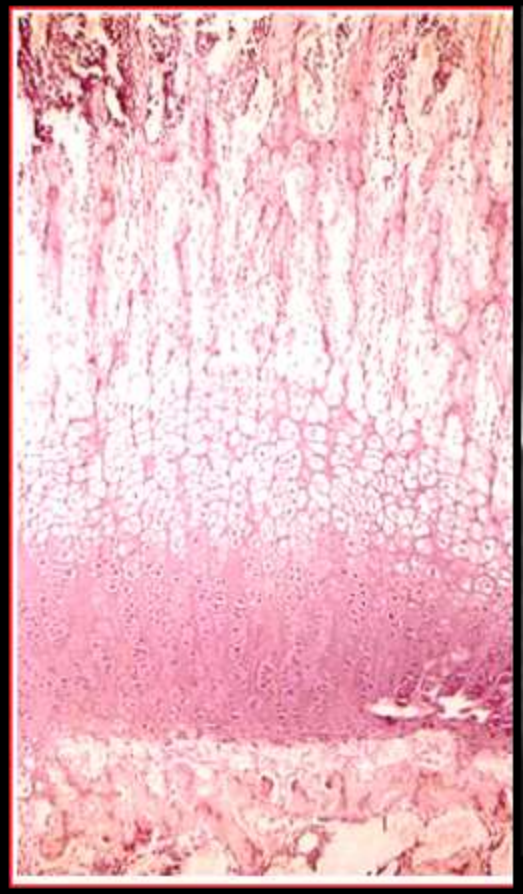
??

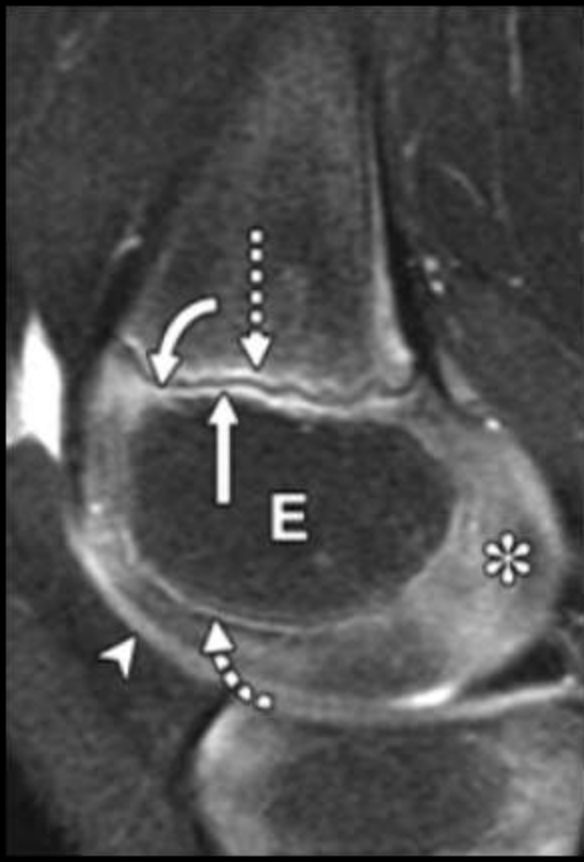
Bone Growth

- Primary physis
  - longitudinal growth of the tubular bones
  - newest bone forms the metaphysis
- Secondary physis surrounds the secondary center of ossification
  - responsible for its spherical growth diameter of tubular bones
- Juxtaphyseal metaphyses
  - enlarges by means of intramembranous bone deposition from the surrounding periosteum
  - Physeal enlargement from the perichondrium

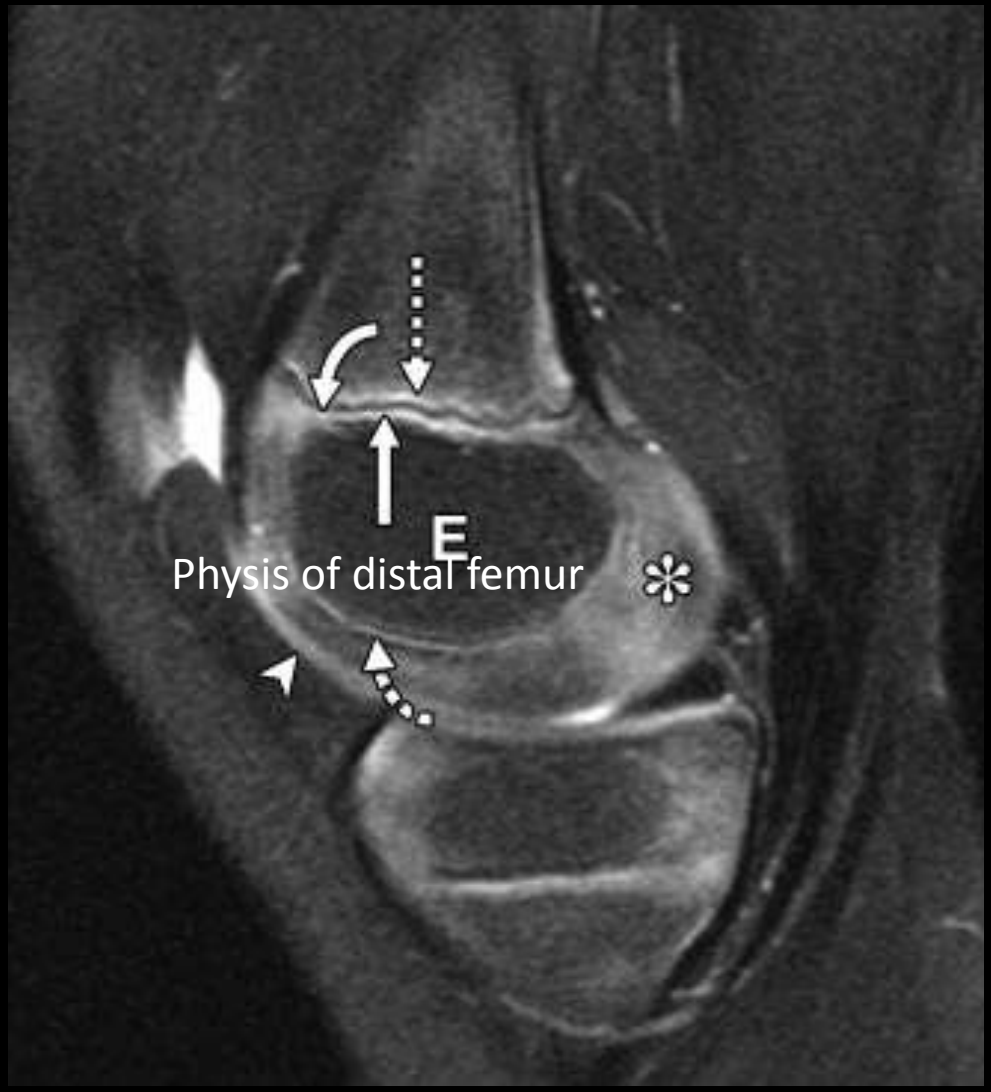
Normal physis on MRI

- Normal trilaminar appearance on fluid sensitive sequences
  - Hyperintense physis
  - Hypointense zone of provisional calcification
  - Hyperintense primary spongiosa

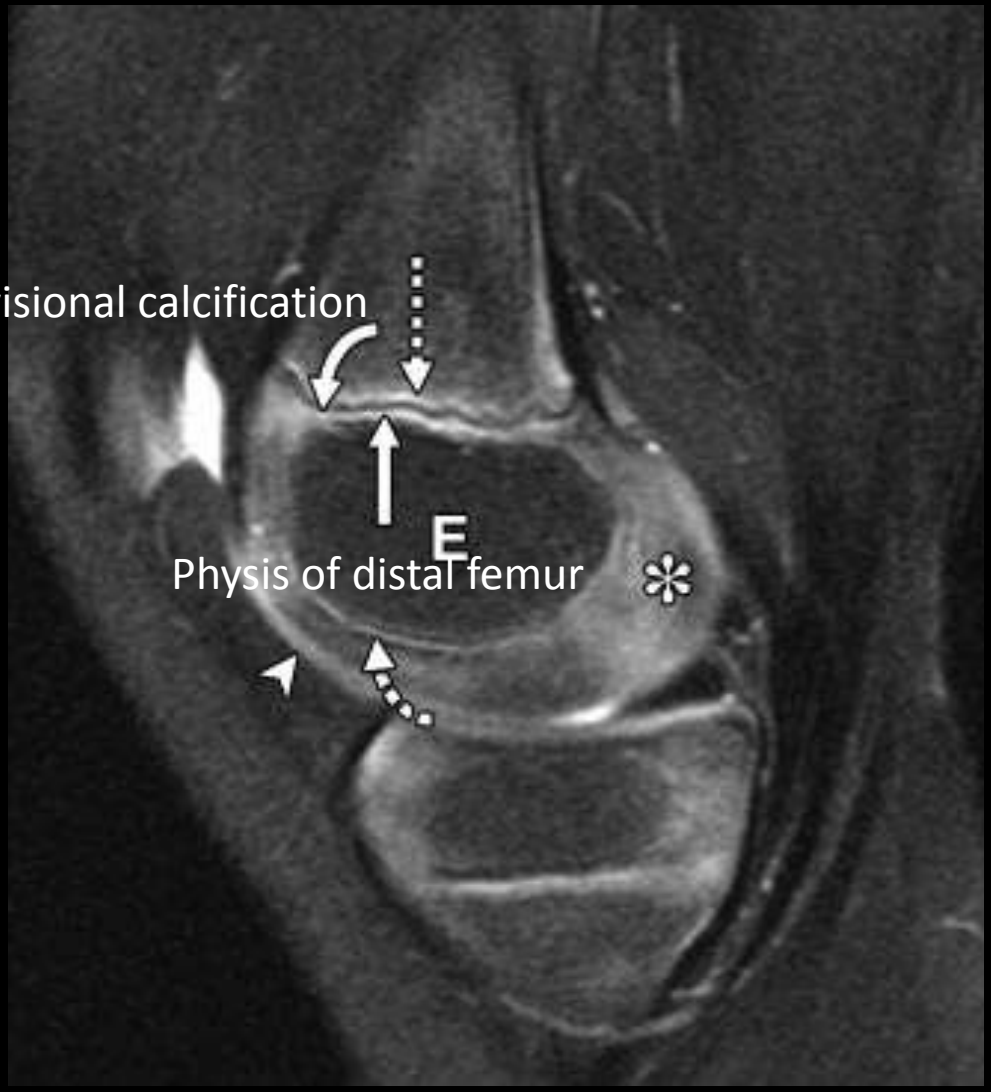




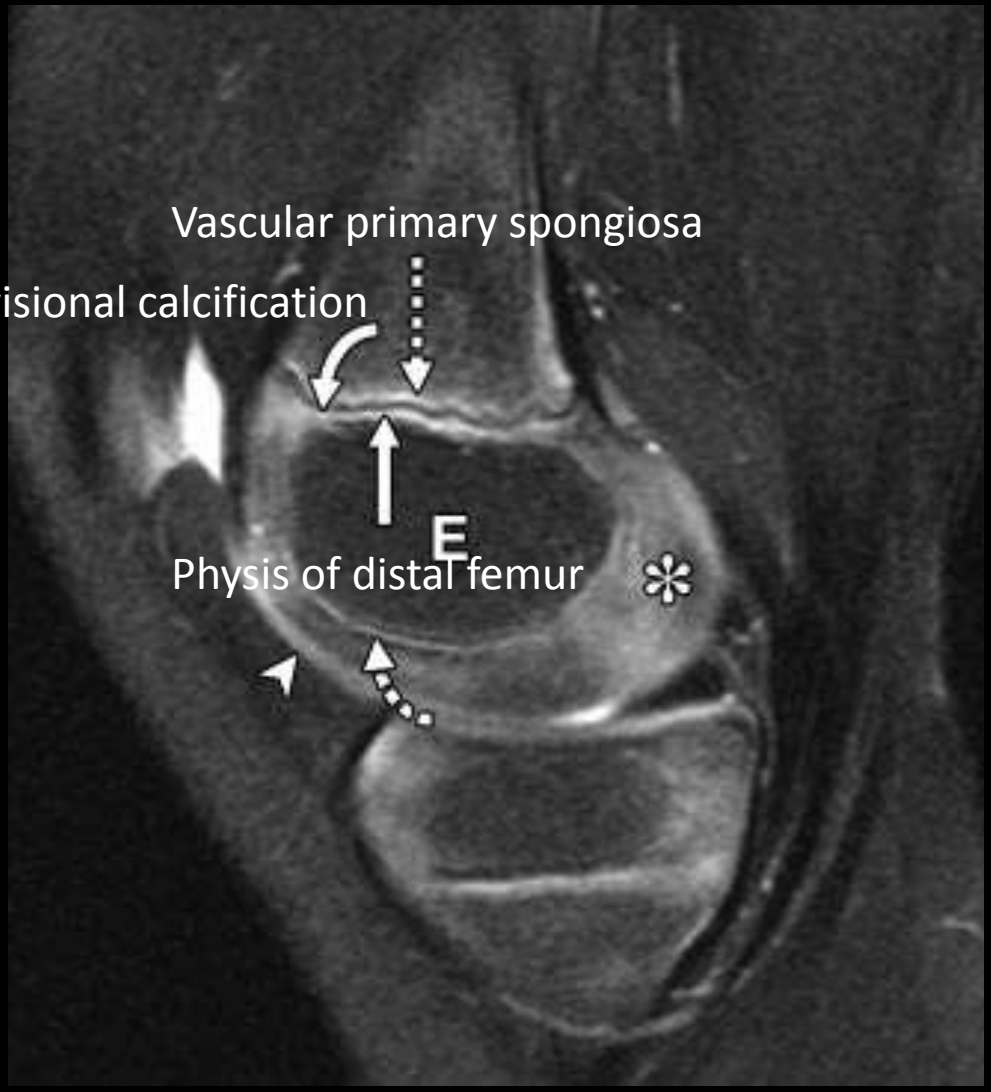
T2 Anatomy



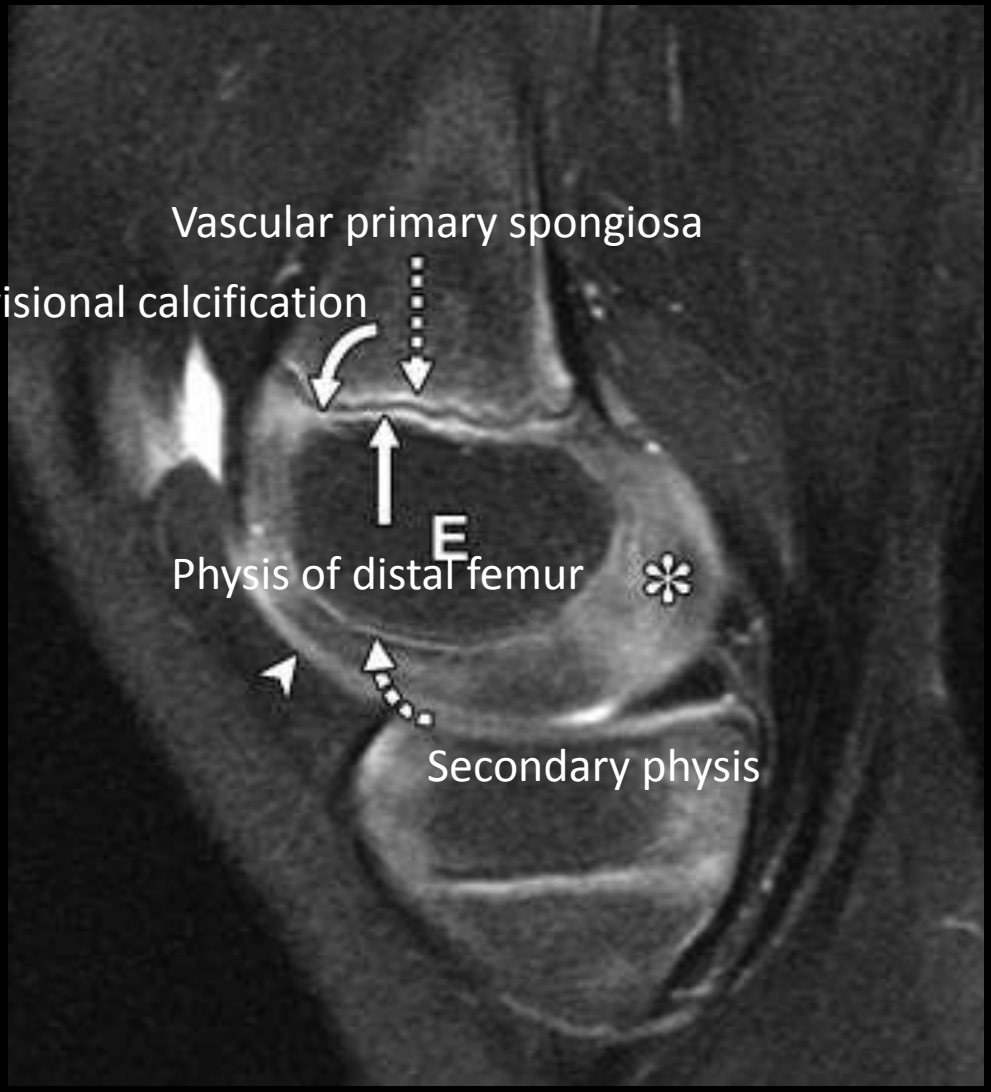
T2 Anatomy


Zone of provisional calcification
E
Physis of distal femur

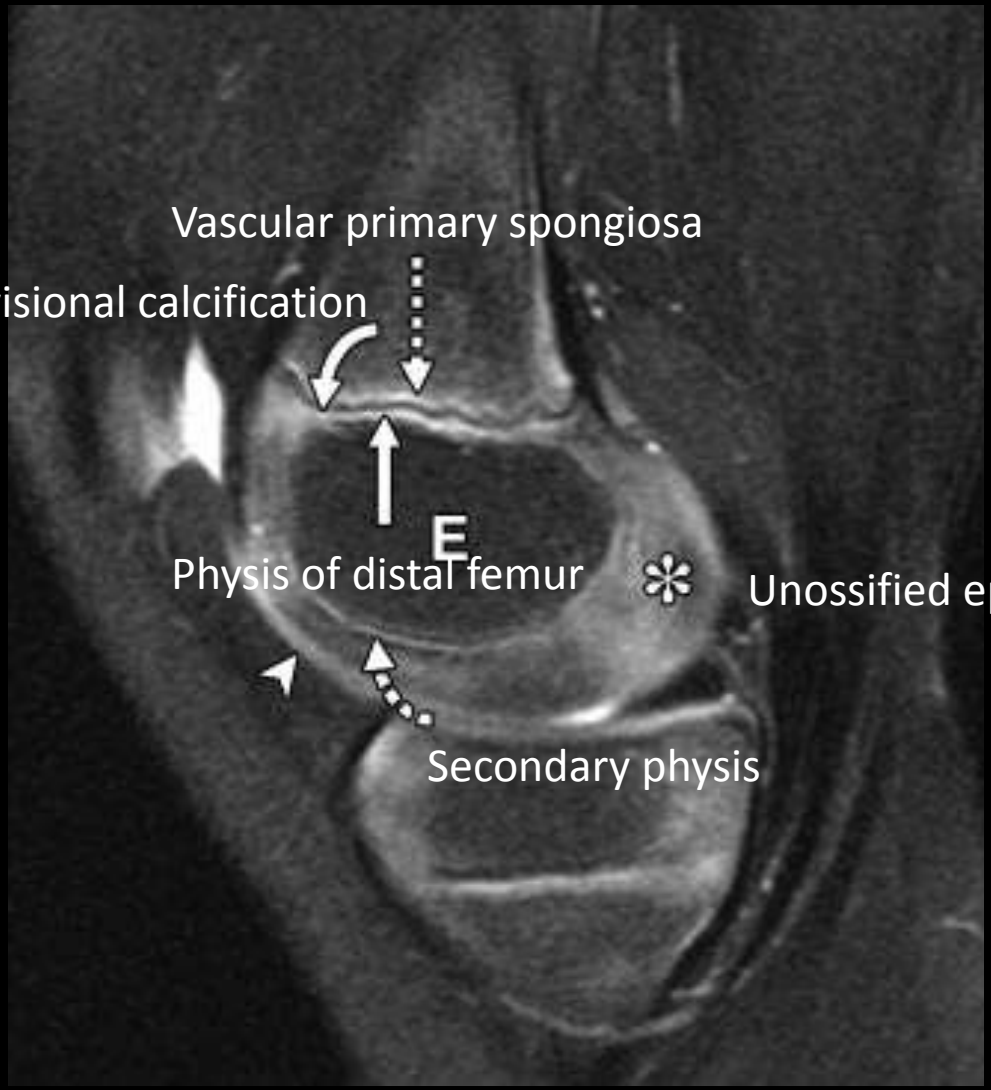
T2 Anatomy


Vascular primary spongiosa
Zone of provisional calcification
E
Physis of distal femur

