Let's Call Radiology: Pediatric MSK Pearls

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Disclosures

- Neither Dr. Barrett nor Dr. Barton has any financial disclosure.

Outline

- Putting the Peds in Pediatric MSK

Outline

- Case Conference:
  - Congenital
  - Trauma
  - Infectious/inflammatory
  - Oncologic

Take-Home Messages

- Kids are not just little adults.
- View(s) and field-of-view matter.
- When in doubt about whether imaging will be helpful/what imaging to order…
  - Let's call radiology!
  - Give MORE history, not less.

Beware the open physis!

I II III IV V

Ankle "sprain"?

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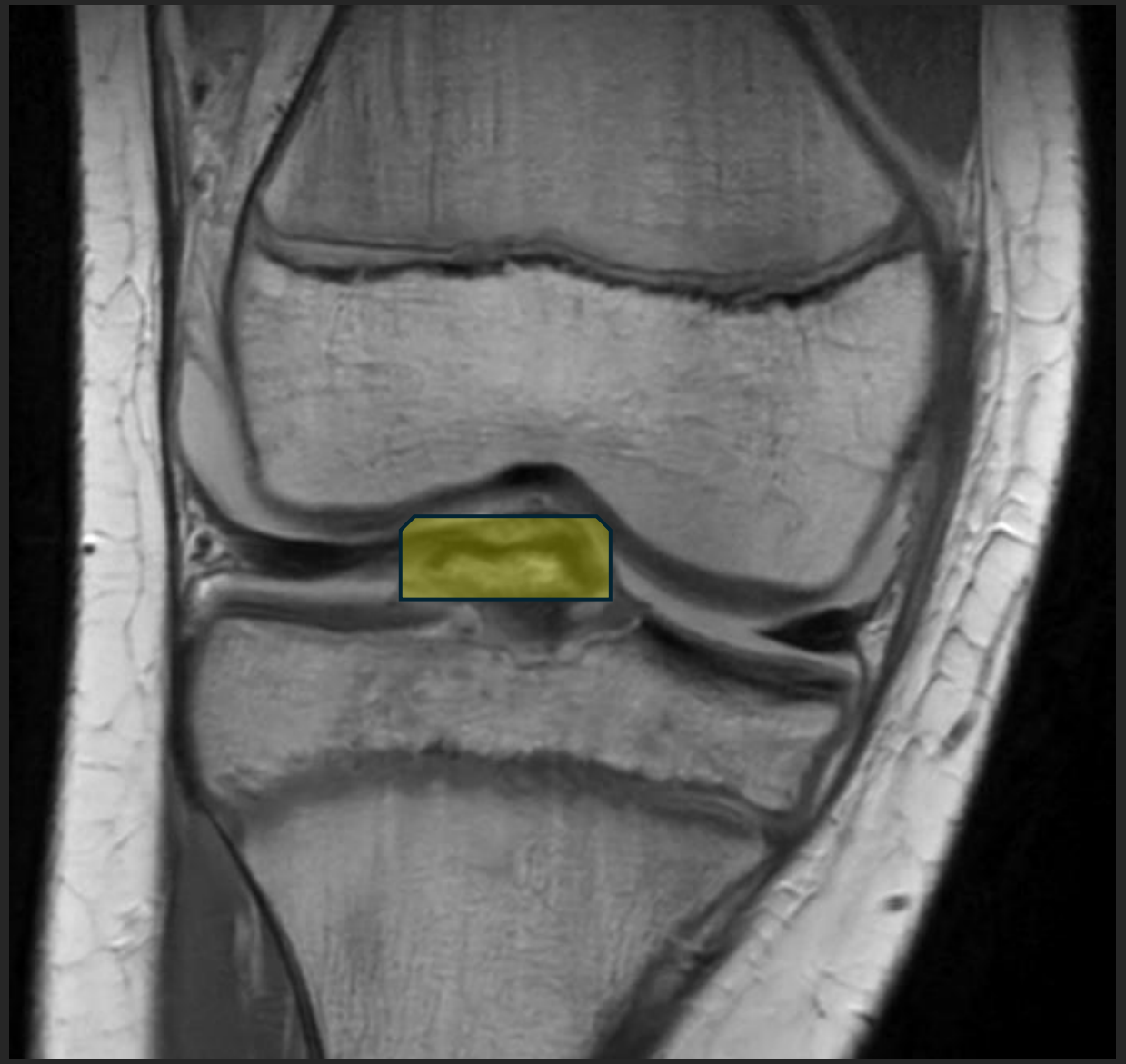
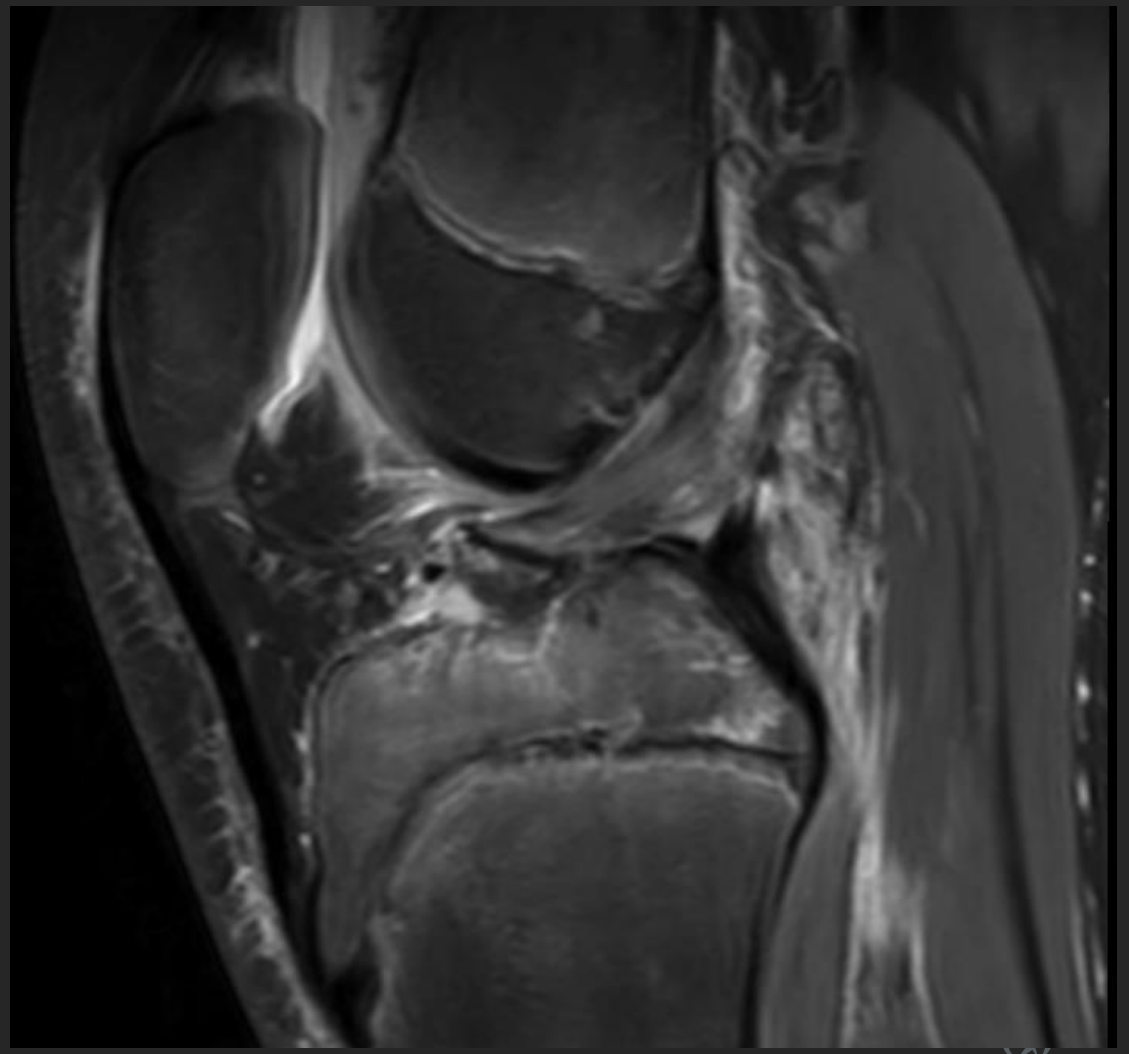
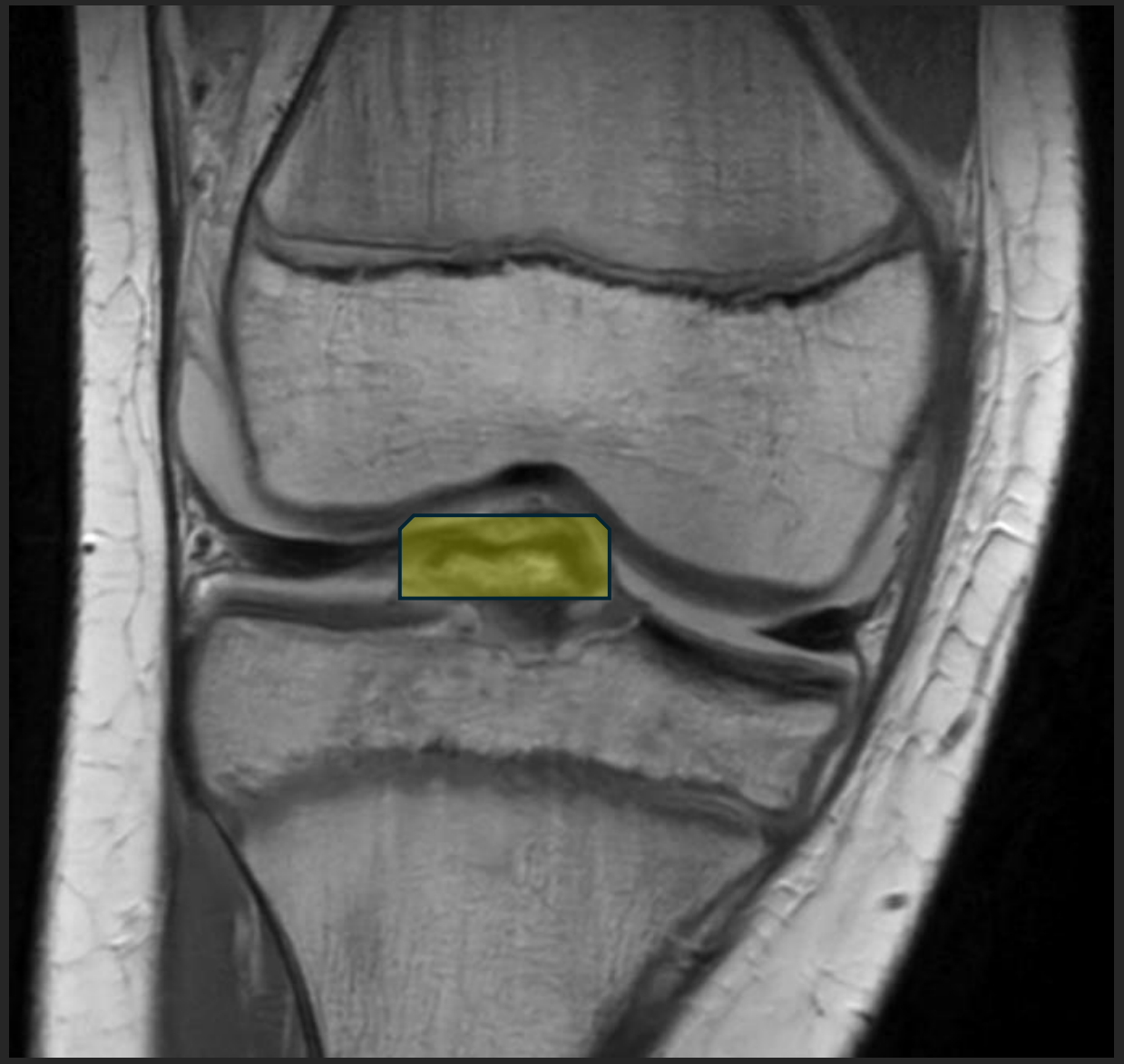
R
TST