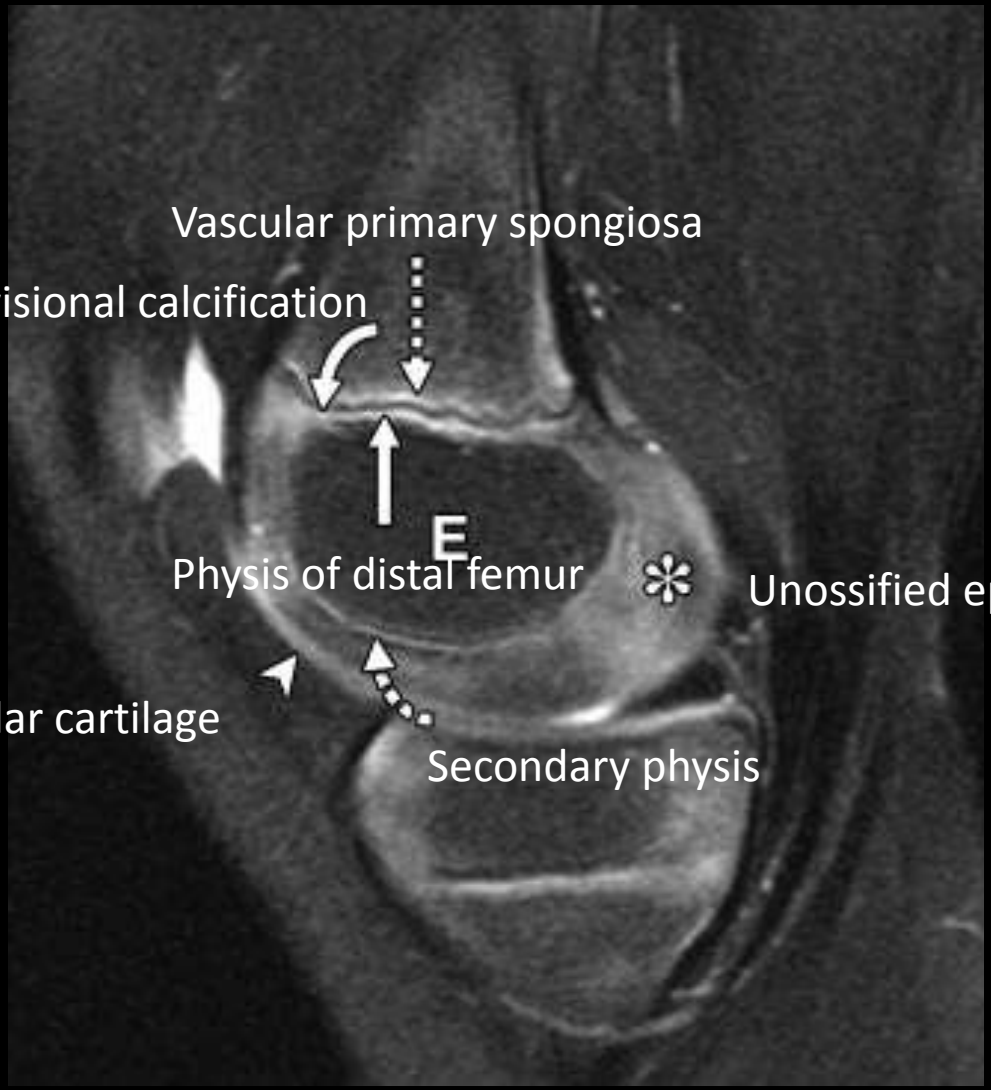
T2 Anatomy


Vascular primary spongiosa
Zone of provisional calcification
E
Physis of distal femur
Secondary physis

T2 Anatomy


Vascular primary spongiosa
Zone of provisional calcification
E
Physis of distal femur
Unossified epiphyseal cartilage
Secondary physis

T2 Anatomy


Vascular primary spongiosa
Zone of provisional calcification
E
Physis of distal femur
Unossified epiphyseal cartilage
Highly organized articular cartilage
Secondary physis

Physis

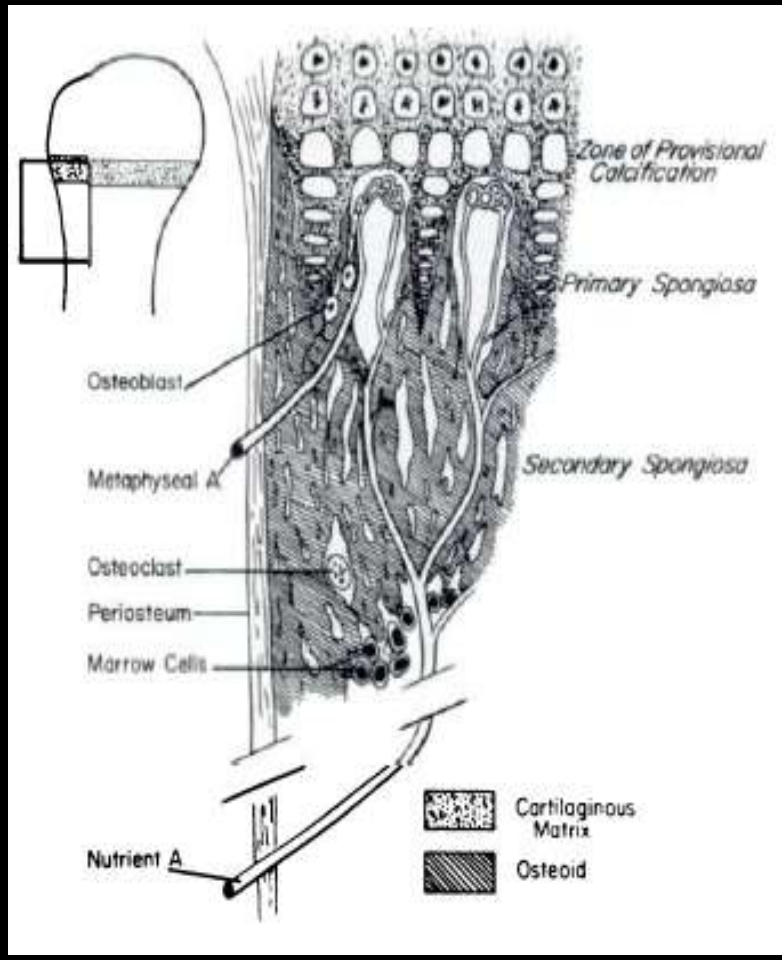
- Long bones have a primary physis (length) and secondary physis (epiphyseal growth)
- Central disc of uniform thickness
  - Thickening indicates disruption of endochondral ossification
  - Injury can cause “tongue” of physeal cartilage into metaphysis

Physis

- Relative barrier to pathology
- Skeletal maturation causes uniform thinning and eventually closure
- Physeal “scar” is remnant of zone of provisional calcification and should parallel the articular surface
- Discontinuity can indicate prior injury

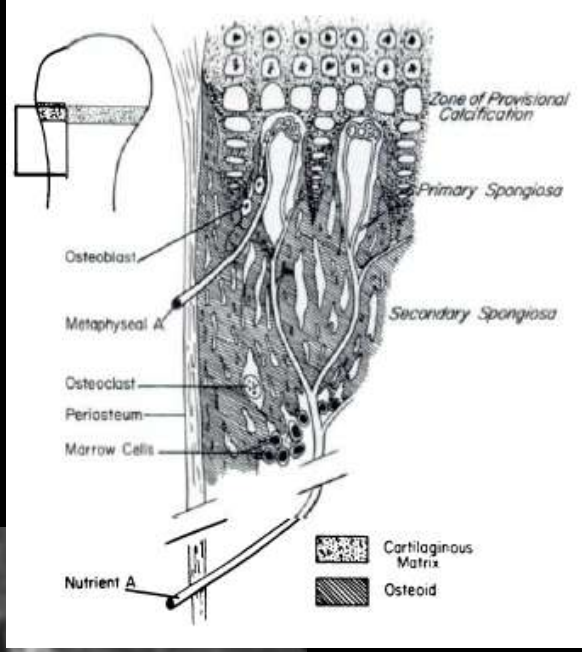
Physeal vascularity

- Dual blood supply
- Metaphyseal vessels provide calcium and Vitamin D via serum and phosphates via RBC
  - aid in the calcification of the matrix
  - removal of degenerate cells
  - deposition of lamellar bone
- Epiphyseal vessels nourish the reproductive cells of the physis



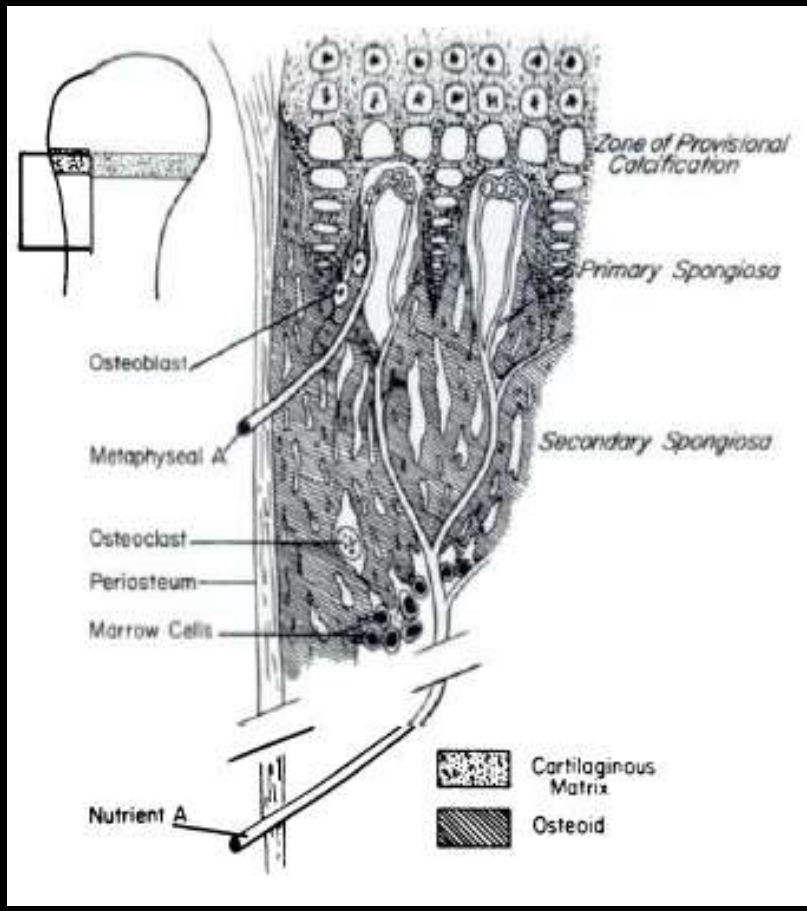
Metaphysis

- Primary spongiosa is most newly formed portion
- Highly vascular with slow flow venous lakes
  - Predispose to seeding from infection, leukemia, or metastasis



Metaphyseal Vascularity

- Densely enhancing primary spongiosa
- Separate blood supply from the epiphysis in children
- Infants can have transphyseal vessels
  - Close from 8-18 months of age
  - Osteomyelitis of metaphysis can lead to septic arthritis



Vascularity

- Nutrient foramina of the long bones enter in diaphysis
- Clinicians may mistake for fx lines
- “To the elbow I go, from the knee I flee”

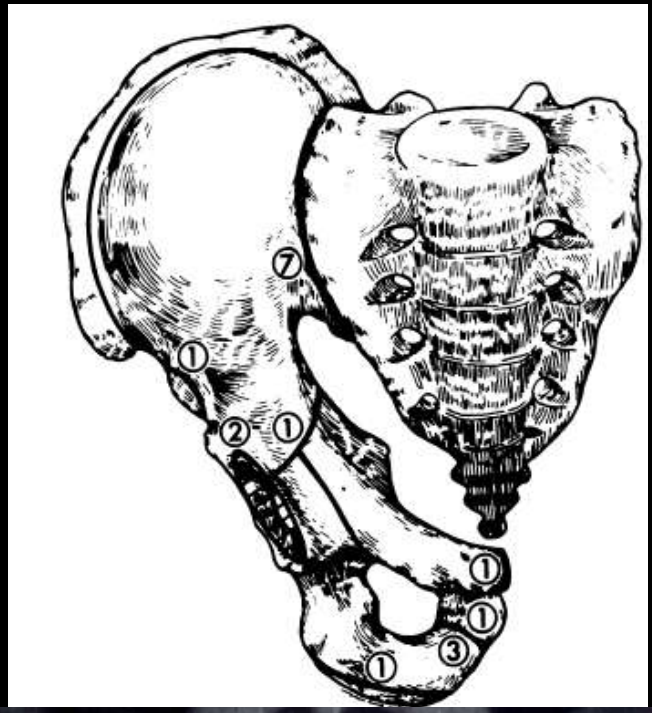
Cortical Layers

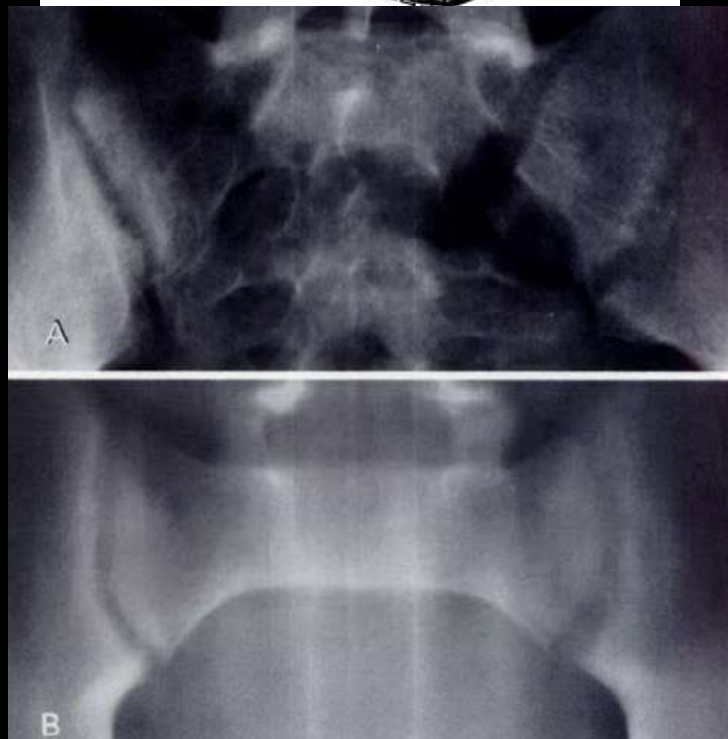
- Periosteal attachment to cortex is loose along shaft and tight at physis
  - Easily elevated by blood, pus, tumor
- Cortex
- Subperiosteal cuff is separated from cortex by layer of fibrovascular tissue
    - Seen at metaphysis of long bones aka “metaphyseal stripe”
    - High T2 signal and dense enhancement
    - Membranous ossification

Post gd T1 FS JRA

Metaphysis and Equivalents

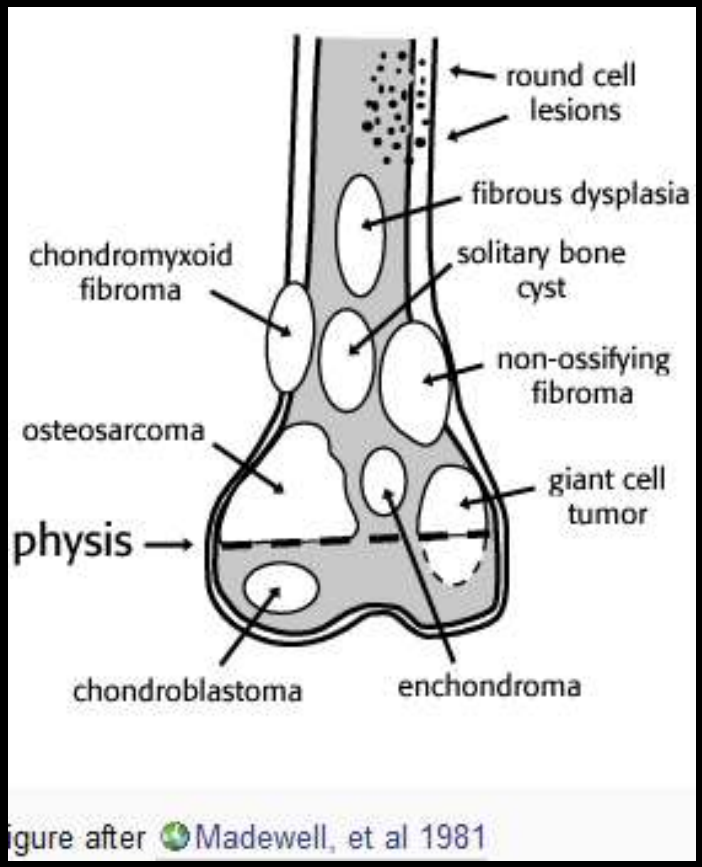
- Growth plate equivalents include flat bones with adjacent cartilage
  - bone adjacent to the triradiate cartilage
  - ischiopubic synchondrosis
  - Bone adjacent to the sacroiliac joints
  - Periphery of the round bones of the hands and feet
  - Patella
  - Sternum





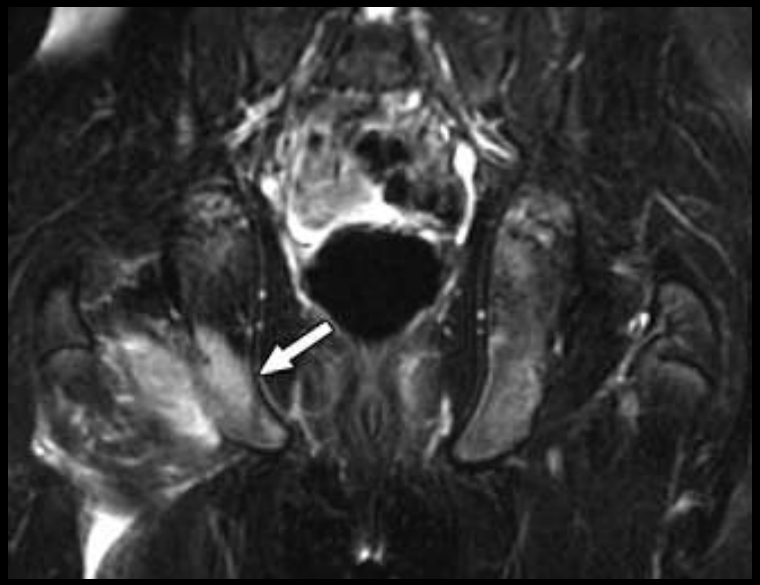
Equivalants

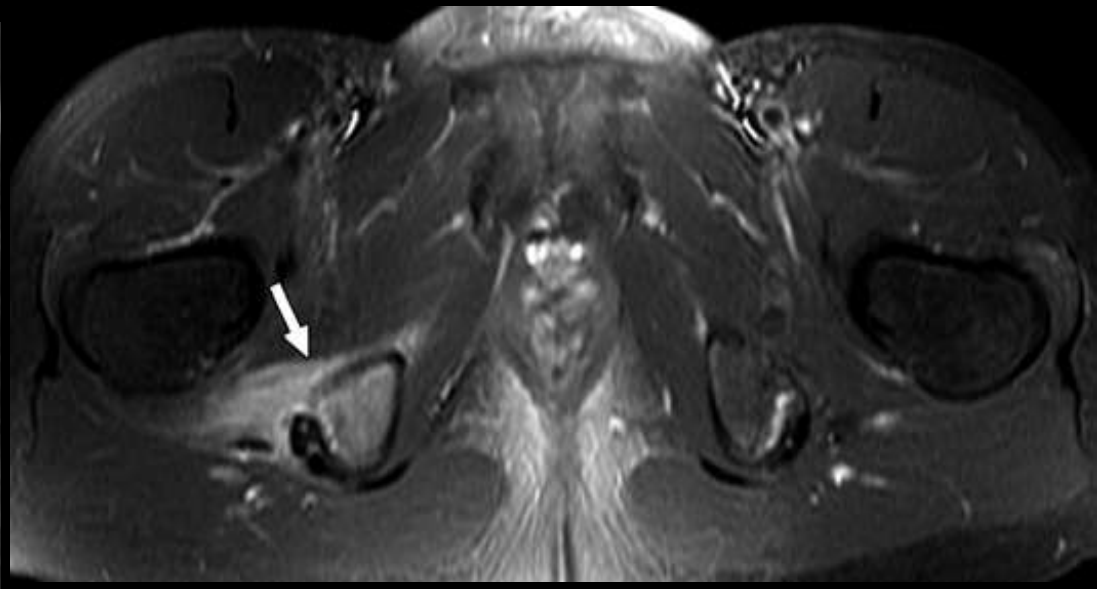
- Osteomyelitis
- Periphyseal solitary bone tumors
  - Chondroblastoma and chondroid tumors
  - GCT
  - UBC
  - etc



Osteomyelitis

- Predominance of vascularity and slow flow cause seeding of metaphyseal and equivalent areas of bone
- MRI can be used for early detection (findings at 24-48 hours after symptoms, 7-10 d for xray)





Metaphysis

- Growth recovery lines (arrest, Harris, Parks) result from local or systemic insult
  - Should parallel physis
- Relative slowing of cartilage transformation to bone but continued mineralization of the developing metaphyseal trabeculae

Metaphyseal lines

- Dense:
  - exuberant calcification of the zone of provisional calcification, a normal variant
    - Seen in normal children, especially following sunlight exposure after winter
  - heavy metal poisoning
  - hypervitaminosis D
  - healing stages of leukemia, rickets, and scurvy
  - Chemotherapy
  - TORCH infections

Lead poisoning

- Lines are most prominent at the knees
  - Also at wrist, any other long bone metaphysis, and in the axial skeleton
- Late manifestation
- Lead deposition is a minor factor for increased attenuation
- Primary cause is increased calcium deposition
  - Impaired remodeling
  - Thicker and more numerous trabeculae
- Fibula (and ulna) can help differentiate from normal bone growth[9]

Metaphyseal lines

- Lucent:
  - Leukemia/Lymphoma
  - Severe systemic illness
  - Trauma/fracture
  - Neuroblastoma
  - Rickets
  - Scurvy
  - Infection (Syphilis)
  - Normal Variant
- After age 2 generalized metaphyseal lucencies are nearly always secondary to leukemia
- Focal met. lucencies are usually from infection or mets

Epiphysis

- Secondary ossification center
- Responsible for spherical growth
- Subjacent to articular cartilage

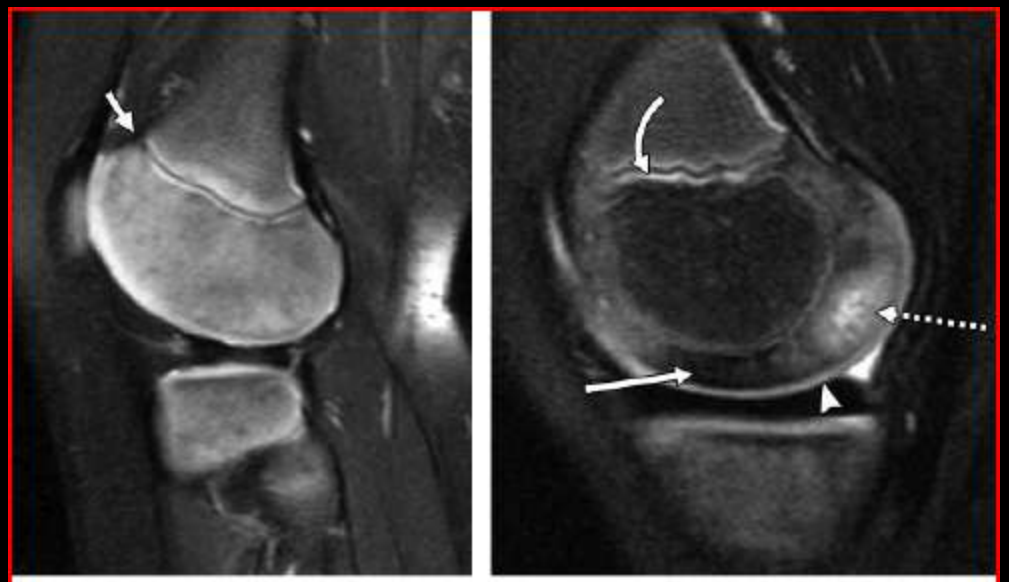
Epiphysis

- Infant epiphyseal cartilage
  - contains few cells
  - matrix rich in glycosaminoglycans and collagen
  - homogeneous intermediate SI on T1-weighted images
  - relatively low SI on water-sensitive images
    - ? strong binding of water to macromolecules in the cartilage

Epiphyseal cartilage

Epiphysis

Figure 12: Preossification. Sagittal fat-suppressed T2-weighted MR image (2350/88) of medial distal humerus in 2½-year-old boy shows focal area of high SI (arrow) where the trochlear ossification center will form.



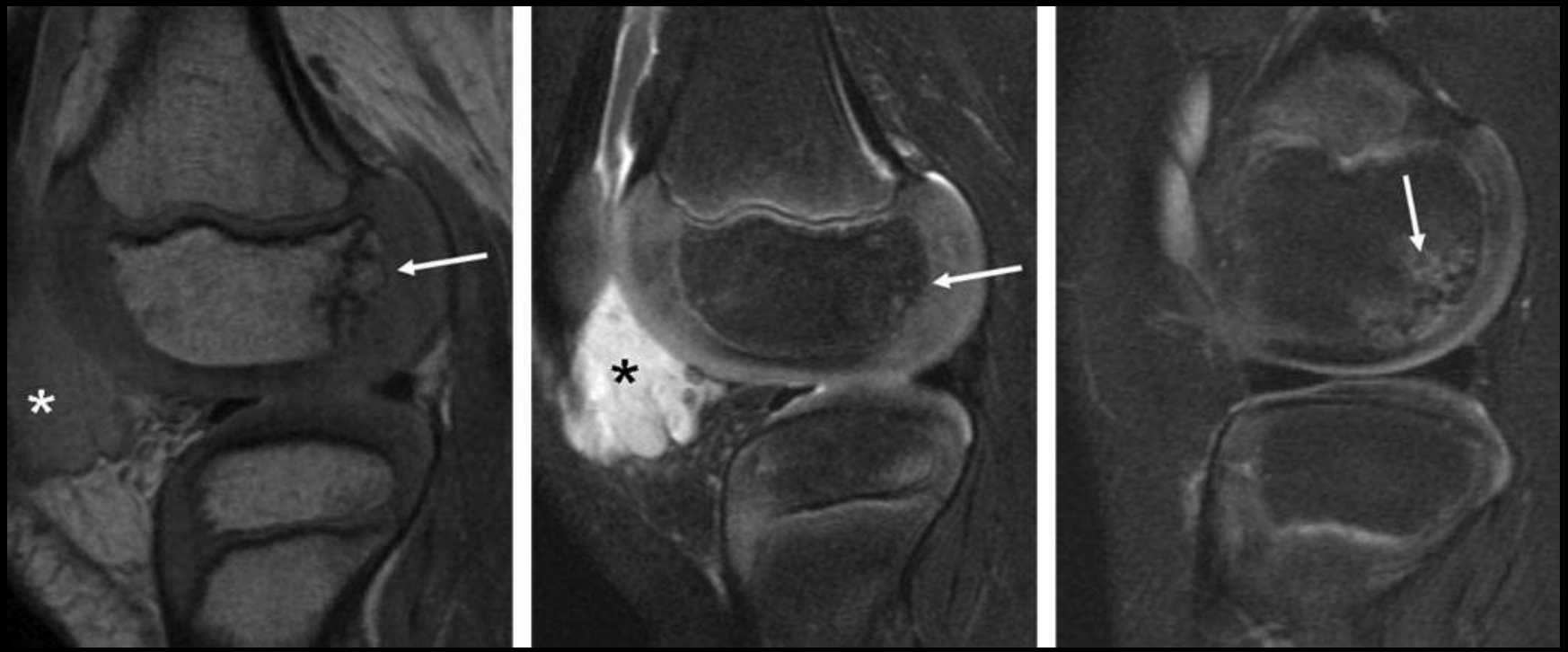
a. b.

Figure 11: Distal femoral epiphyseal changes on sagittal fat-suppressed fast spin-echo T2-weighted MR images (3000/64). (a) Knee in 15-month-old girl. Perichondrium (arrow) is seen as short band of low SI extending from metaphysis to epiphysis. SI of cartilaginous distal femoral epiphysis is relatively homogeneous. (b) Knee in 5-year-old boy. SI is heterogeneous in posterior cartilaginous distal femoral epiphysis. A blister-like hyperintense focus (dotted arrow) can be seen in sites undergoing rapid ossification. SI along the weight-bearing portion of the condyle is decreased (straight solid arrow). Articular cartilage SI is high (arrowhead) and easily distinguishable from unossified epiphyseal cartilage on T2-weighted images. SI of the physis is high (curved arrow) adjacent to low SI of the zone of provisional calcification.

Epiphysis

- Ossification of the epiphysis from the secondary physis
  - Single ossification center as in distal femur
  - Numerous small foci that will eventually coalesce with underlying bone as in humeral trochlea
- When irregular can be confused with osteochondritis dissecans
- Problematic along the ossifying margin of the distal femoral condyle
- Lack of adjacent bone marrow edema within the adjacent epiphysis CAN help confirm that this is normal development

Images of Irregular ossification versus OCD

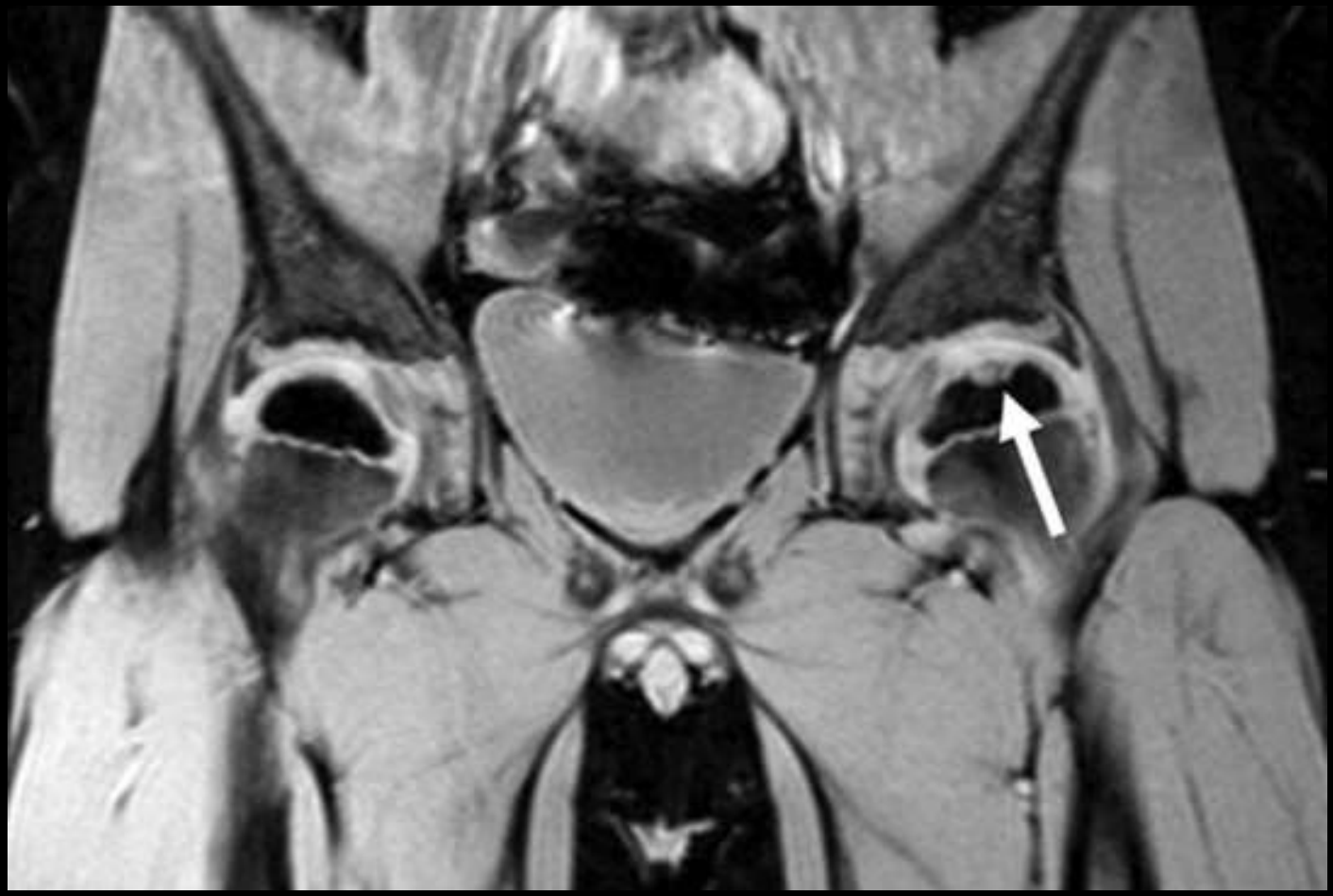


Images of Irregular ossification versus OCD

Irregular ossification versus OCD

- Irregular ossification causes a notch at vertex of femoral head in children
- MC in boys
- Normal overlying cartilage and no surrounding edema
- Can be mistaken for
  - LCP
    - More common laterally
    - Associated with other abnormalities
  - Foveal insertion site
    - More medial
  - Epiphyseal dysplasia
    - Larger defect
    - Broadened femoral head and neck

Irregular ossification versus OCD



Epiphyseal vascular supply

- Epiphyseal vascular canals supplied separately from metaphysis
- Canals are apparent after the intravenous administration of contrast material
- More apparent in hypervascular states like JRA or septic arthritis
- Involute with skeletal maturation

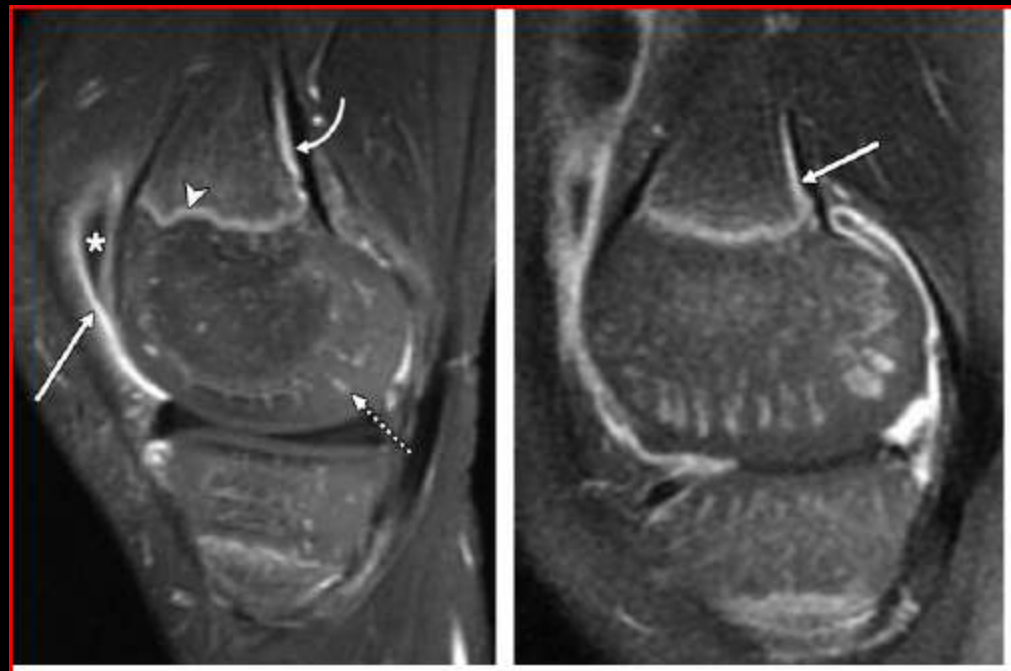


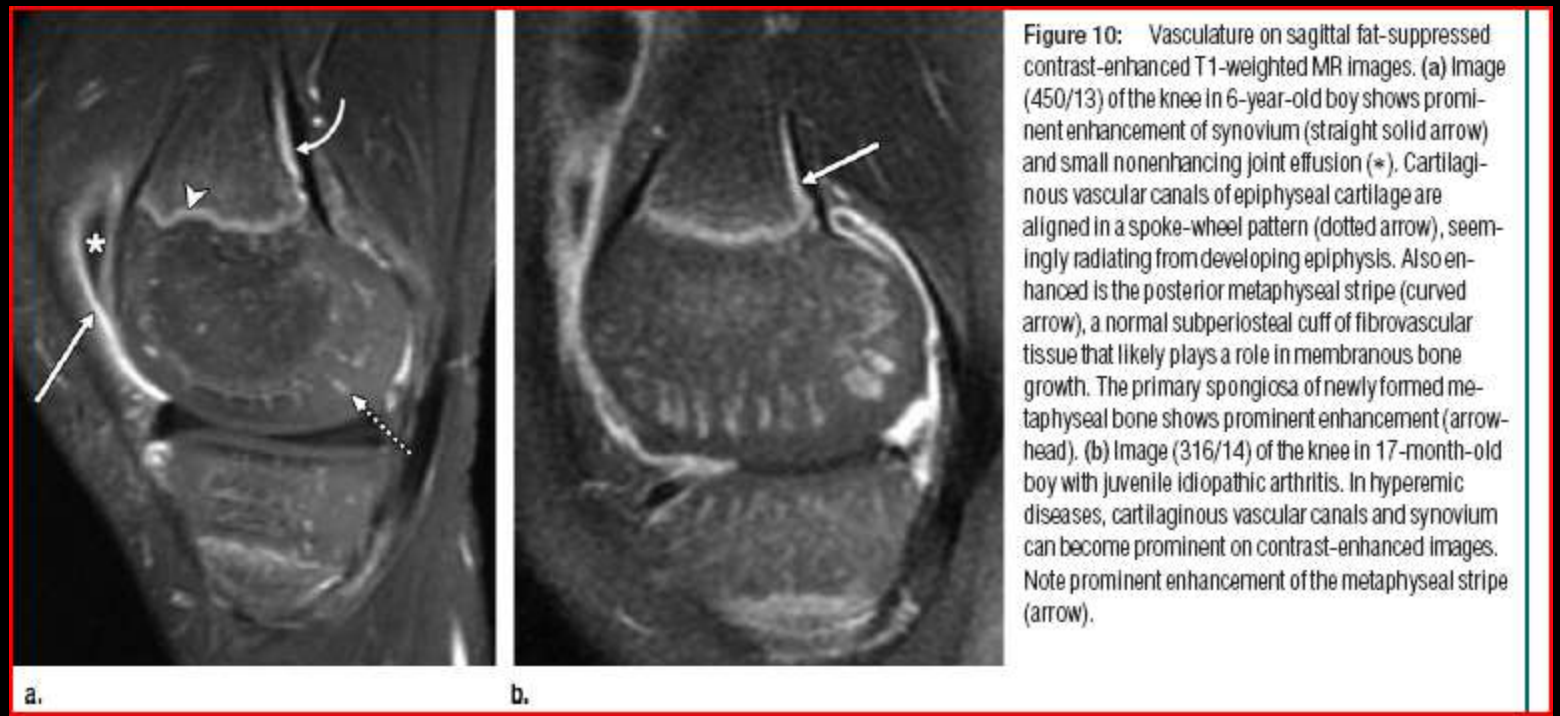
Figure 10: Vasculature on sagittal fat-suppressed contrast-enhanced T1-weighted MR images. (a) Image (450/13) of the knee in 6-year-old boy shows prominent enhancement of synovium (straight solid arrow) and small nonenhancing joint effusion (*). Cartilaginous vascular canals of epiphyseal cartilage are aligned in a spoke-wheel pattern (dotted arrow), seemingly radiating from developing epiphysis. Also enhanced is the posterior metaphyseal stripe (curved arrow), a normal subperiosteal cuff of fibrovascular tissue that likely plays a role in membranous bone growth. The primary spongiosa of newly formed metaphyseal bone shows prominent enhancement (arrowhead). (b) Image (316/14) of the knee in 17-month-old boy with juvenile idiopathic arthritis. In hyperemic diseases, cartilaginous vascular canals and synovium can become prominent on contrast-enhanced images. Note prominent enhancement of the metaphyseal stripe (arrow).