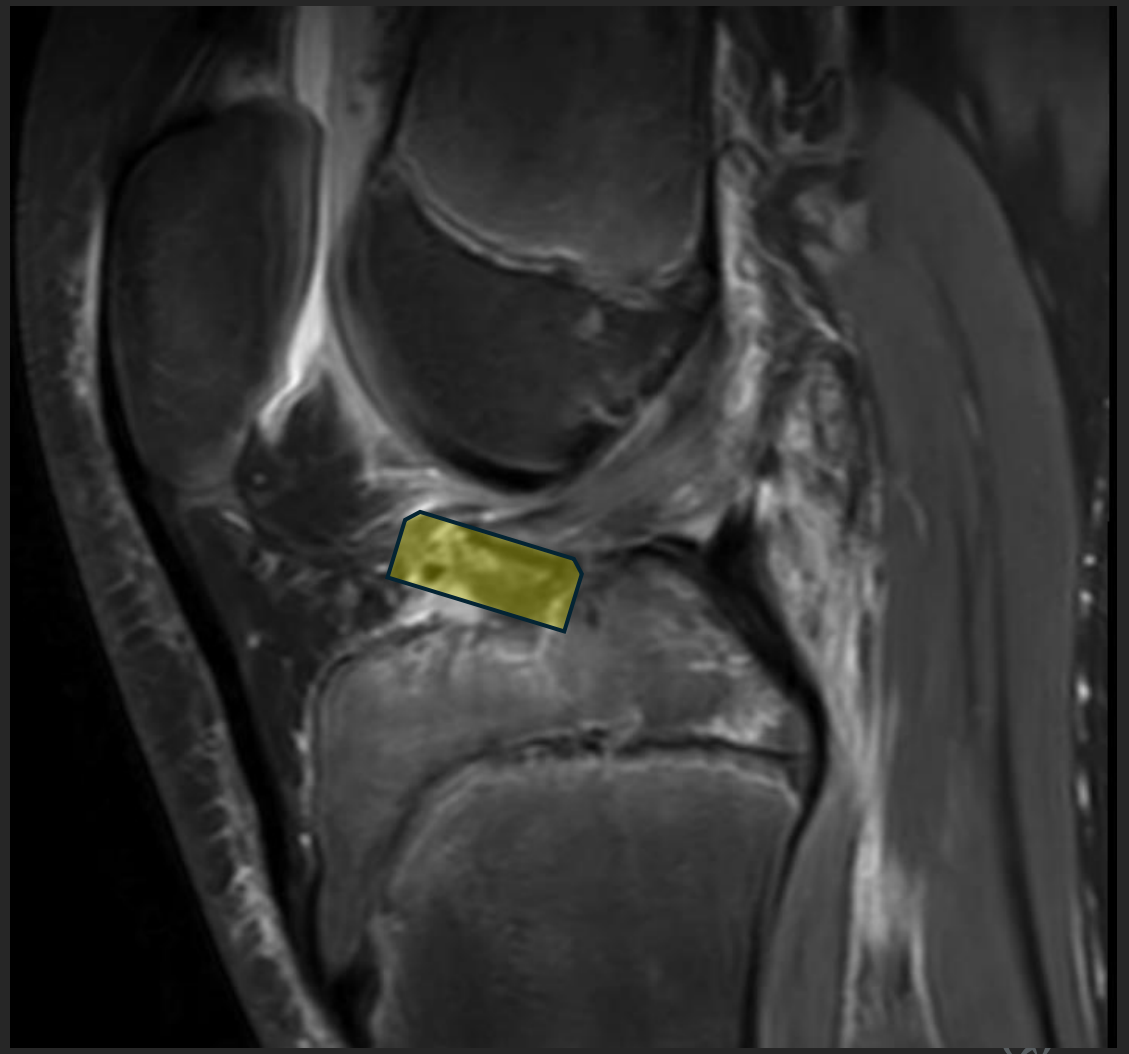

R
TST

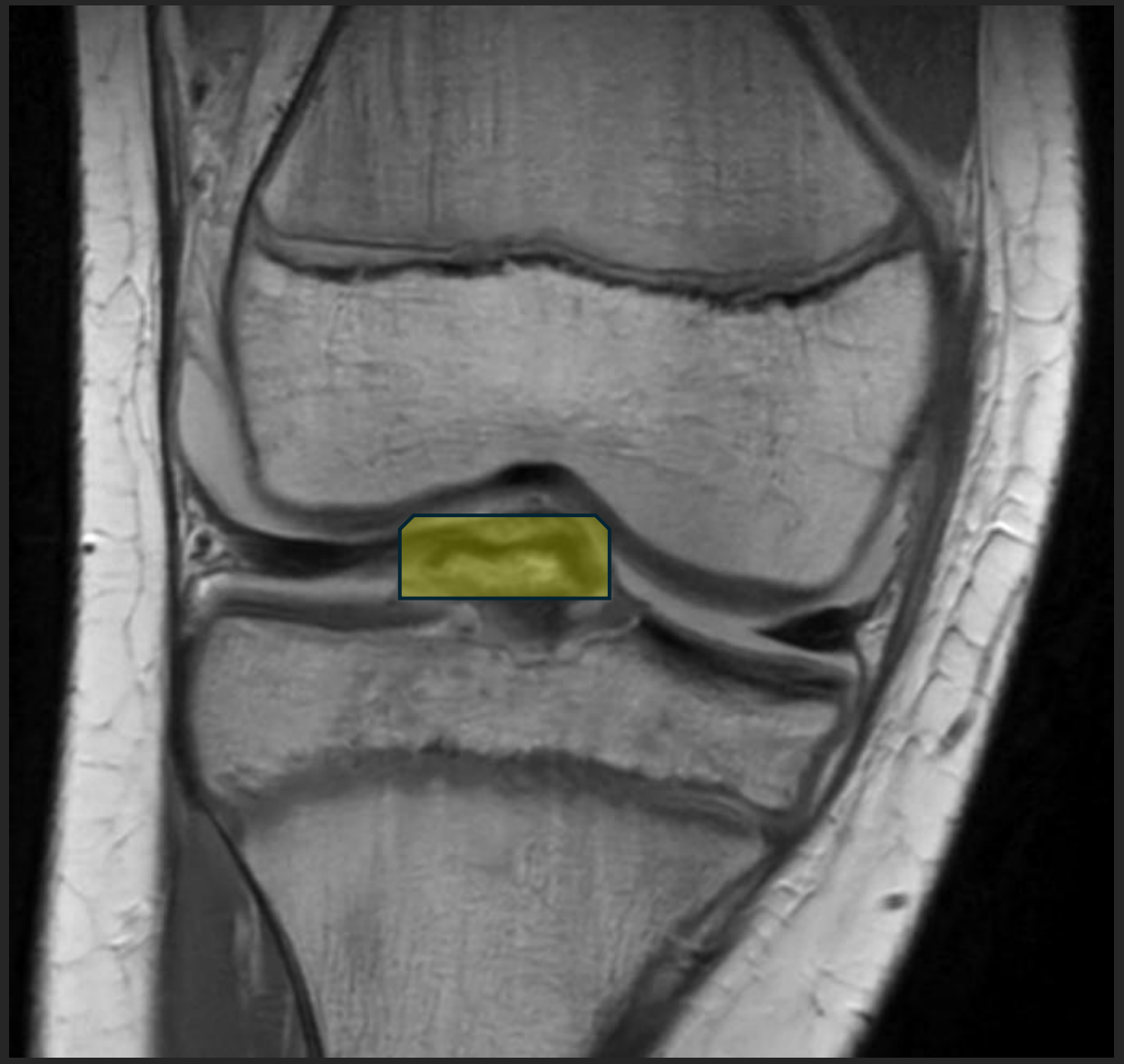

R
EAG

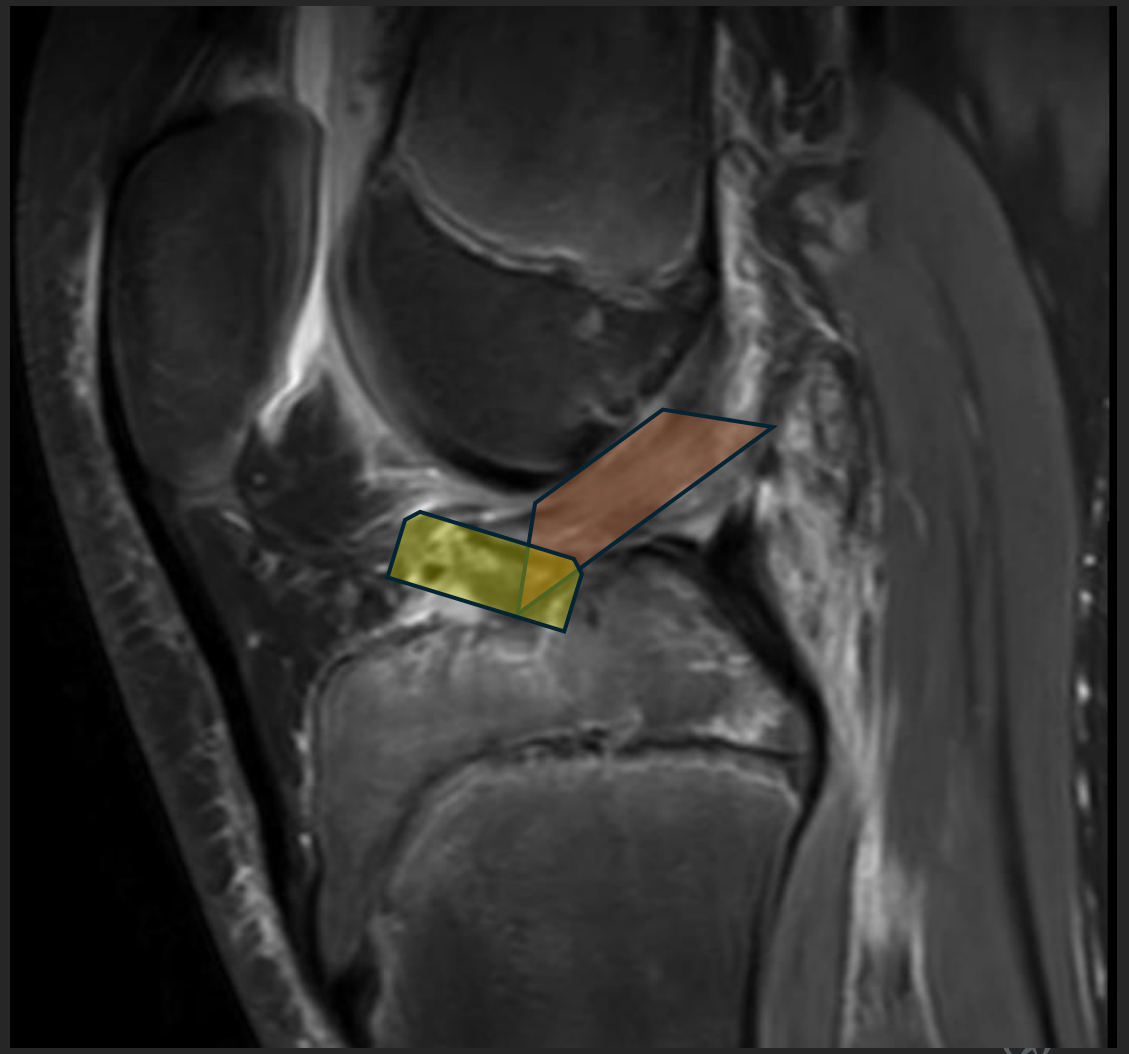












1 view?

2 views!

1 view?

2 views!

History matters!


Congenital

Developmental dysplasia of the Hip (DDH)

- AAP supports routine screening
- Broad range of severity: mild acetabular dysplasia without dislocation to frank hip dislocation
- Goal of treatment:
  - Achieve/maintain concentric reduction of femoral head in the acetabulum to allow normal development