Epiphyseal vascular supply

- Contain numerous vessels at birth
- With progressive secondary center ossification vessels are lost
- Physis has transphyseal vessels around birth
- Gone by 1 year of life
- Vessel concentration is highest around secondary center of ossification

Epiphyseal vascular supply

- Parallel in young children
- Radial as secondary ossification continues



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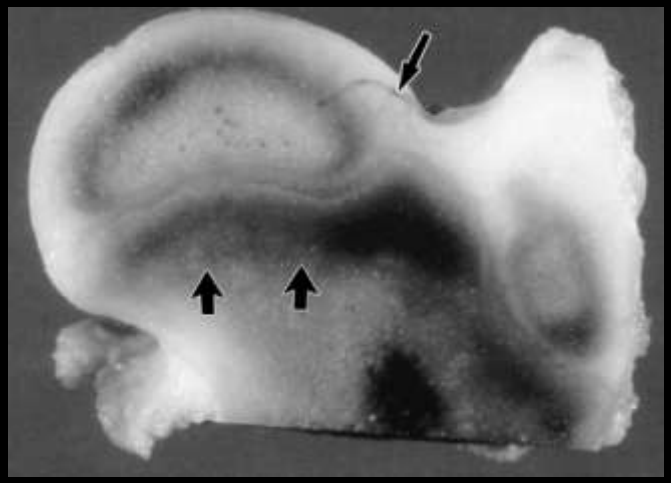
Epiphyseal vascularity

- Epiphyses with near complete coverage of the articular surface (proximal femur and proximal radius) blood supply is supplied by metaphyseal vessels
  - more injury prone with physeal injury and result in AVN (like femoral head)



AVN

- First effect of ischemia is cessation of growth at the secondary osssification center around epiphysis[6]
- Apparent fragmentation of epiphysis represents irregular endochondral ossification after ischemia of secondary ossification center

AVN

- Can be detected early with ADC/diffusion imaging before abnormalities are seen on conventional MRI
  - Decreased ADC at 3 hours
    - Cell swelling/ decreased diffusion

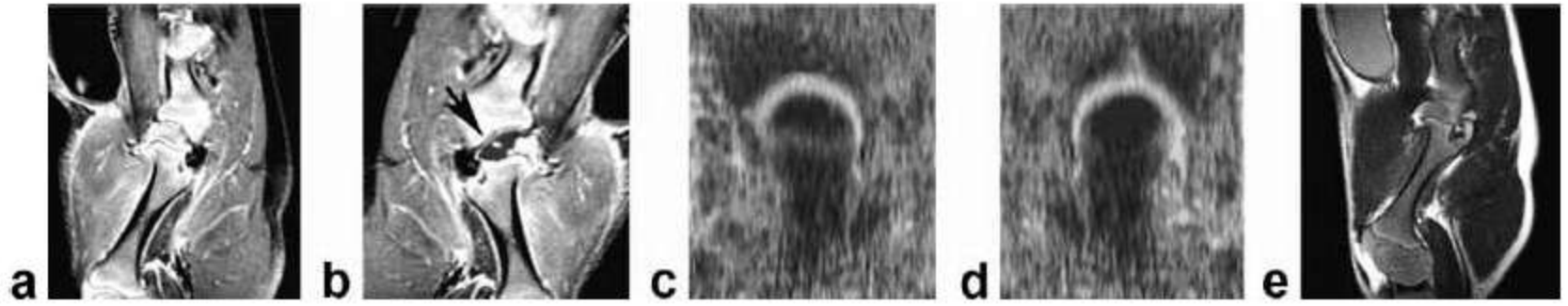


Figure 2. **a:** Sagittal Gd-enhanced SE T1WI of control side three hours after the surgery. **b:** Sagittal Gd-enhancement SE T1WI of ischemic side three hours after the surgery. The localized unenhanced area in the femoral head indicates ischemia (arrow). **c:** Coronal ADC map of the control side three hours after the surgery. **d:** Coronal ADC map of the ischemic side three hours after the surgery. SI was decreased in the femoral head. **e:** Sagittal FSE T2WI of the ischemic side three hours after surgery. No abnormality in SI was observed.

AVN

- Can be detected early with ADC/diffusion imaging before abnormalities are seen on conventional MRI
  - Increased ADC at 72 hours
    - Cell death and disorganization/increased diffusion

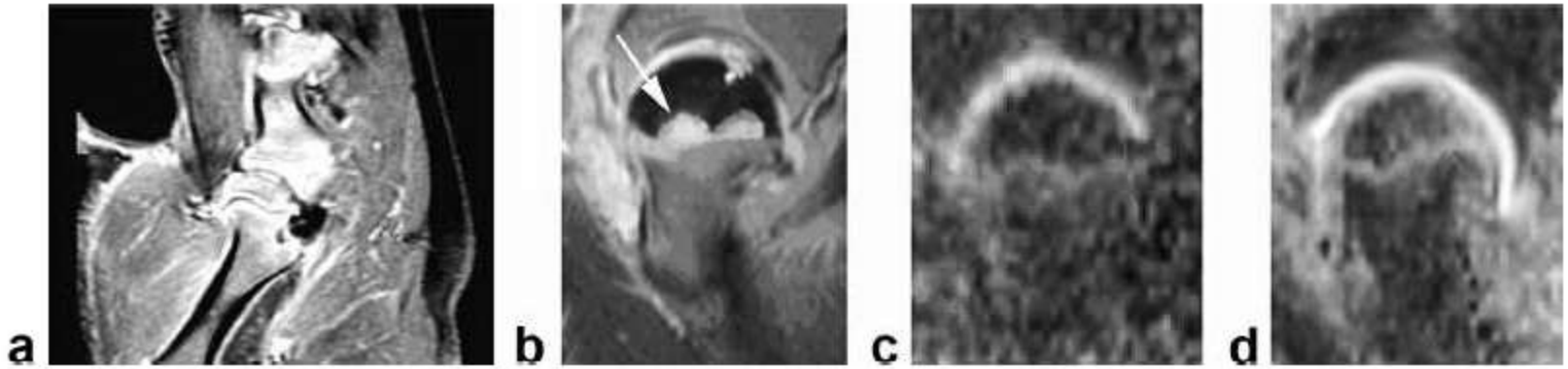


Figure 3. **a:** Sagittal Gd-enhanced SE T1WI of the control hip one week after surgery. **b:** Coronal Gd-enhanced SE T1WI of the ischemic hip one week after surgery Obvious uneven partial enhancement was observed in the femoral head (arrow). **c:** Coronal ADC map of the control hip one week after surgery. **d:** Coronal ADC map of the ischemic hip one week after surgery. SI of the femoral head was elevated.

AVN

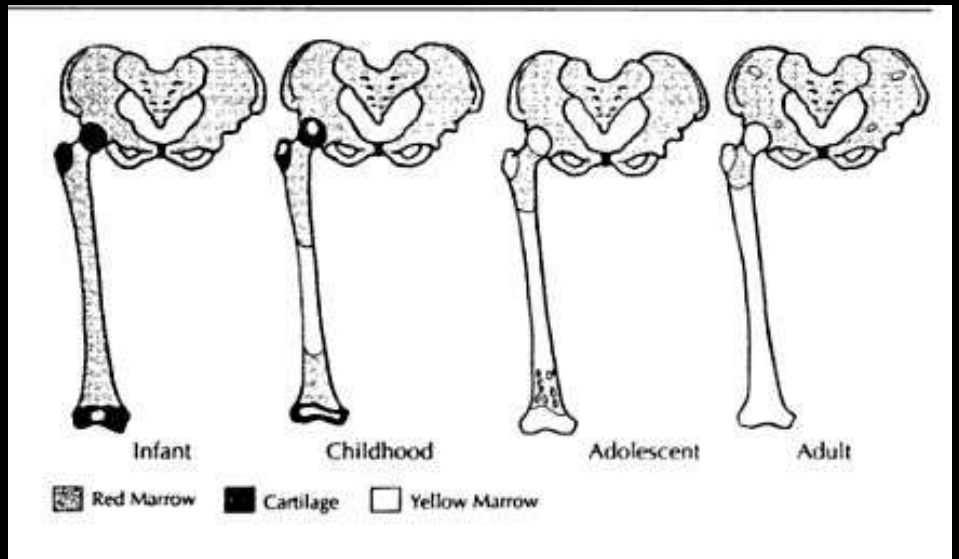
- Dynamic contrast enhancement can also be used for ischemic changes
  - Dynamic can detect ischemia at 30 min
  - Traditional CE MRI can detect ischemia at 1 hour
  - Could (in theory) to detect ischemia caused by hyperabduction to access optimal position in the treatment of hip dysplasia
  - Reversible up to 6 hours
- Is this all ready for “prime time”???

Marrow imaging

- Hematopoietic marrow of the adult is predominantly RBC but
  - 40% fat
  - 40% water
  - 20% protein
- Fatty marrow
  - 80% fat
  - 15% water
  - 5% protein
- If marrow signal on T1 is less than skeletal muscle and higher on T2 suspicious for infiltrative marrow process
- Fatty marrow conversion is from peripheral to central in body
  - Epiphysis, Central to peripheral in diaphysis
  - Reconversion is opposite

Marrow imaging

- Epiphyseal conversion first
  - Fatty marrow w/in 6 months of radiologic appearance of secondary center of ossification
- Last parts to convert in appendicular skeleton are at prox. humeral and femoral metaphyses
  - Red marrow seen into adulthood



Normal Marrow appearance T1

7 months

11 months

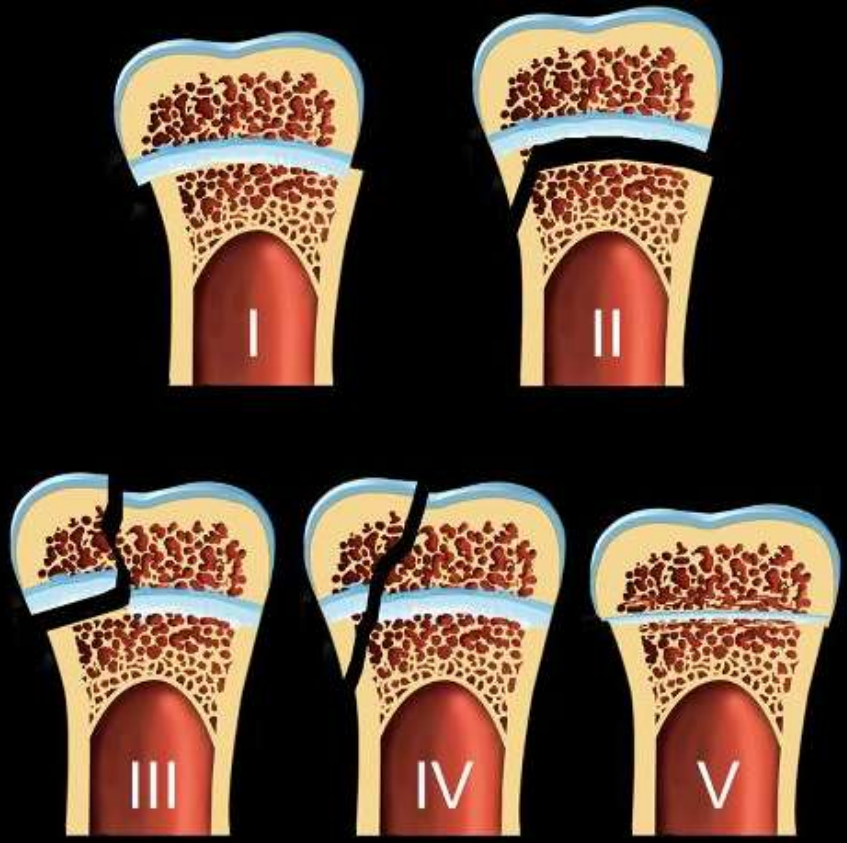
10 years

Variants of normal marrow

- Isolated foci of metaphyseal red marrow
  - Flame shaped
  - Should be increased T1 SI compared to muscle
- Marrow changes due to altered weight bearing
  - Speckled appearance in midfoot
  - Focal areas of perivascular red marrow
  - Analagous to disuse osteopenia on XRAY

Trauma (Acute)

- Growth plate is comparatively weak particularly in time of growth spurt
- Widely used Salter-Harris classification
- SH II is most common except in distal humerus (nearly all IV) and distal tibia (II=III=IV)
- Low SH grade fractures are generally non operative
- MR is generally not needed but can alter SH staging and can change physical management in up to 1/3 of cases[5]
- Physis is “weakest link” as compared with bone and surrounding ligaments



Trauma (Acute)

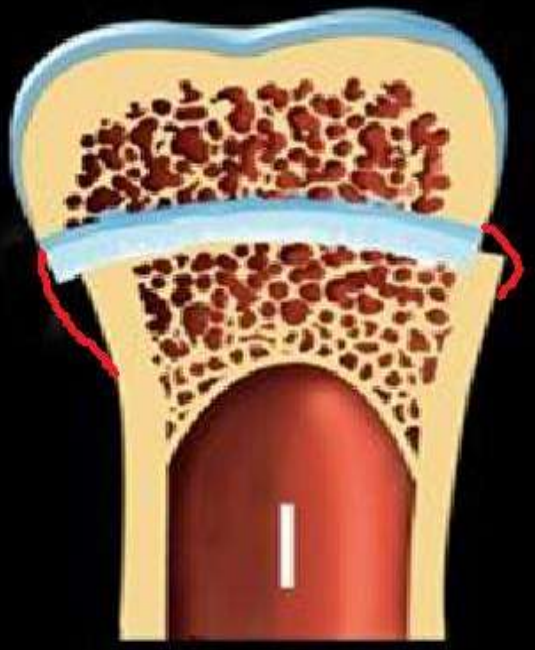
- Fractures stimulate bone growth
  - Between 2 & 10 yrs, side to side apposition w/ 0.5 to 1 cm overriding is the ideal position
  - 9mm of expected overgrowth
  - Up to 2 cm is accepted
- Fractures in children illicit intense inflammatory response and lead to hyperemia, fever (up to 40 deg C), and bone overgrowth

Trauma (Acute)

- Rotational and angular deformities (out of plane of motion) do not usually correct
- Healing is more rapid in younger children because of thick, already growing periosteum
  - Neonatal femoral fx – 2-3 wks to union
  - Early childhood- 4 wks
  - 7-10 YO- 6 wks
  - Adolescence- 8-10 wks

SH I

- Shear or avulsive force usually through hypertrophic zone
- MC in wider physis as seen in
  - Young children
  - Rickets
  - Scurvy
  - Osteomyelitis
- Motion is held in check by thick periosteal attachments
- No growth disturbance unless vascularity is disrupted (SCFE)



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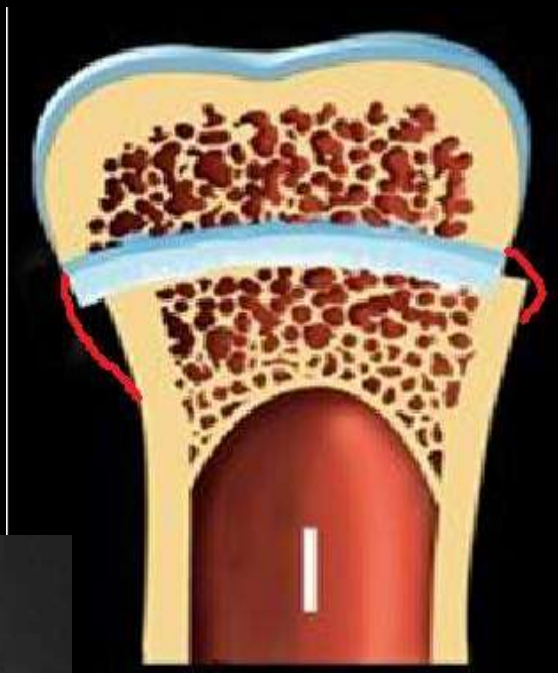
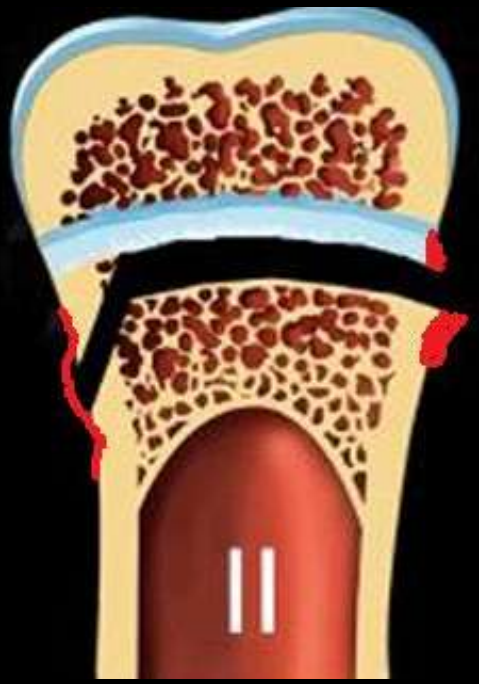
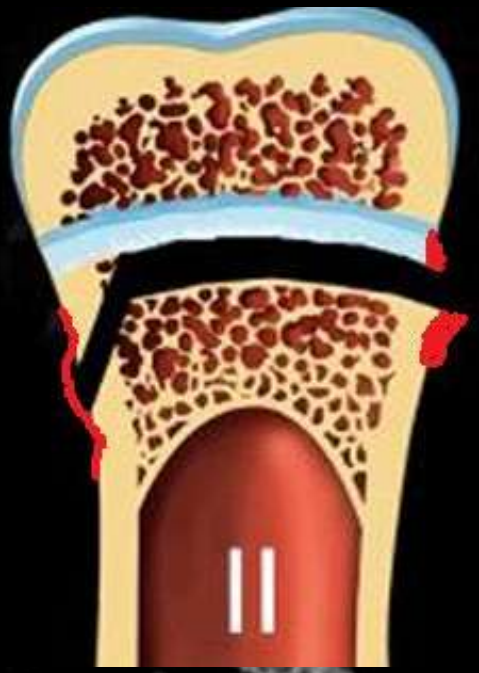