  - Prevent chronic hip pain/early development of hip osteoarthritis/functional impairment
- Developmental dislocation of hip Incidence:
  - 1 in 1000 live births

-Yang S, Zusman N. Developmental Dysplasia of the Hip. Pediatrics (2019) 143 (1): e20181147. Accessed 1/1/25. https://doi.org/10.1542/peds.2018-1147
-Shaw B, Segal L. Evaluation and Referral for Developmental Dysplasia of the Hip in Infants. Pediatrics (2016) 138 (6): e20163107. https://doi.org/10.1542/peds.2016-3107

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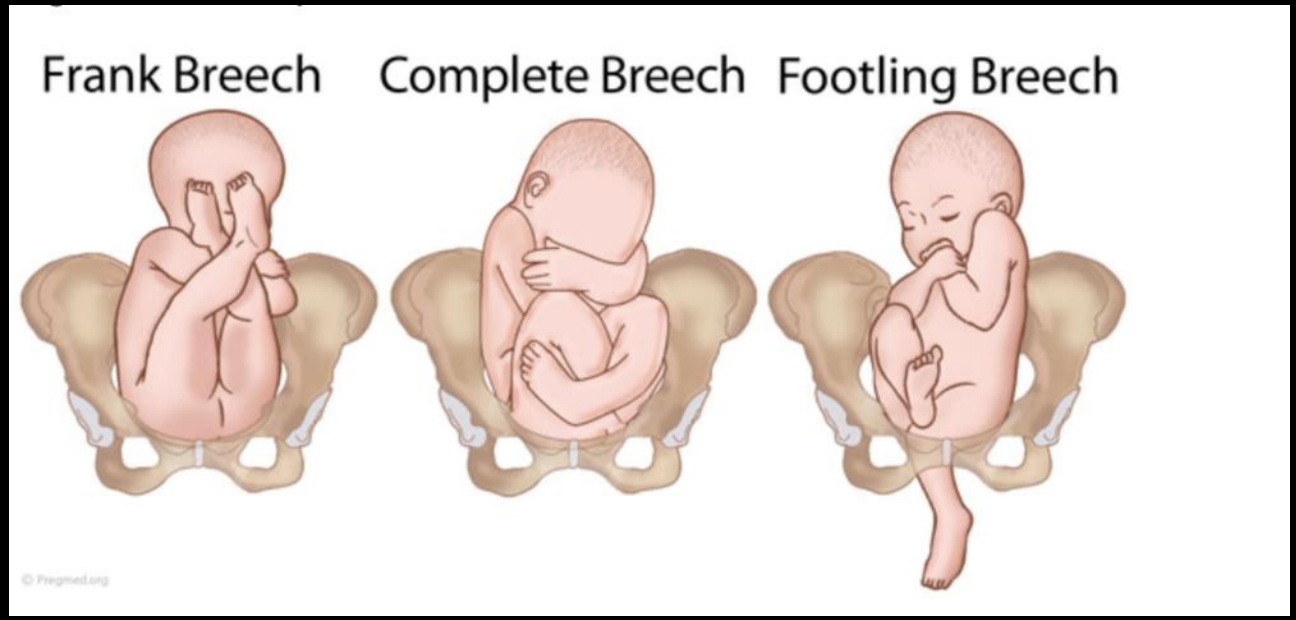
Risk Factors