SH II

- Shearing or avulsion force
- MC
- Extends along hypertrophic zone then out through metaphysis
- Reduction is usually achieved and maintained as periosteum is partially intact
- No sig growth disturbance as germinal chondrocyte layer remains attached to epiphysis

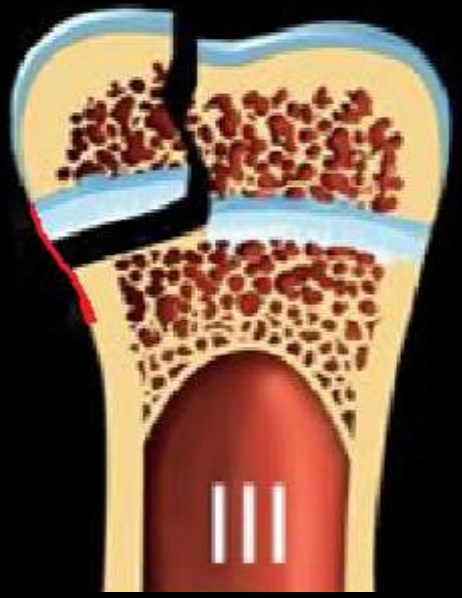


SH II

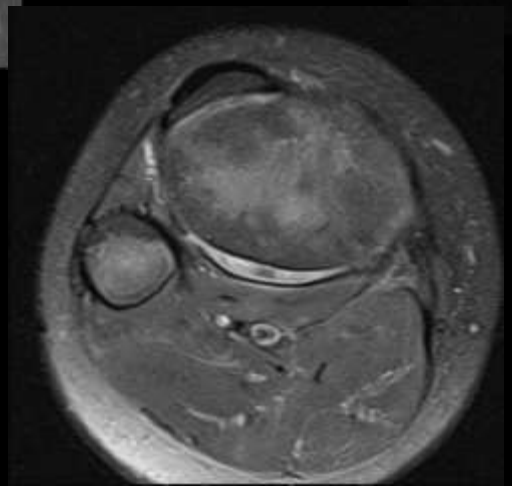


SH III

- Intraarticular shear force
- Rare injury
- Usually in proximal or distal tibial epipysis
- IA fx extending through hypertrophic zone of physis
- Surgical treatment based on degree of congruity of IA surface
- Generally good prognosis as long as reduction is adequate

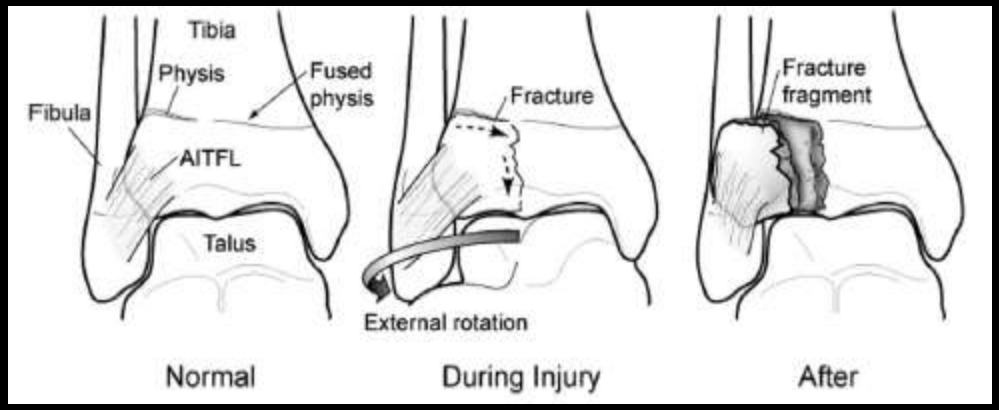


12 YO gymnast hyperextension injury

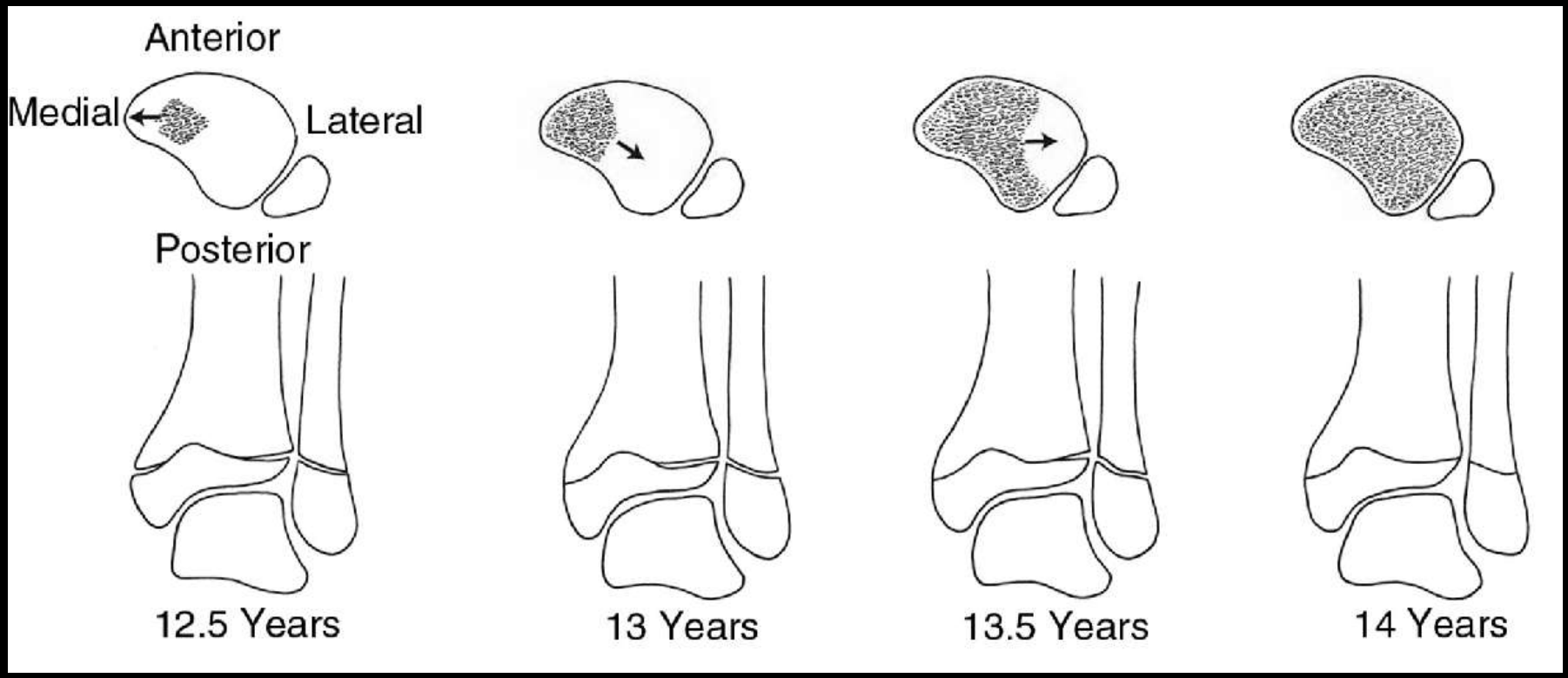


Tillaux

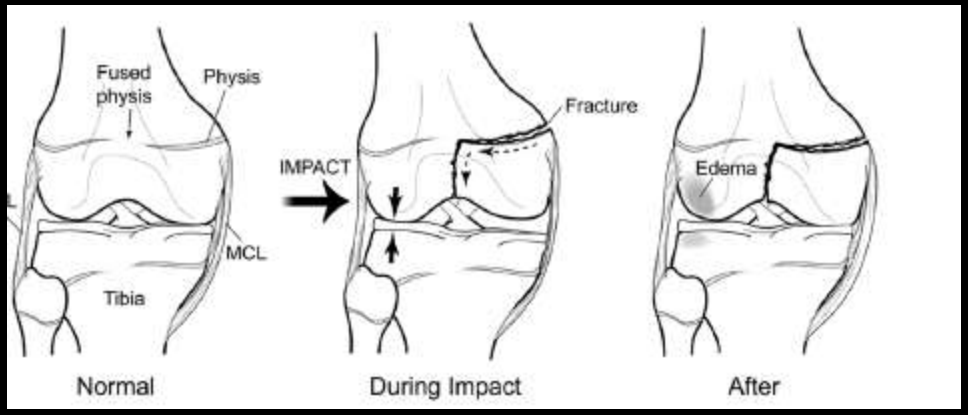
- SH III fracture of distal tibia at 18 months of physeal closure
- Growth plate closes from medial to lateral and posterior to anterior from Kumps bump
- Stress transmitted through anterior tibofibular ligament
- More skeletally mature fracture occurs more laterally
- Reverse is called Tillaux-Chaput

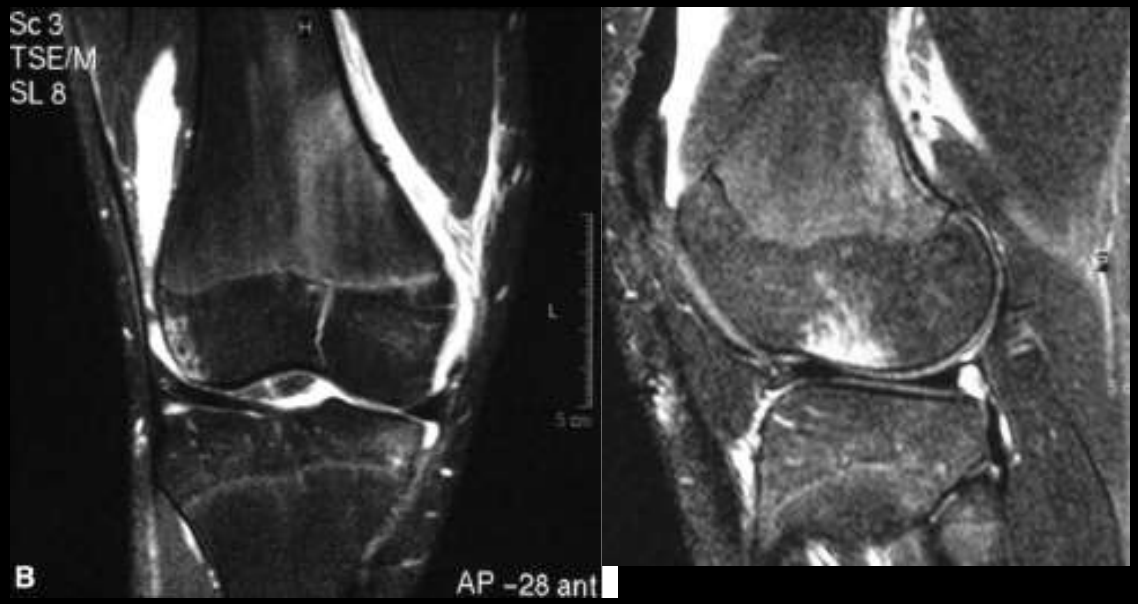


Distal Tibial Physeal Fusion



Images courtesy of Tudor Hughes, MD

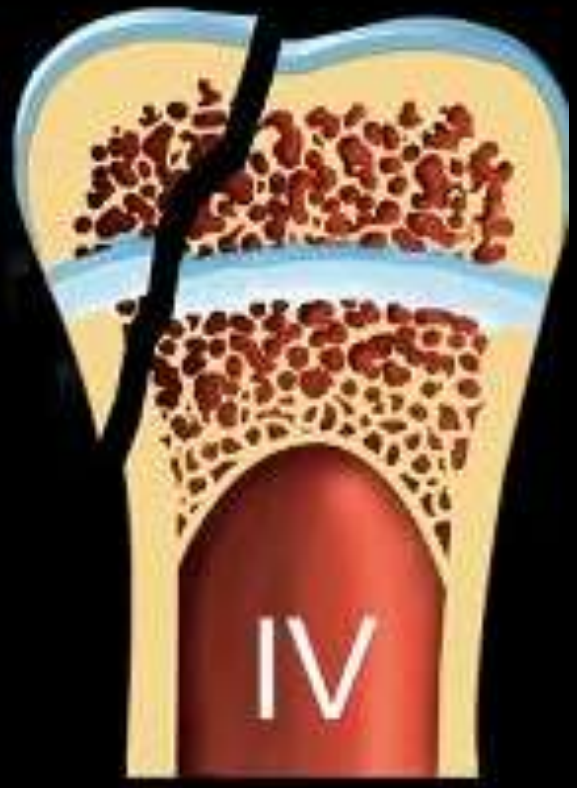




- SH III fx of MFC
- Same mechanism?
- Happens at time of growth plate closure
- Fx terminates around normal central closure site

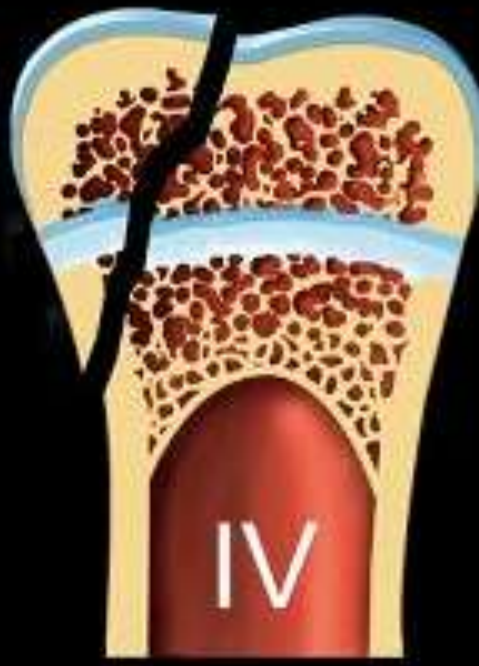
SH IV

- Fx begins at articular surface and extends through epiphysis, physis, and metaphysis
- Involves important germinal layer of physis
- Reduction must restore smooth articular surface and at physis
- Only smooth fine K wires should be used and should traverse plate perpendicularly to avoid arrest
- MC with lateral condylar fractures



SH IV

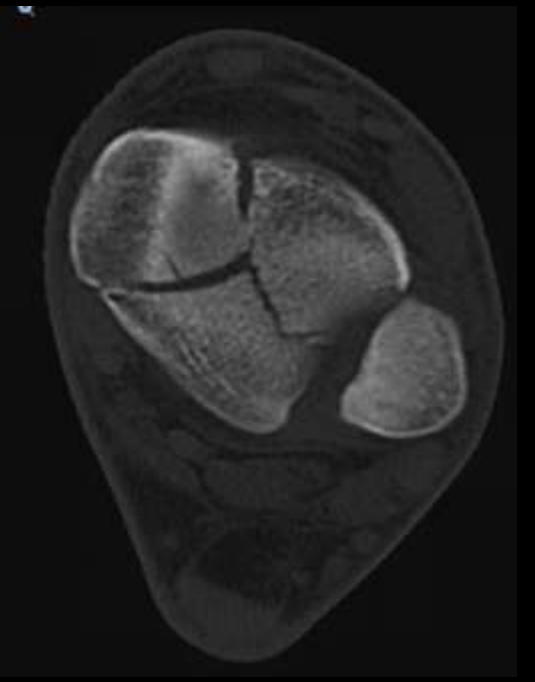
- Prototypical SH IV fracture
- Wrist and finger extensor muscle attachment
  - Pull the fracture apart
  - Tends to flip it over
- ORIF



www.pediatric-orthopedics.com/.../elbow.html

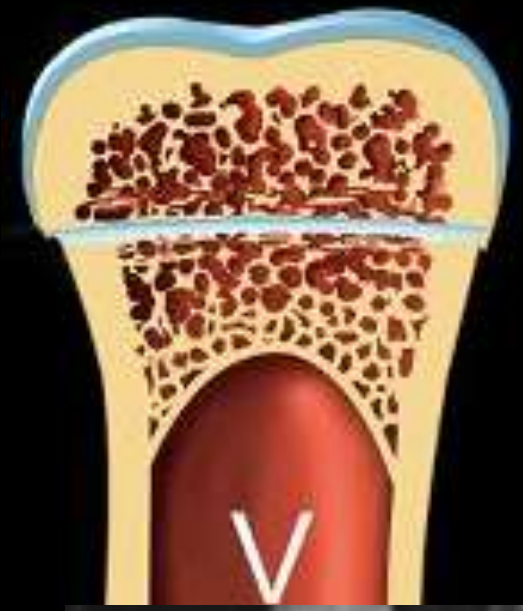
Triplane

- SH IV
- MC just before epiphyseal closure
- Mechanism of injury is forced external rotation
- IA to physis to metaphysis
- Two or three part



SH V

- Rare injury usually at joint with movement in one plane (knee/ankle)
- With marked ab or adduction severe compression force can crush the germinal layer of chondrocytes
- Severe injury as rate of closure is high
- Seen on MRI as increased T2 signal in physis and surrounding contusion in epiphysis and metaphysis without fx line evident



Images courtesy of Tudor Hughes, MD

Fracture Treatment

- Reduction should be performed early (< 1 wk)
- Malunion is accepted in SH I and II when seen late (7-10 days) rather than cause damage to physis
- SH III open reduction may be indicated to restore articular surface
- SH IV open reduction almost always performed

Physeal fractures of interest

- Beware of irreducible fractures leading to CT or MRI
- Greater than 3mm of widening of physis after reduction often indicates entrapped periosteum or surrounding tissue
- Poorer prognosis and can lead to bar formation

13 YO New Mexican with valgus force to knee after being hit by a car

Avulsive Fractures (acute)

- Common in the skeletally immature patient
- Involve practically every ligament or tendon attachment in the body

Physeal bar/bridge

- Bar formation is dreaded complication of SH fractures
- Increased incidence in the lower extremities (up to 27%)
- Etiology:
  - Axial compression causes injury to germinal chondrocytes
  - Anastomoses between epiphyseal and metaphyseal blood supplies lead to bone formation
  - Fractures to physeal epiphyseal border disrupts vascular suppy