- Breech position-greatest risk
- Female Sex
- Firstborn
- Positive family history
- Possibly prolonged abnormal postnatal positioning via swaddling

--Shaw B, Segal L. Evaluation and Referral for Developmental Dysplasia of the Hip in Infants. Pediatrics (2016) 138 (6): e20163107. https://doi.org/10.1542/peds.2016-3107
-Breech presentation: diagnosis and management. Safer Care Victoria. Nov 2018. https://www.safercare.vic.gov.au/best-practice-improvement/clinical-guidance/maternity/breech-presentation-diagnosis-and-management

Physical exam

- Periodic hip exam from newborn to walking age
- Barlow/Ortolani-before 3 months
- Limb length discrepancy
- Asymmetric thigh/buttock creases
- Restricted abduction-generally positive after 3 months

-Yang S, Zusman N. Developmental Dysplasia of the Hip. Pediatrics (2019) 143 (1): e20181147. https://doi.org/10.1542/peds.2018-1147. Accessed 1/1/25.
-Developmental Dysplasia of the Hip in Infants: A Clinical Report from the AAP on Evaluation and Referral. Am Fam Physician. 2017;96(3):196-197. Accessed 1/1/25.
--Shaw B, Segal L. Evaluation and Referral for Developmental Dysplasia of the Hip in Infants. Pediatrics (2016) 138 (6): e20163107. https://doi.org/10.1542/peds.2016-3107

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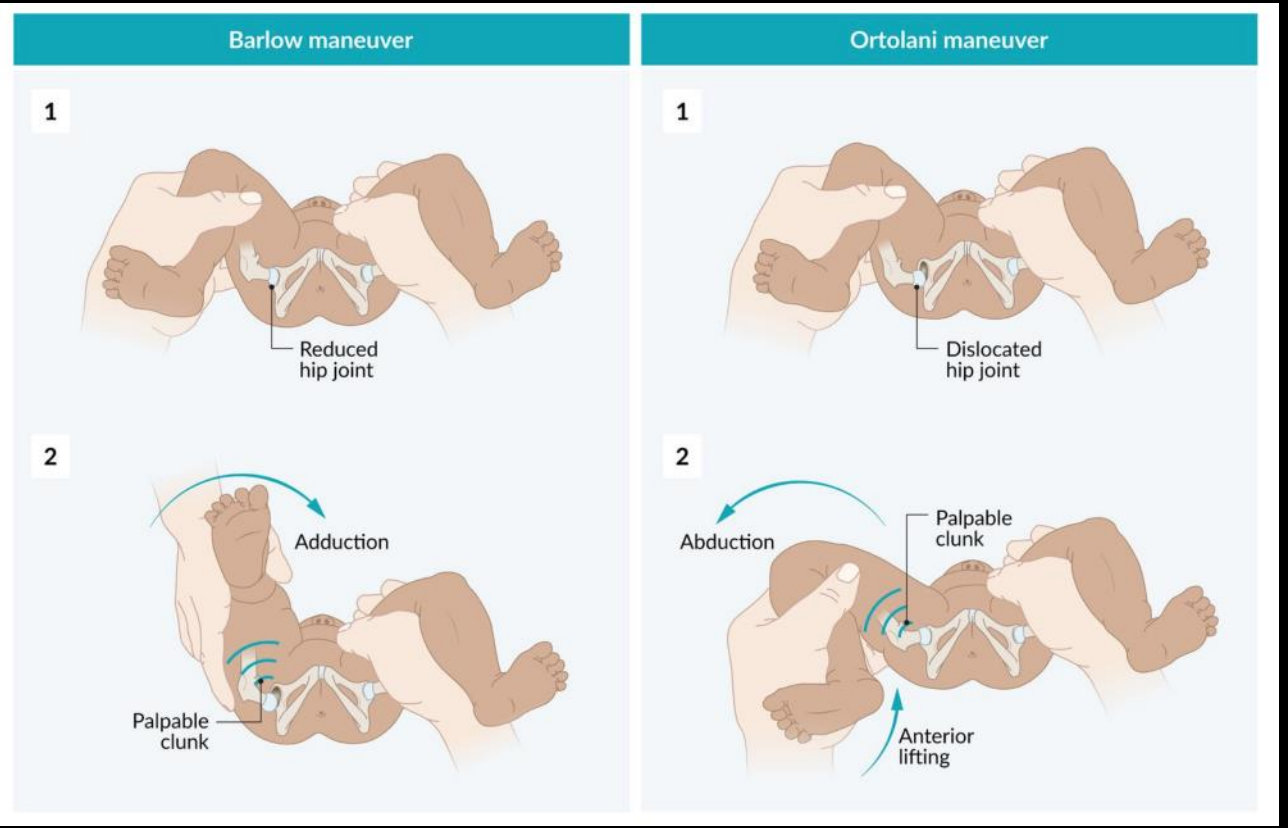
Barlow/Ortolani



https://gpexams.com/barlow-ortolani/

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Pediatrics. 2019;143(1). doi:10.1542/peds.2018-1147

Figure Legend:

Galeazzi sign. With the pelvis level on a flat surface, the heights of the knees are asymmetric. The right knee height is shorter, suggesting possible hip dislocation.

Pediatrics. 2019;143(1). doi:10.1542/peds.2018-1147

Figure Legend:

The right hip has limited abduction compared with the left, suggesting possible hip dislocation.

Consider imaging before 6 months of age for male or female infants with normal findings on physical examination and the following risk factors:

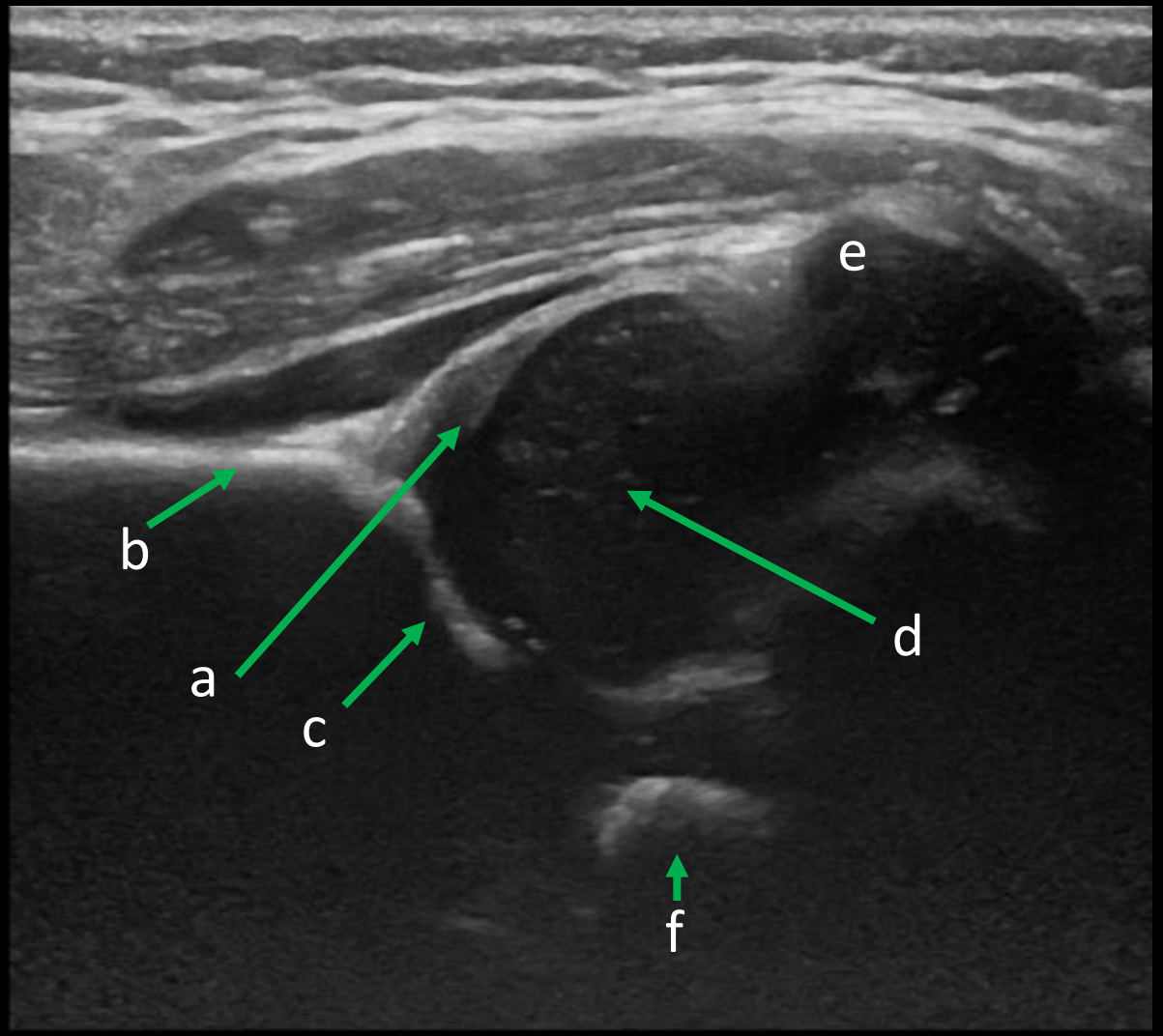
1. Breech presentation in third trimester (regardless of cesarean or vaginal delivery)
2. Positive family history
3. History of previous clinical instability
4. Parental concern
5. History of improper swaddling
6. Suspicious or inconclusive physical examination

DDH Imaging

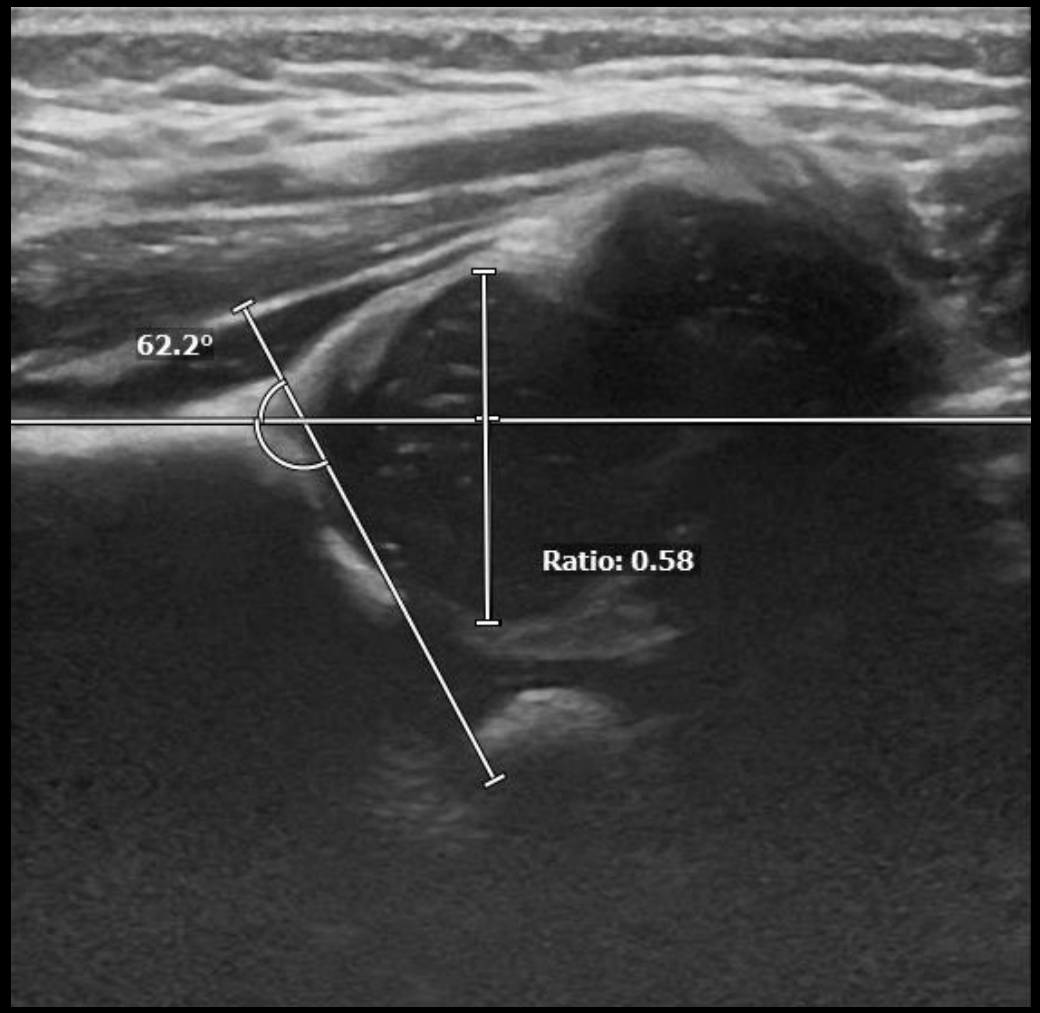
- Guidelines from American Academy of Pediatrics for DDH screening:

Ultrasound Hip Anatomy

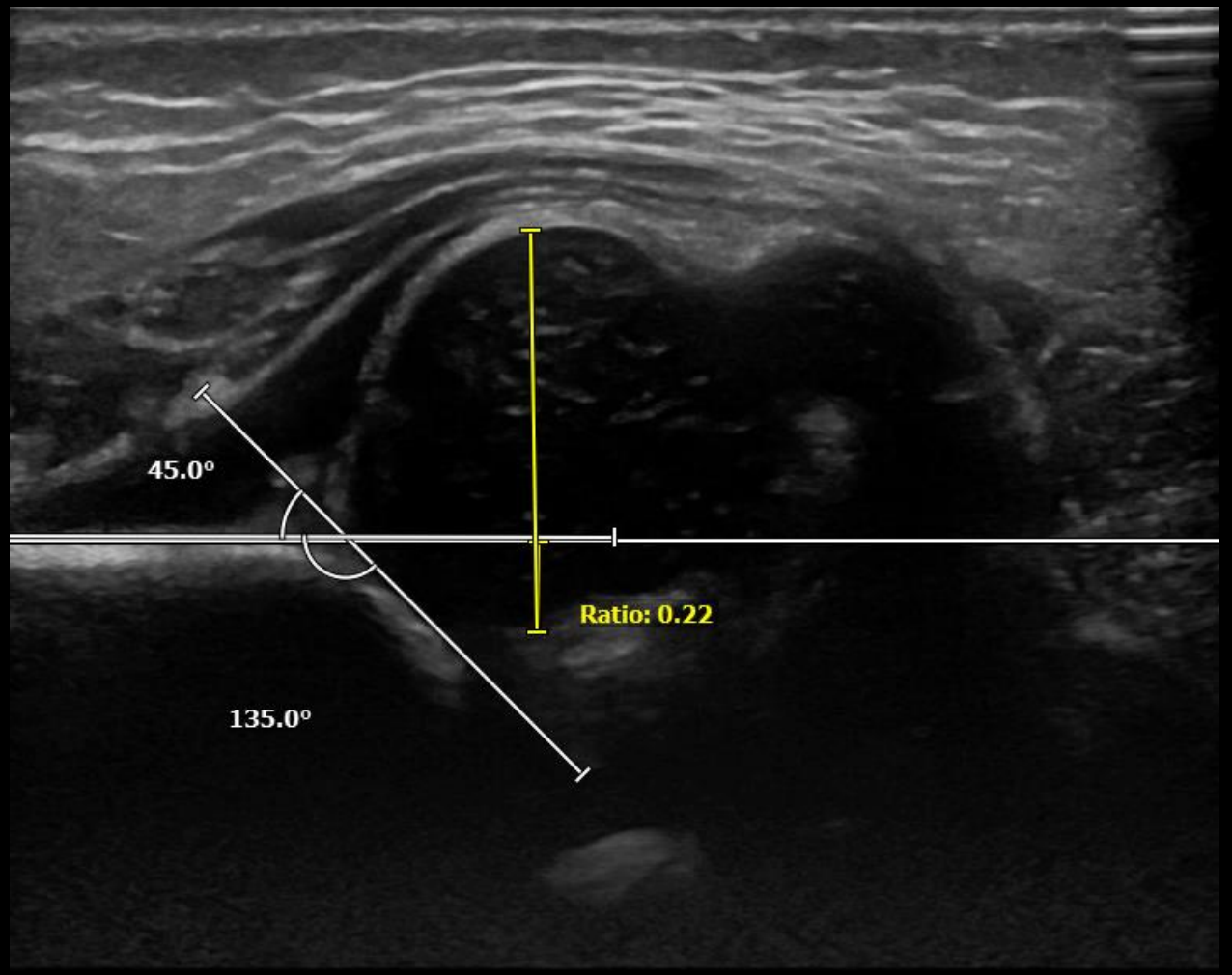
a. Labrum
b. Os Ilium
c. Acetabulum bony rim
d. Femoral head epiphysis
e. Femoral greater trochanter
f. Os Ischium