Physeal bar/bridge

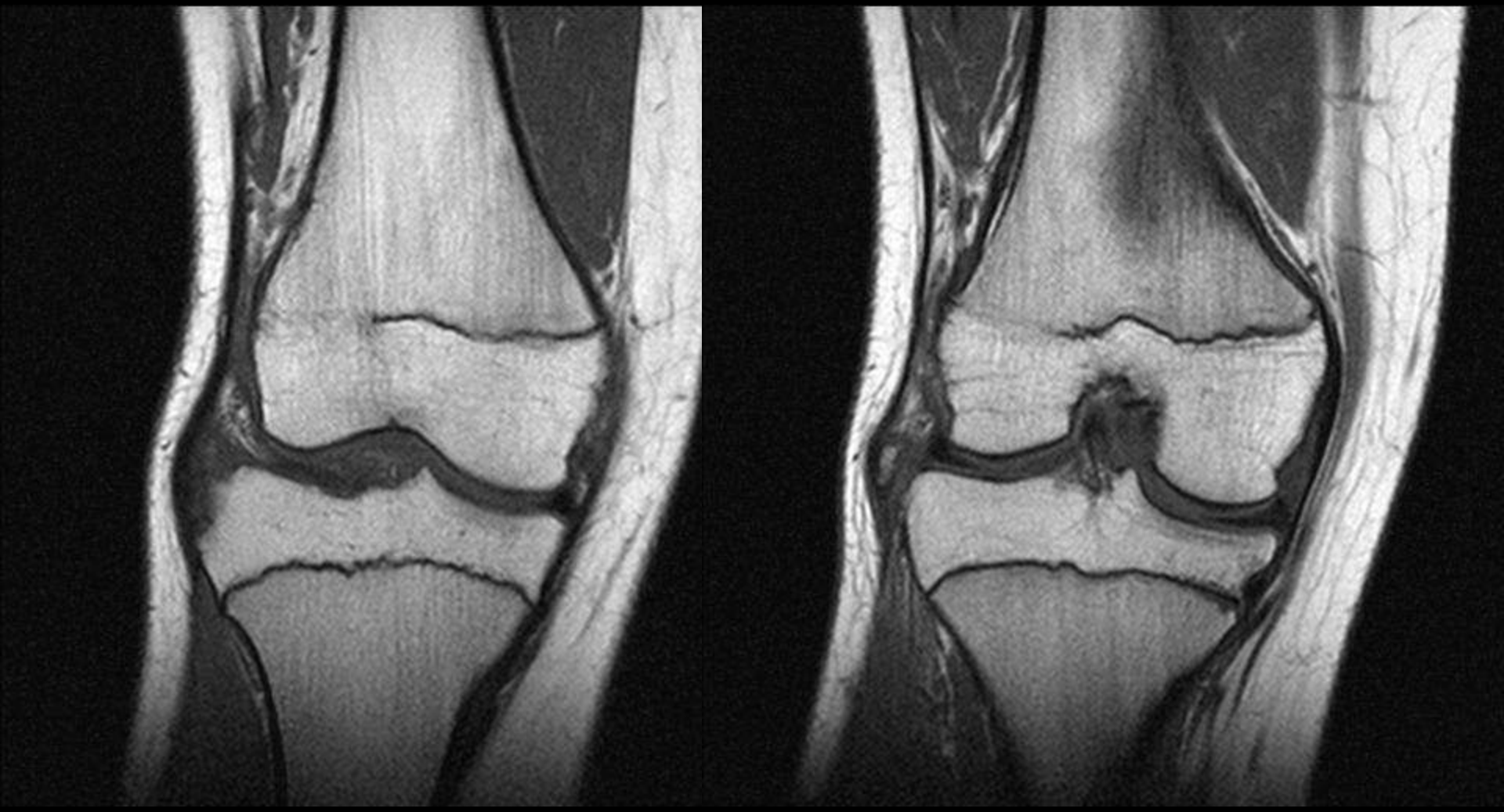
- MC posttramatic bar at distal portion of long bones (esp tibia)
- Growth arrest of due to other causes (infection, ischemia, radiation, Blounts) is MC proximally

Physeal bar diagnosis

- XRAY:
  - Look for direct evidence of bar formation
  - Growth arrest lines should parallel physis
  - Radiographs can overestimate size so MR or CT is preferable
- CT/MR:
  - Excellent for assessing size and position of bar
  - Consider 3D SPGR with fat sat for high spatial resolution
  - First sign on MR is disappearance of high T2 signal physeal cartilage

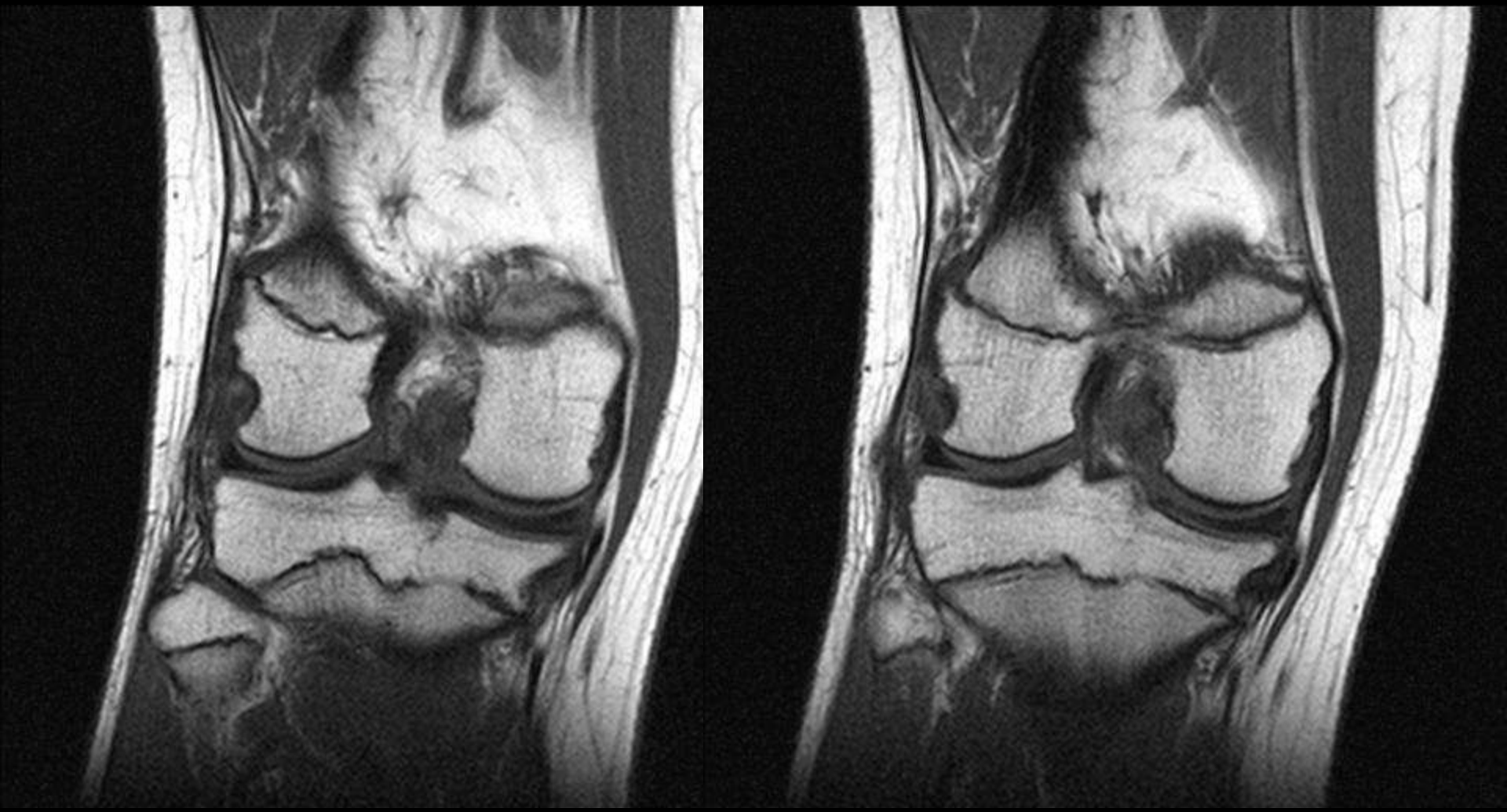
Physeal closure

Previous SH IV



T1

Images courtesy of Tudor Hughes, MD

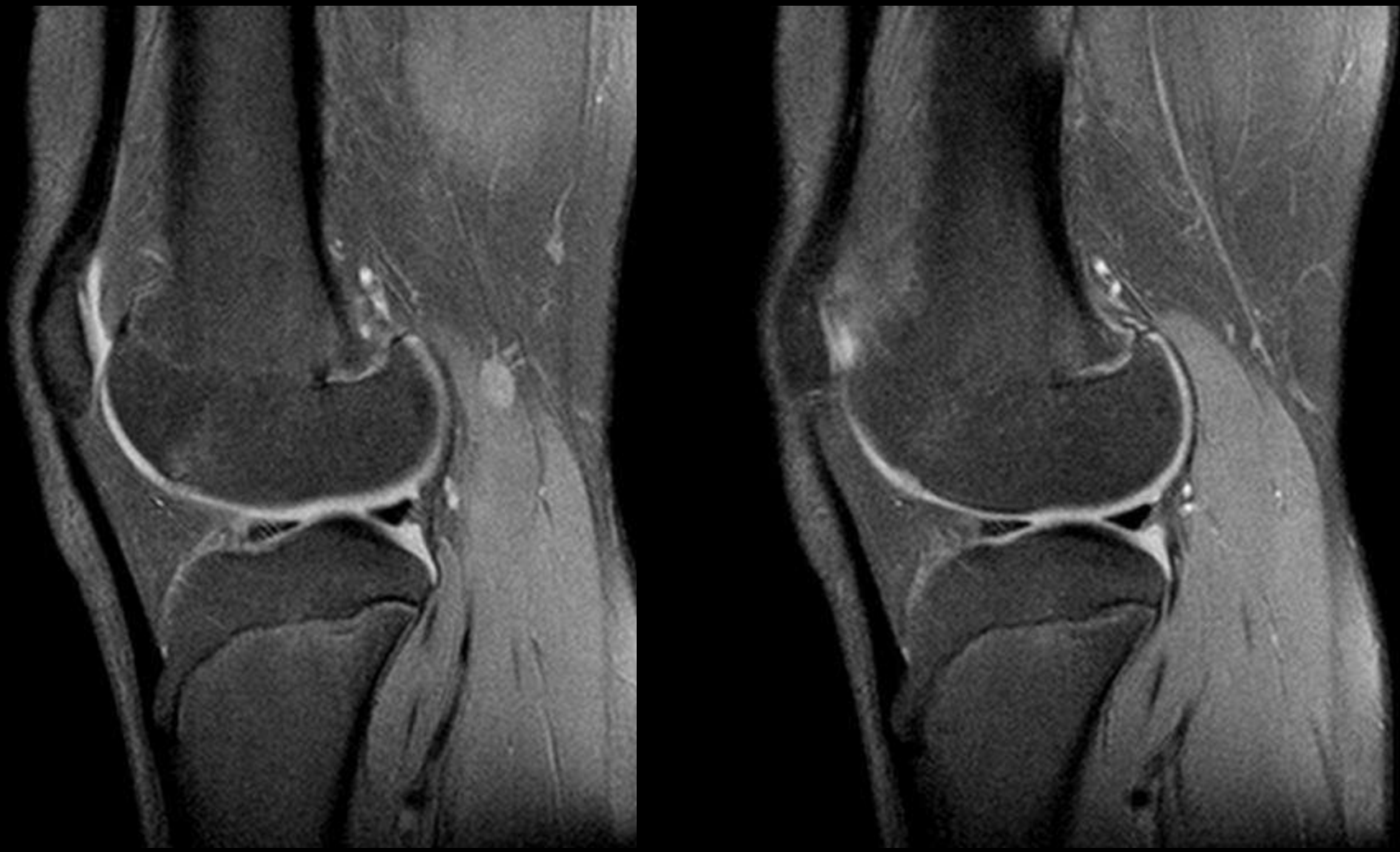


T1

Images courtesy of Tudor Hughes, MD

PD Fat Sat

Images courtesy of Tudor Hughes, MD



PD Fat Sat

Images courtesy of Tudor Hughes, MD

Physeal bar/bridge treatment

- Are treated according to size of bar
  - <30% treated nonoperatively (depending on position)
  - 30-50% surgical bar removal with fat interposition
  - >50% more extensive surgery
- Treated when child is expected to have 2 cm or 2 years of growth remaining
- Epiphyseodesis to correct angular deformity or LLD

Trauma (repetitive microtrauma)

- MR findings are likely related to disruption of normal blood supply
  - Normal apoptosis of chondrocytes disrupted
- Similar increase in metaphyseal signal intensity in immature rabbits with induced metaphyseal injury
- Histologic examination showed persistent chondrocytes and cartilaginous matrix in the primary spongiosa of the metaphysis

Repetative Microtrauma

- Persistent compression affects blood flow on one or both sides of the physis
- Metaphyseal side affected in early stages
  - Inhibition of hypertrophic cell apoptosis
  - Cartilage layer becomes up to 4x thicker
  - Pressure increases on epiphyseal side of physis
  - After callus bridges physis vascular ingrowth from both sides occurs
- The open physis of the immature athlete is subjected to repeated stress, without adequate time to heal
- Animal studies have shown that the ability of physeal cartilage to withstand shear forces decreases during puberty

Repetative Microtrauma

- Essentially represents stress fx of the physis (chronic SH I)
- Without history it is difficult to reliably differentiate an acute from chronic process
- Does differentiation matter?
  - Treatment and followup is the same
  - Rest and immobilization

General Imaging Findings

- Similar imaging manifestations in multiple sites
- XRAY:
  - Widening and irregularity of physis greater than 2 mm
  - Assymetrical (depending on site)
- MR:
  - Widening and increased T2 signal in affected physis
  - Can be focal (tonguelike) or diffuse
  - Surrounding edema within metaphysis and epiphysis


MTX:25
Sag
I81


0
50
I81

Same disease many names:

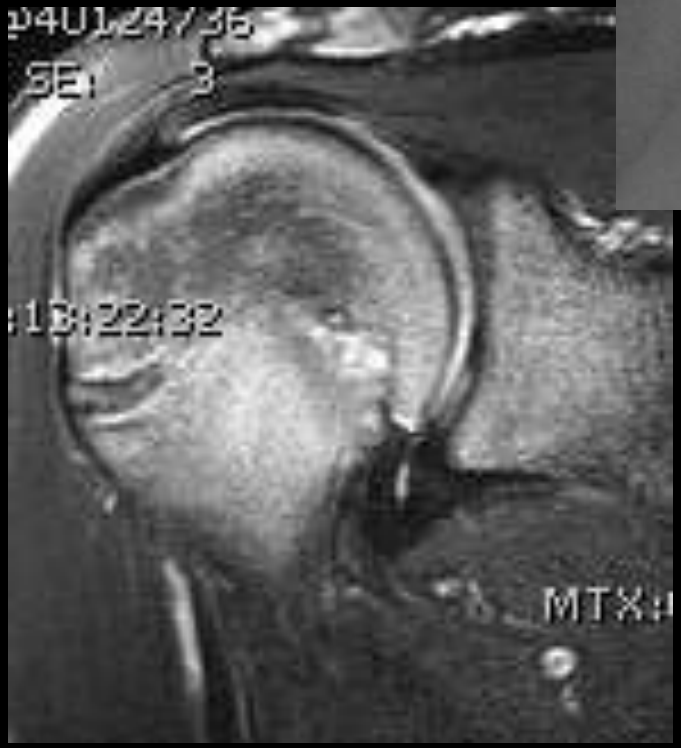
- Gymnast's wrist
  - Distal radius and ulna
  - Isolated ulna or radius
- Catcher's or runner's knee
  - Affects distal femur or proximal tibia
- Little leaguer's shoulder
  - Proximal humerus
- Little leaguer's elbow
  - Medial epicondyle

Little Leaguer's Shoulder

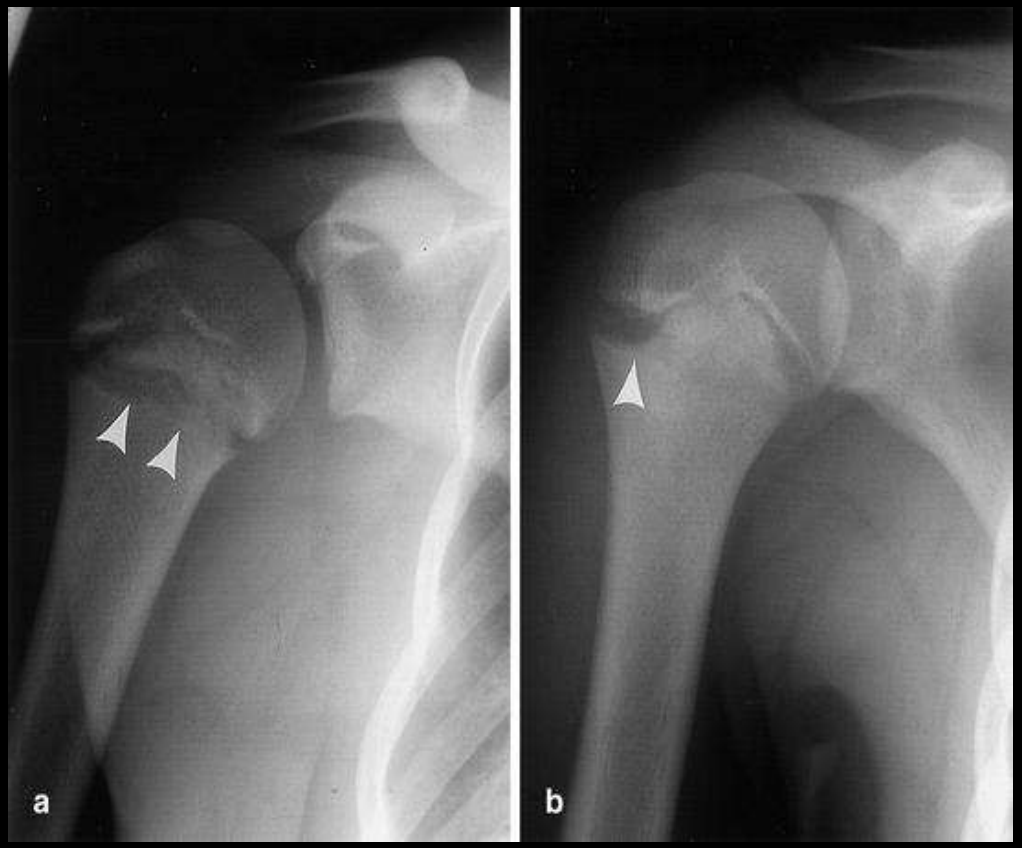
- Radiologic findings:
  - physeal widening of the proximal humeral physis (especially laterally)
  - lateral metaphyseal fragmentation or calcification, demineralization
  - sclerosis of the proximal humeral metaphysis
  - rarely, an apparent slipped humeral capital epiphysis
- Complications:
  - limb shortening(10%)
  - osteonecrosis of HH
  - humerus varus deformity
- Treatment:
  - rest from throwing for at least 3 months
  - return to throwing when the shoulder is asymptomatic