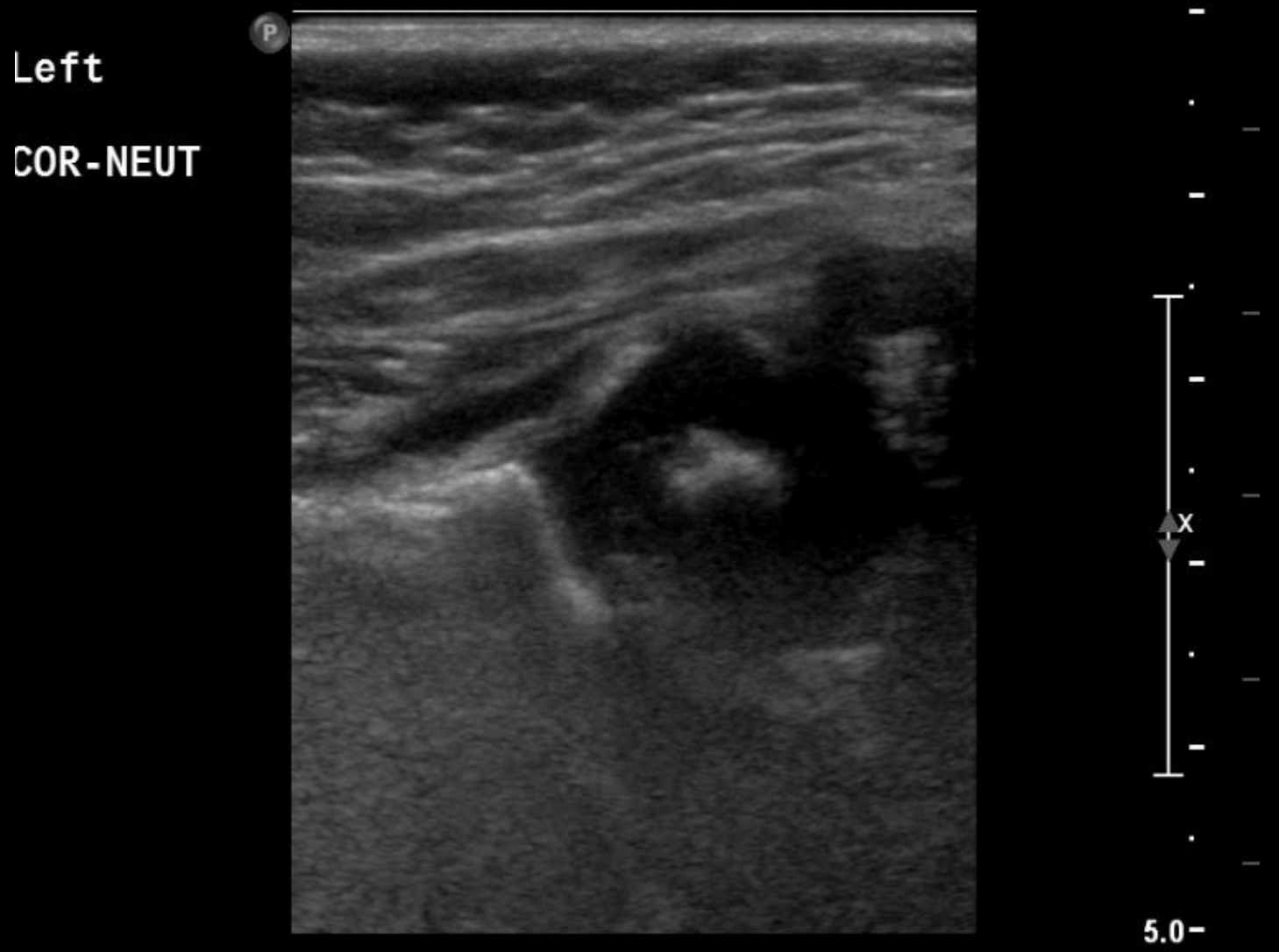
Normal



Abnormal



Modalities other than US?



Modalities other than US?

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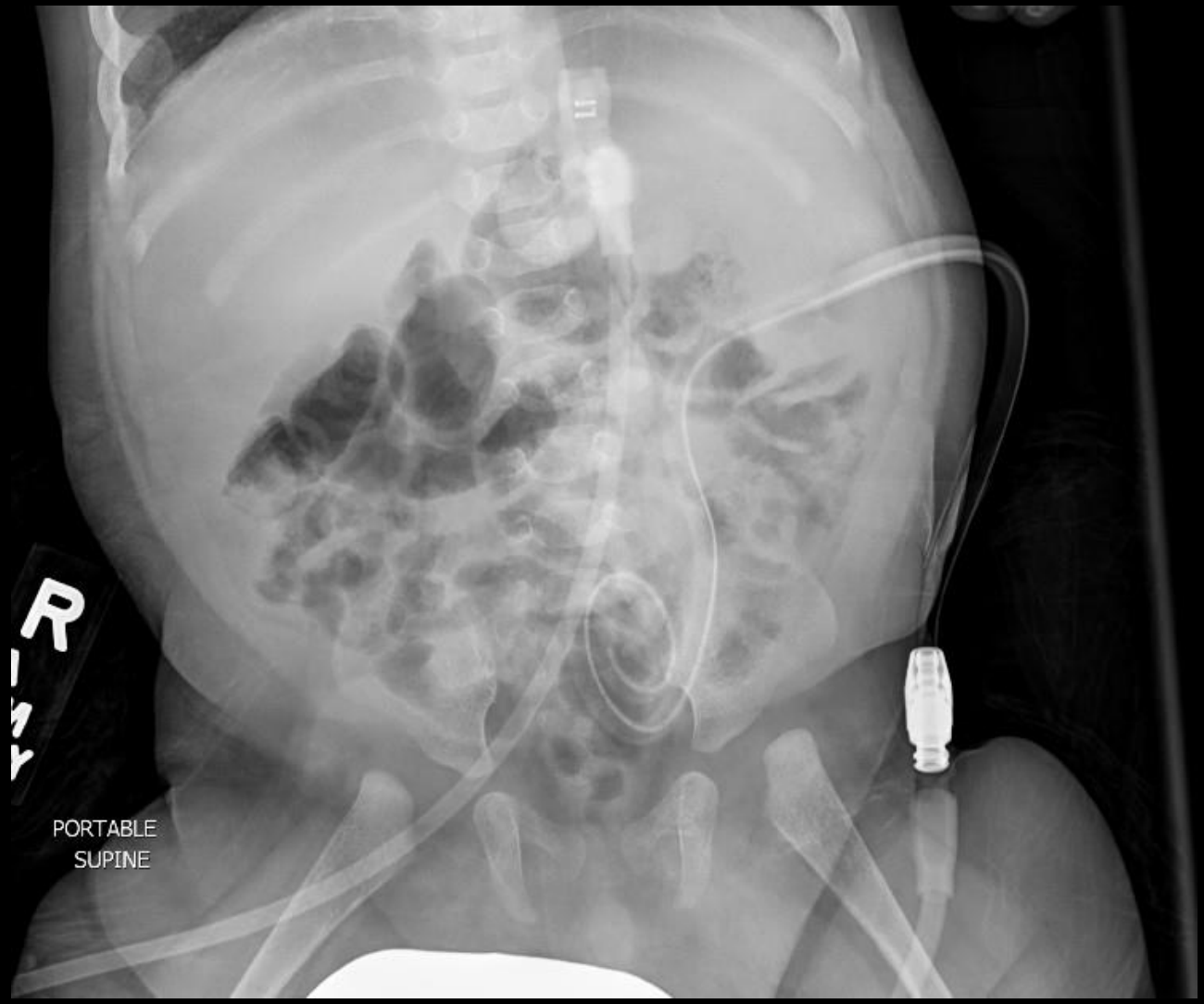

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DDH Management/Pearls

- Management dependent on clinical signs and imaging abnormalities
  - Ortho referral
    - Bracing in early infancy
    - Surgery when presenting later
  - Risks of bracing and surgery include avascular necrosis
- Medicolegal risk to provider of 'missed' DDH
- Newborn and periodic physical exam screening
- Imaging for high risk infants between 6 weeks and 6 months

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Spinal Dysraphism

- Well documented association between lumbosacral cutaneous findings and occult spinal dysraphism

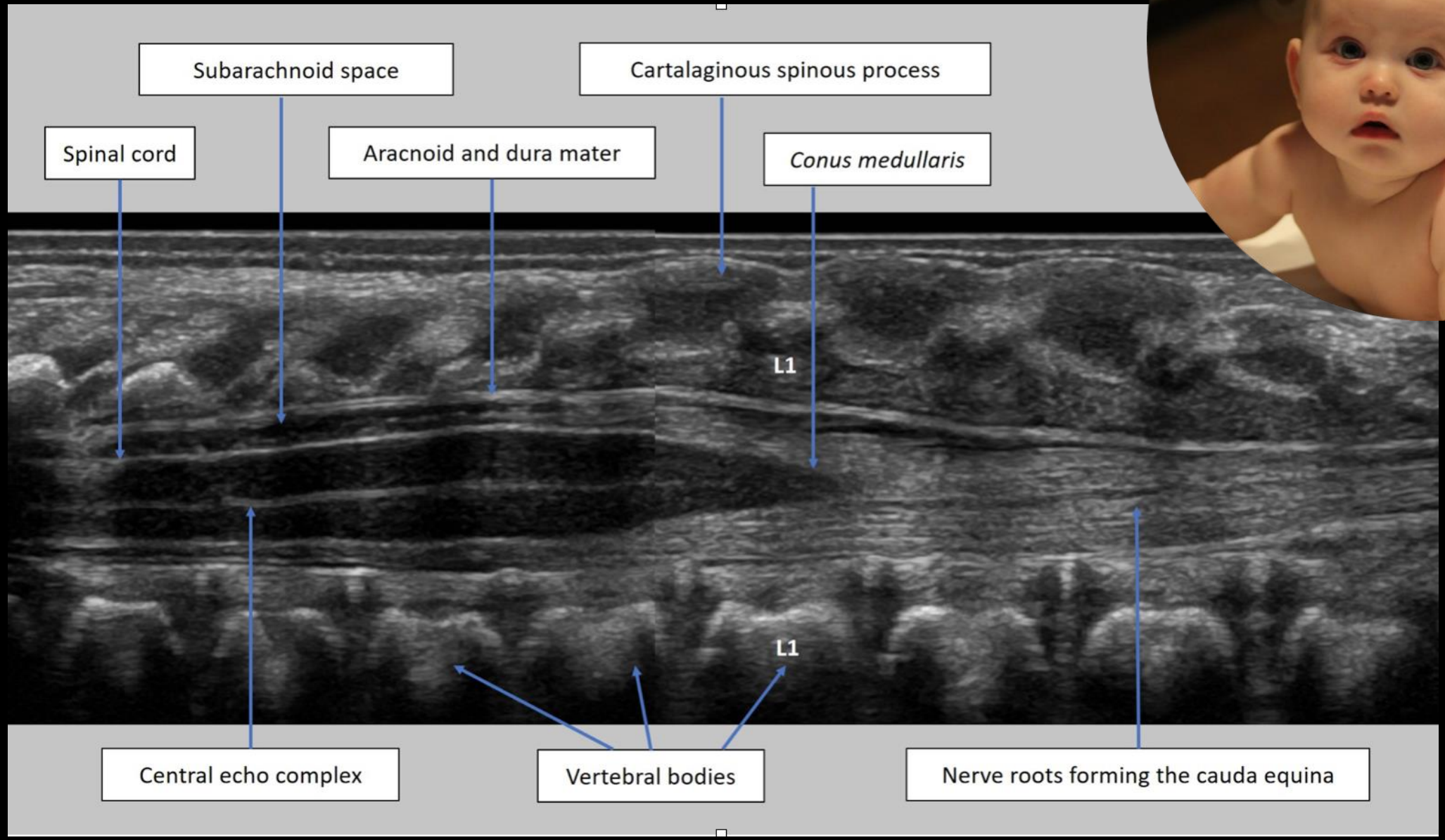
Common variants:

- Lipoma
- Coccygeal tag
- Sacral dimple-Up to 15% of neonates
- Hemangioma
- Lumbosacral/coccygeal hair
- Duplicated/deviated gluteal crease
- Vascular macule
- Congenital dermal melanocytosis

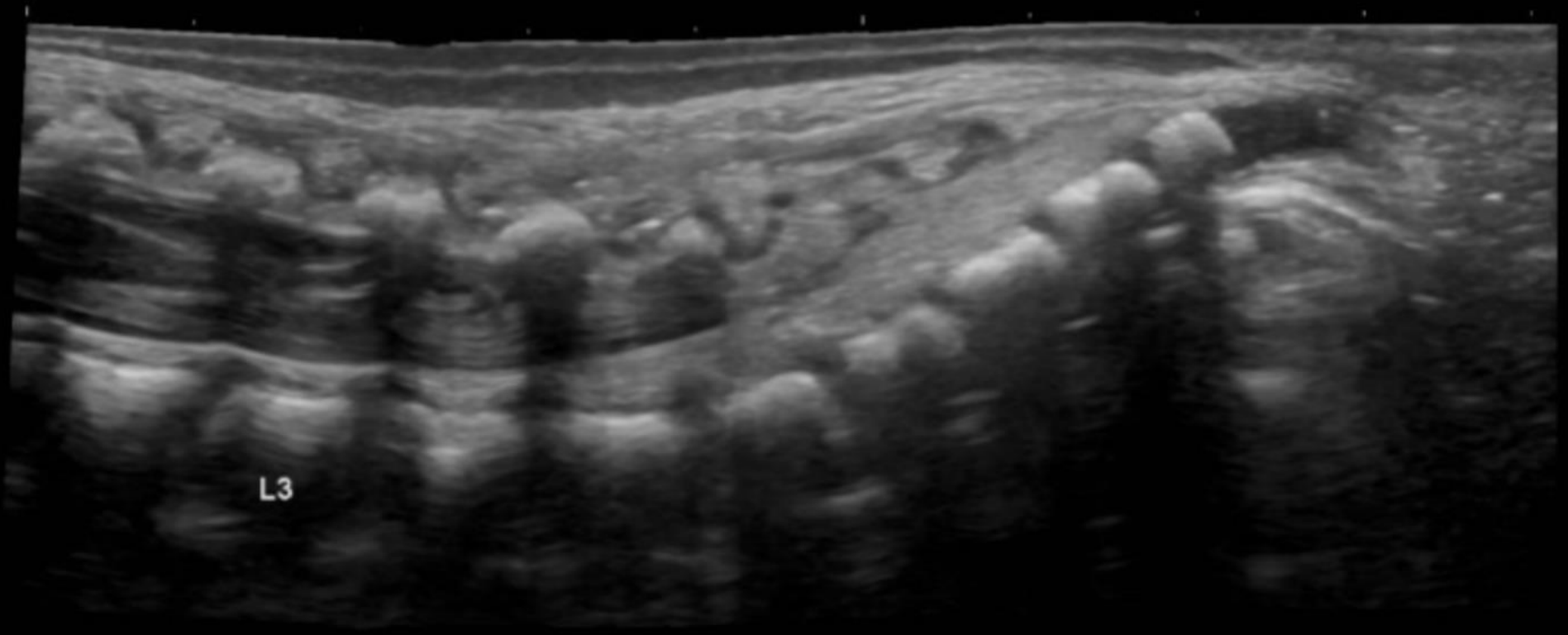
When/how to image:

- Options are US, MRI
- If high degree of concern (limited movement), MRI
  - Sedation?
- If screening,
  - US
  - >30d of life

-Aby J, Kim J. Variation in Management of Cutaneous Lumbosacral Findings in Newborns. Hosp Pediatr (2020) 10 (6): 496–501. https://doi.org/10.1542/hpeds.2019-026
Accessed 1/1/25.
-J Ultrasound Med 2019; 38:1241–1247


Subarachnoid space
Cartalaginous spinous process
Spinal cord
Aracnoid and dura mater
Conus medullaris
L1
L1
Central echo complex
Vertebral bodies
Nerve roots forming the cauda equina