Little Leaguer's Shoulder

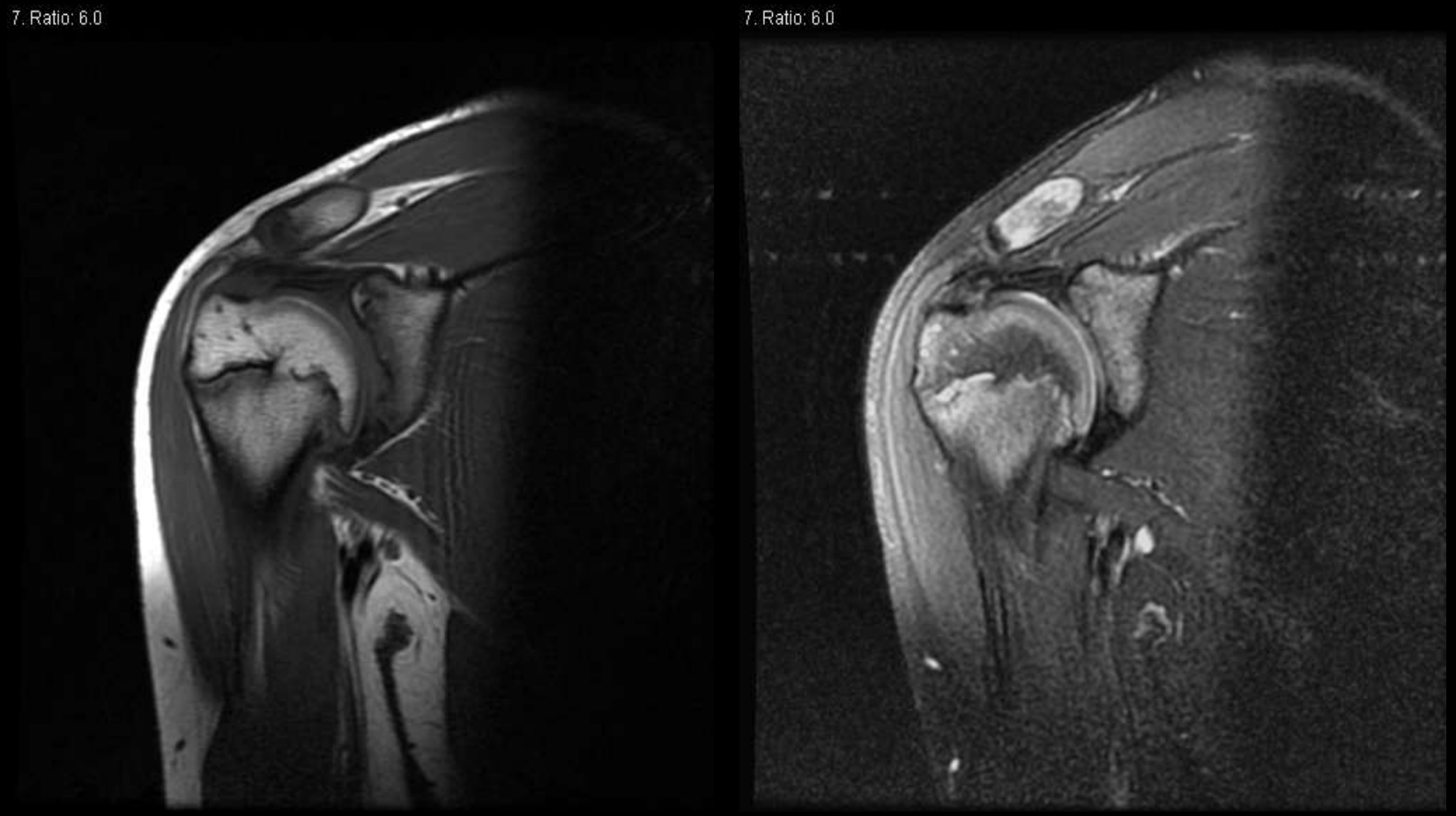
- seen in adolescent throwers (baseball/cricket) between the ages of 11 and 16
- Excessive traction and rotational shear forces across the proximal humeral physis



Little Leaguer's Shoulder



Little Leaguer's Shoulder



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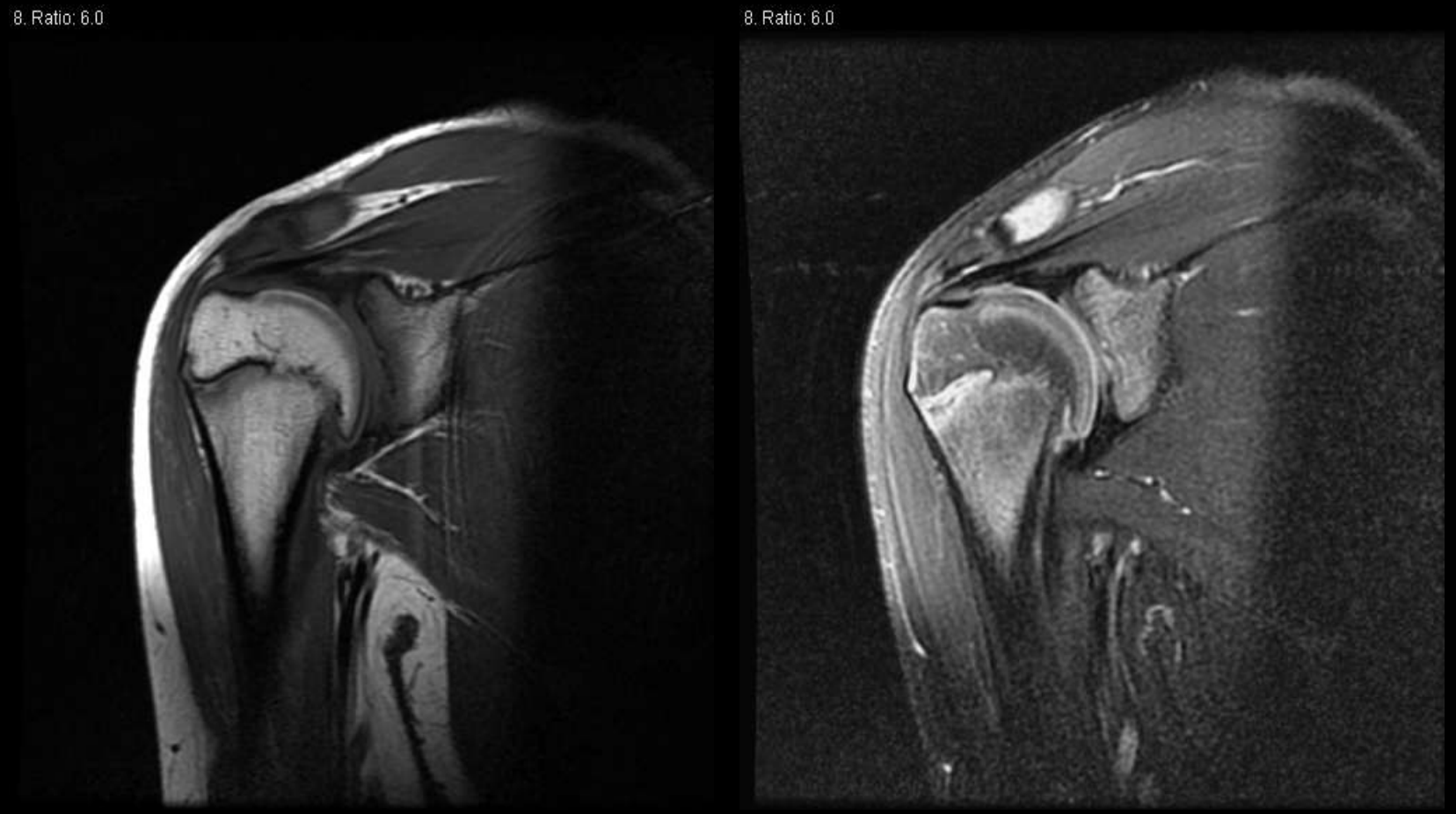
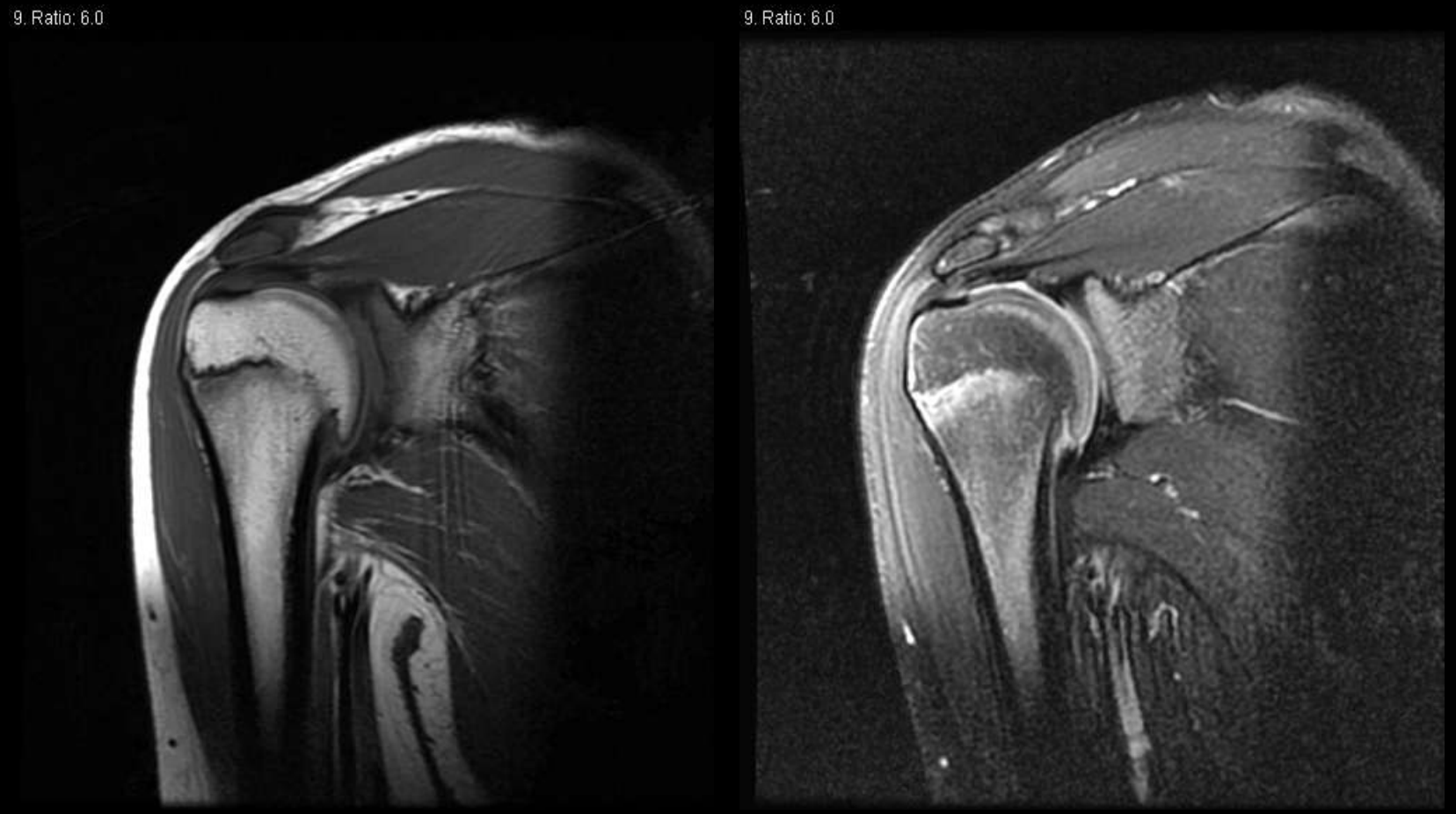
Little Leaguer's Shoulder



Images courtesy of Tudor Hughes, MD

Little Leaguer's Shoulder



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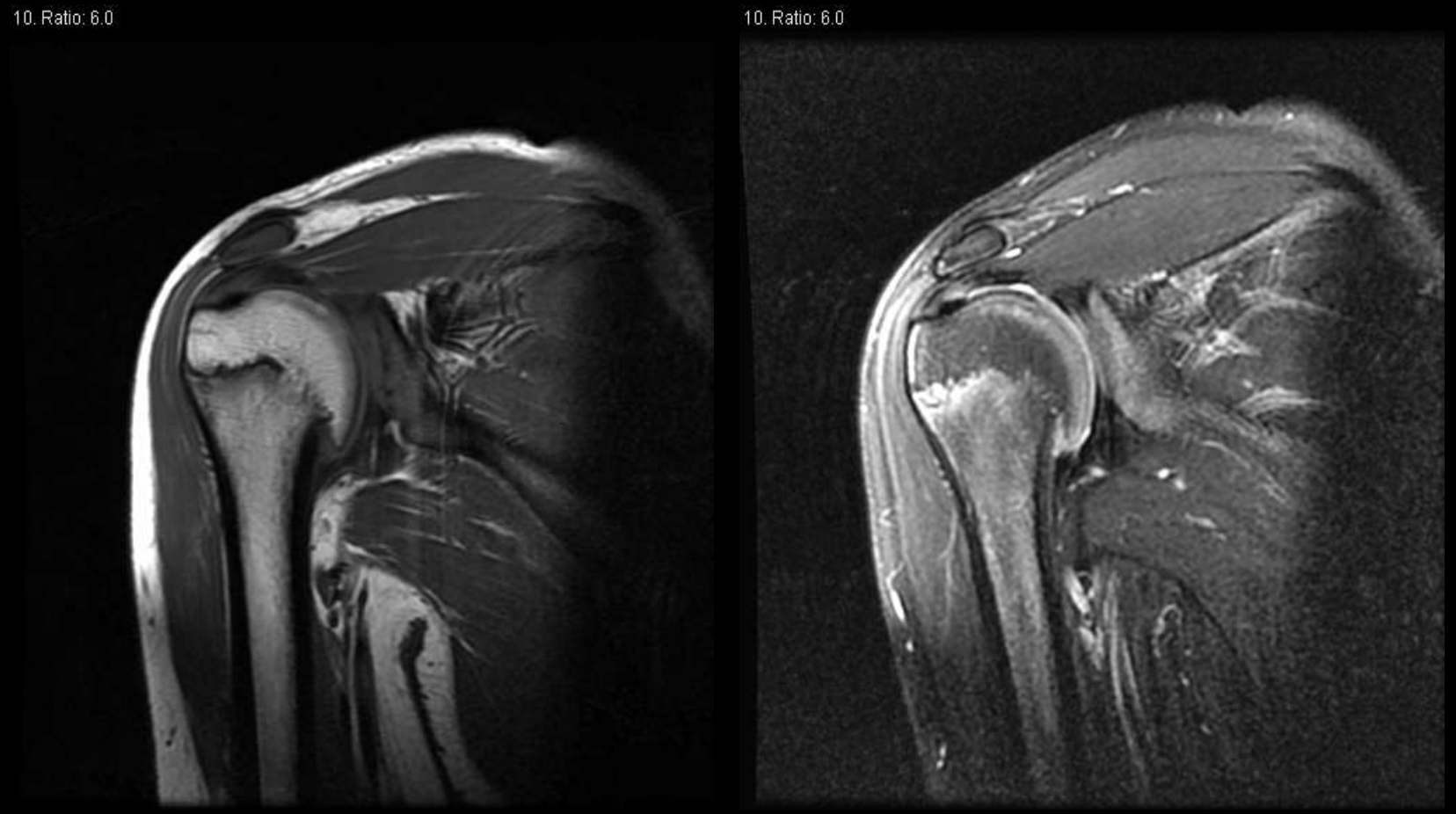
Little Leaguer's Shoulder



Images courtesy of Tudor Hughes, MD

Little Leaguer’s elbow

•Adolescent throwers

Repetitive tensile stress

caused by contraction of the flexor–pronator muscles and repetitive valgus loads can result in apophysitis of the medial

Epicondyle

Severe cases can result in avulsion of medial epicondyle

Gymnast wrist

- Widening of distal radius and ulna physis
- Secondary to abnormal weightbearing
- Injury occurs in both male and female gymnasts and is much more common between the ages of 10 and 14

Gymnast wrist

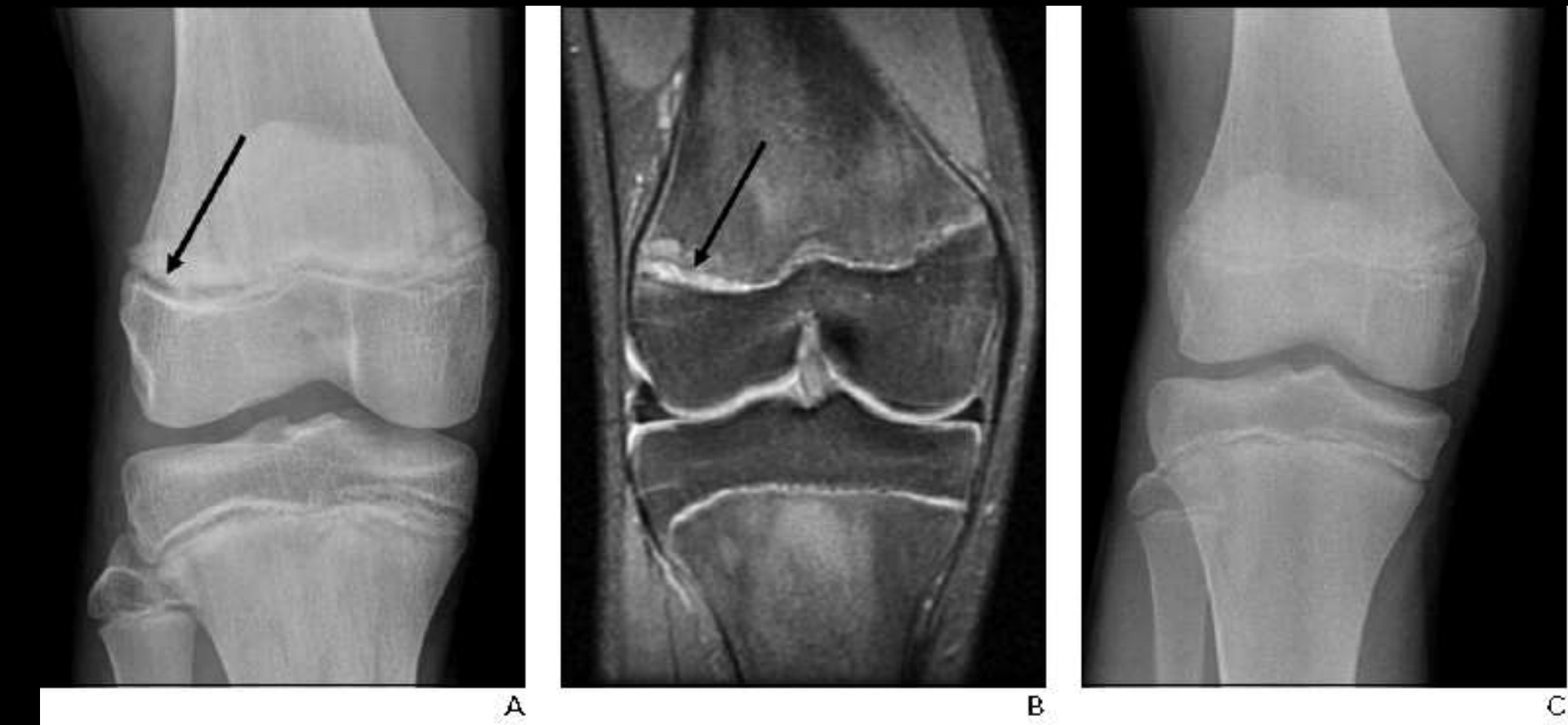
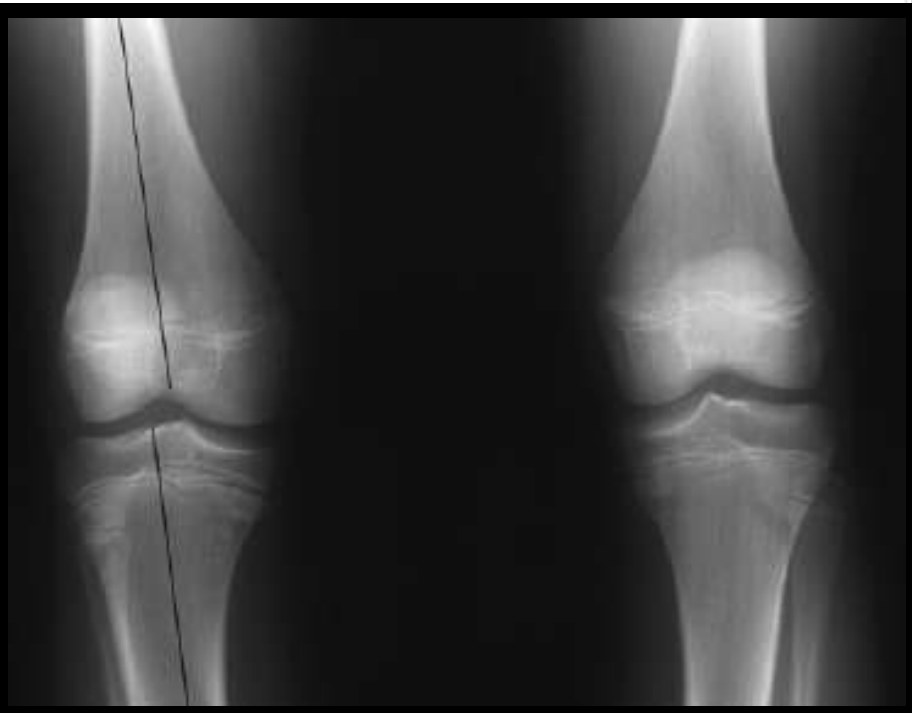
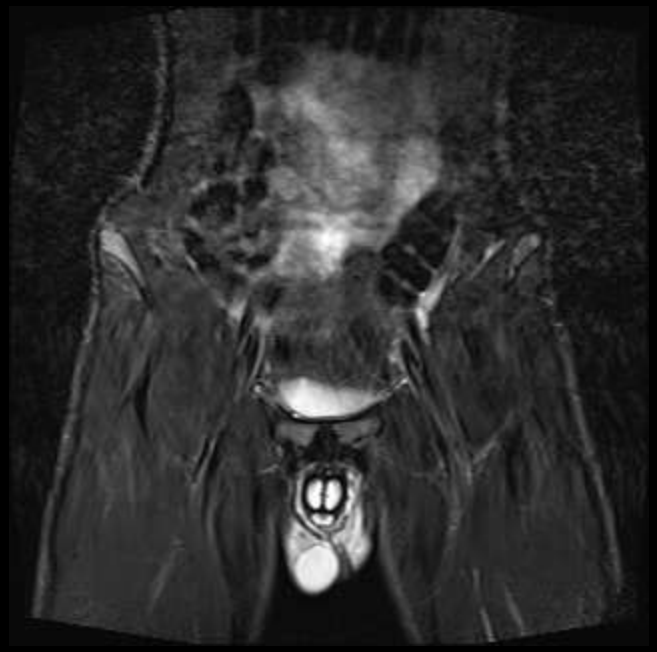
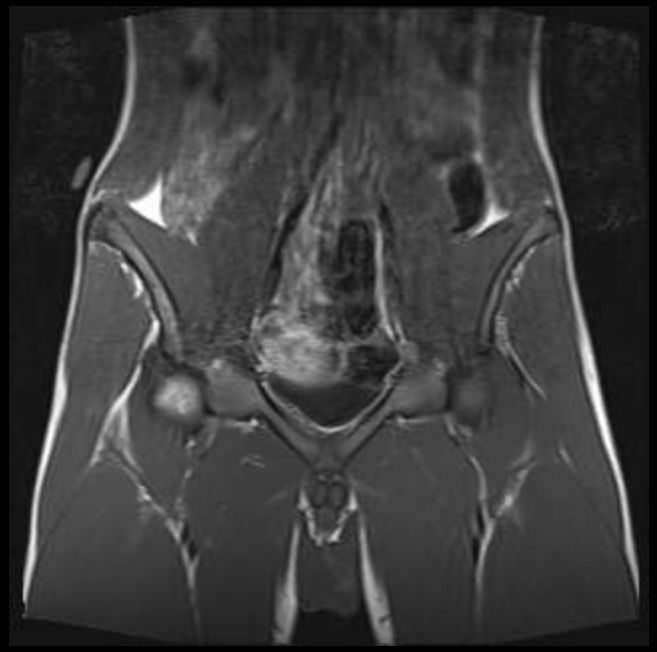


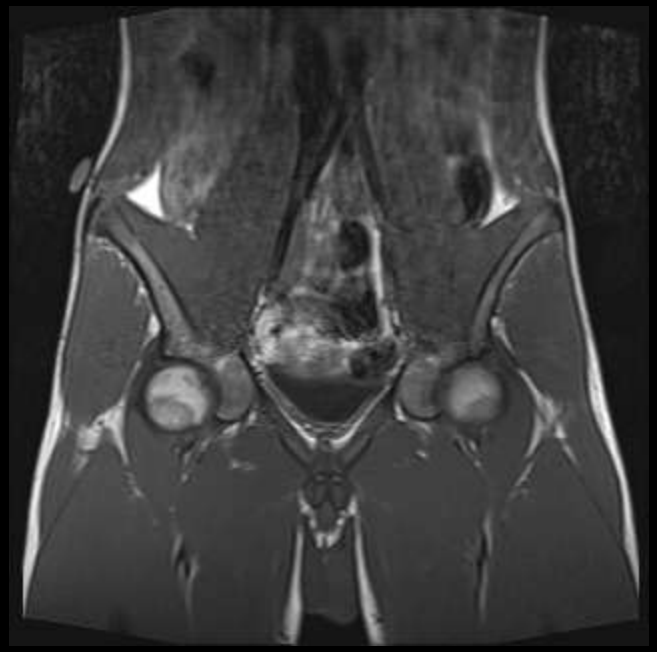
Fig. 1—15-year-7-month-old boy who is football place kicker.
A, Frontal radiograph of right knee shows broad band of physeal widening of lateral aspect of distal femoral physis (*arrow*).
B, Coronal fast spin-echo proton density–weighted image (TR/TE, 2,500/11) with fat saturation of right knee shows broad area of lateral physeal widening of distal femur (*arrow*). Signal is isointense to that of rest of physis.
C, Frontal radiograph obtained 3 months after immobilization of knee shows near complete resolution of physeal widening.

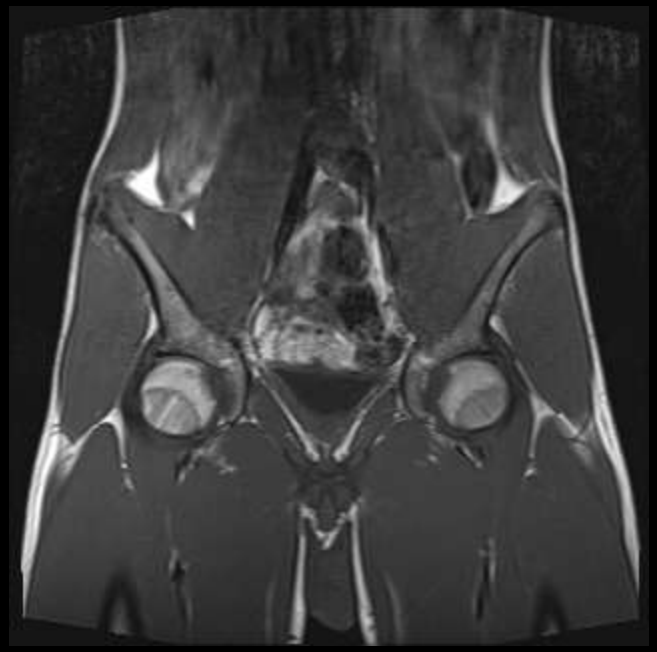


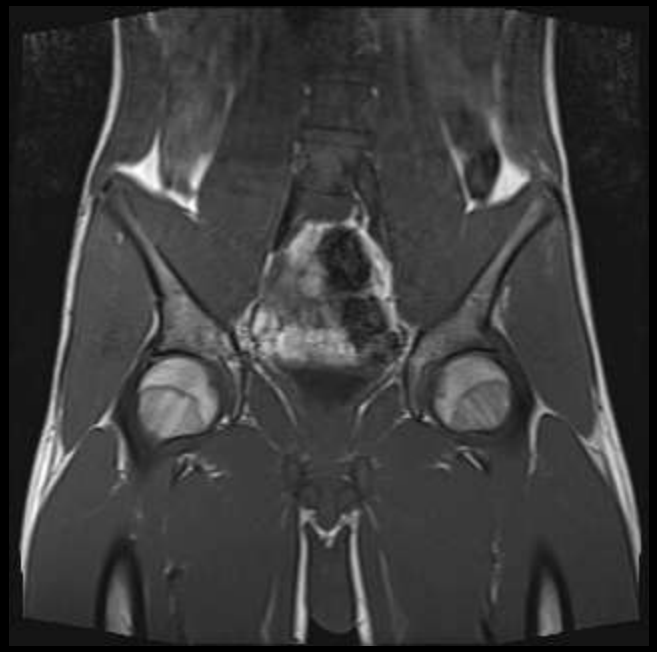
17 YO in training for Marine Corps

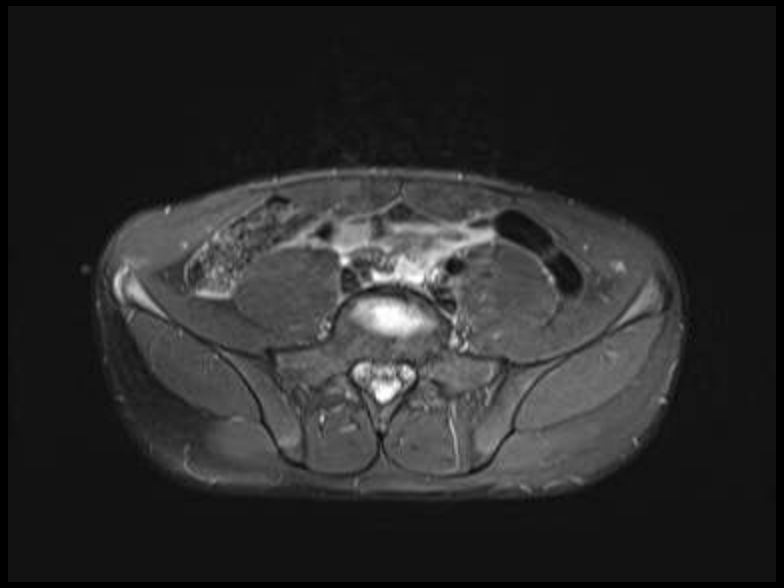


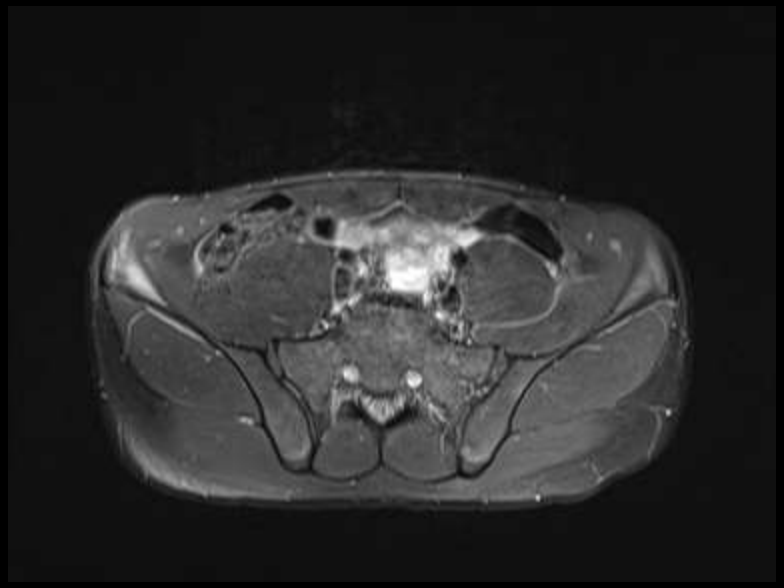


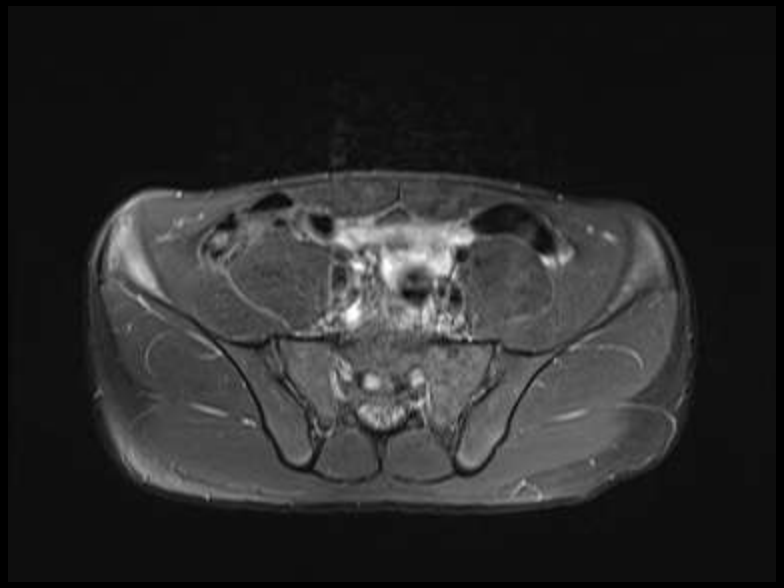


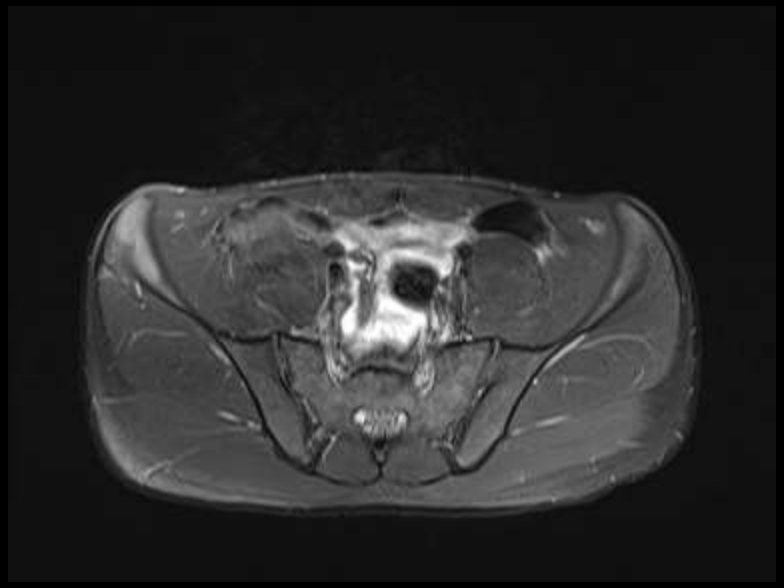


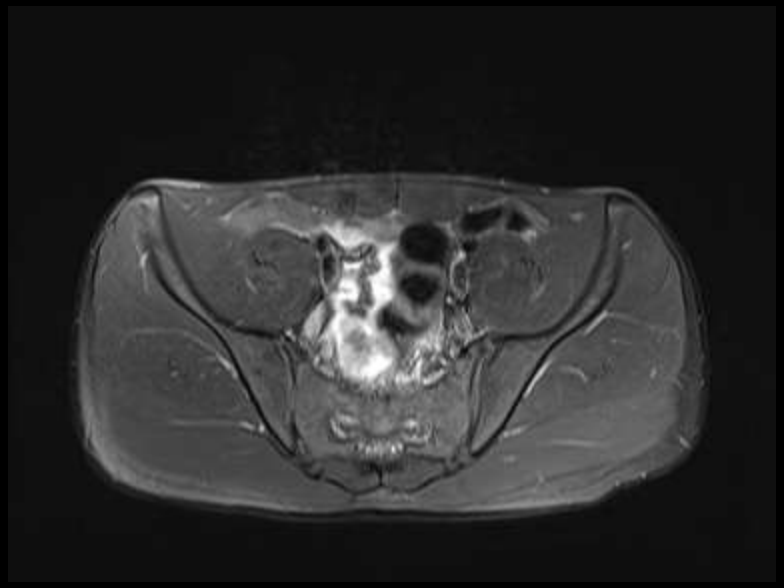












Chronic stress injury to Iliac crest apophysis

- This patient was doing around 1000 situps per week
- Associated with chronic traction from repetitive rotatory motion
  - Gymnastics
  - Cross country running
  - Soccer
  - Baseball
- Iliac crest apophysis ossifies from anterolateral to anteromedial but most lateral aspect is last to fuse
- At attachment site of Internal oblique, external oblique, and transverse abdominis

SCFE

- As with the well-known physeal overuse syndromes, the typical age at presentation for SCFE is 13–15 years old, during the pubertal growth period
- Seen primarily in obese children
- Likely a similar mechanism as overuse syndromes except with greater shearing force at femur

Slipped Capital Femoral Epiphysis

- Epiphysis moves posteriorly and medially relative to metaphysis secondary to stress of weight bearing
- Eventually becomes bilateral in a majority of untreated patients within 24 months of first occurence
- On AP view - Klein's line is drawn along top of femoral neck towards acetabulum, should cross a small portion of epiphyseal ossification center
- Frog leg best view to assess migration

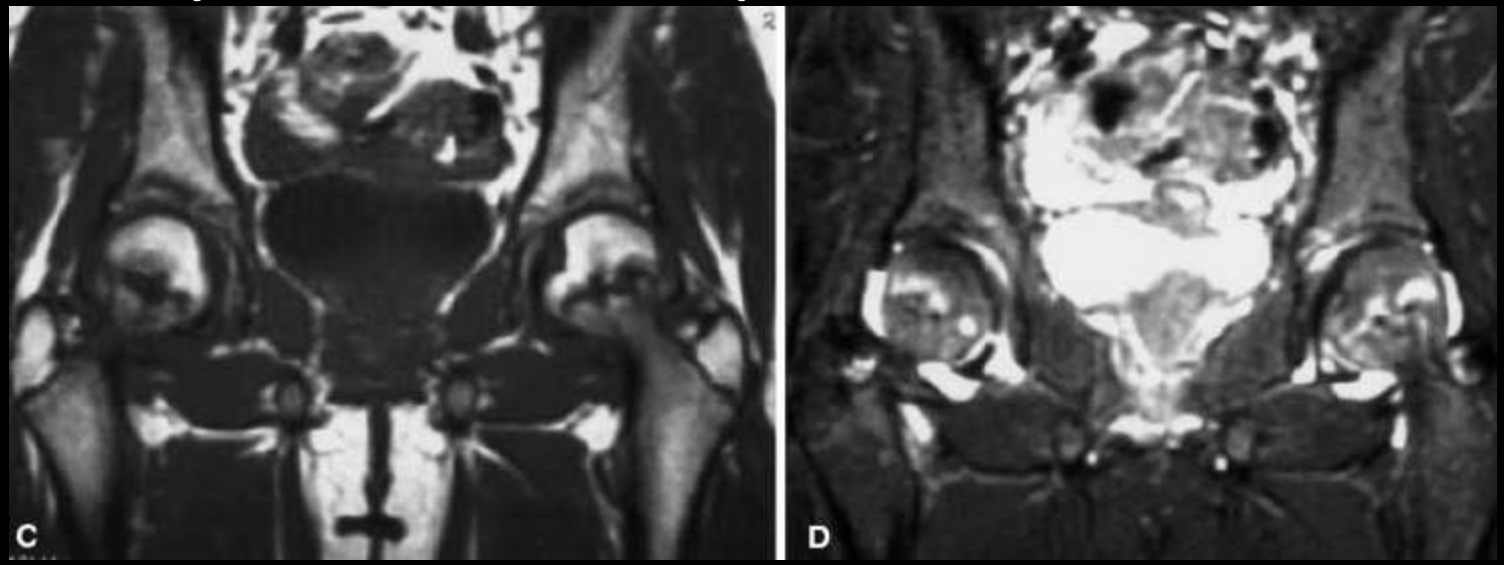
Images courtesy of Tudor Hughes, MD

Image courtesy of Tudor Hughes, MD

Image courtesy of Tudor Hughes, MD

SCFE

- Early findings include irregularity and widening of growth plate
- MR findings are same in early as in late, except without displacement
- Early detection can prevent AVN



- *Future fellows, you will go to the Dagobah children's hospital. There you will learn from Yoda, the Jedi Master who instructed me."*

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