Low Lying Conus



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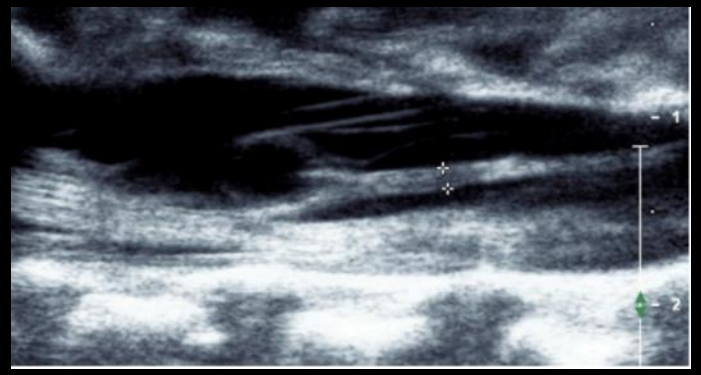
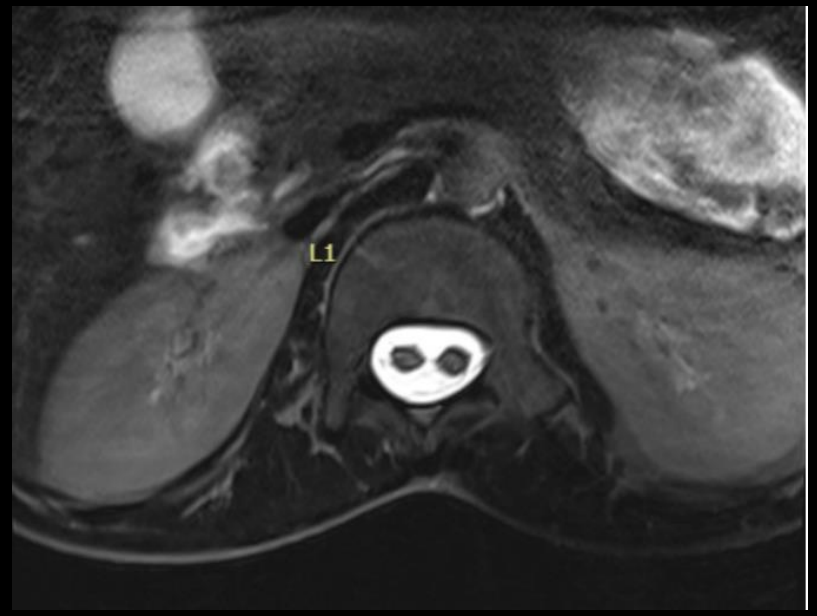
Tethered Cord Syndrome

Signs associated with a tethered cord

- Low conus - below the level of L2
- Tickened or tight filum terminale
- Lipoma in the spinal column
- Dermal sinus tract
- Diastematomyelia - split spinal cord
- Restricted movement of the nerve strands





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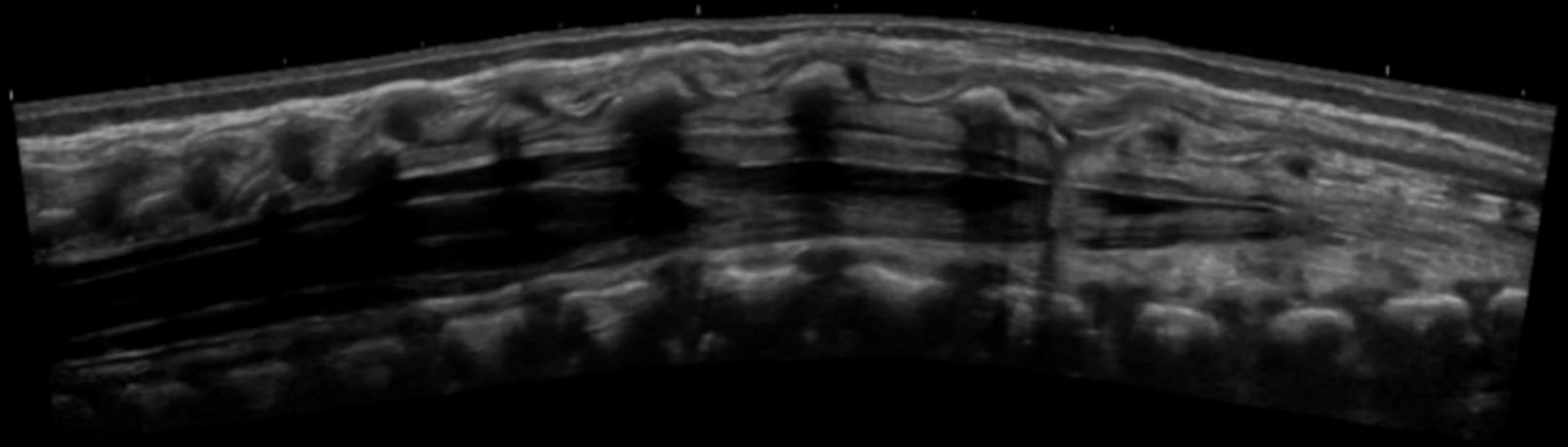
Epidural Hematoma after LP



Filum Cyst


SUPINE
R
LS

Blount's Disease

- Bowing deformity at the knees (genu varum)
- Two types: infantile & adolescent
  - Infantile risk factors: early walking age, large stature, obesity
  - Adolescent risk factors: primarily obesity
- Incidence:
- Less than 1% of population
- Presentation:
  - Bow legged
  - Pain in adolescents (not in toddlers)
  - Difficulty walking

-Karkenny, A. How to recognize, manage orthopedic co-morbidities of obesity. 9/1/2023. AAP News. https://publications.aap.org/aapnews/news/25433/How-to-recognize-manage-orthopedic-co-morbidities accessed 1/1/25
-Blount's Disease. Cleveland Clinic. Reviewed 2/25/22.

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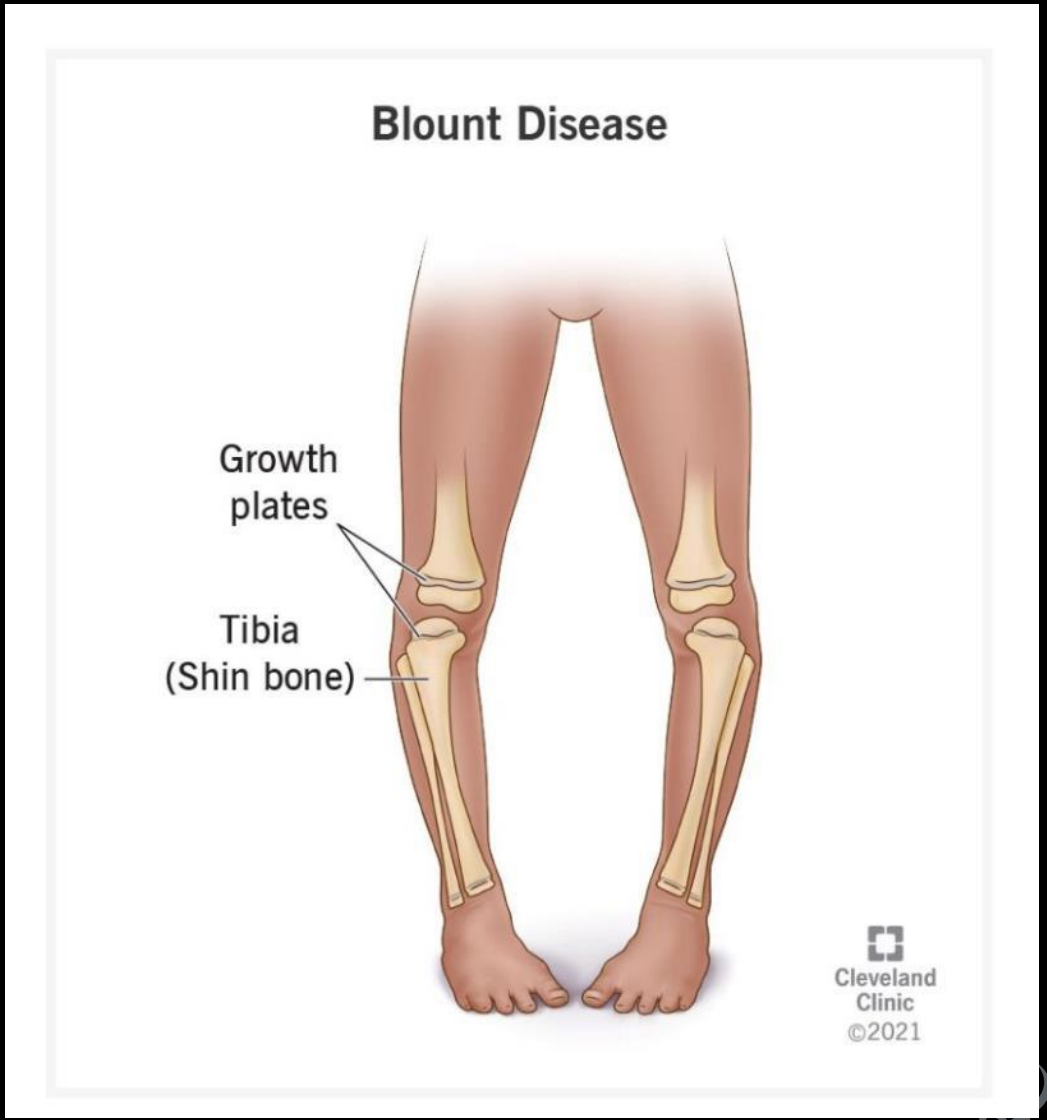
- Physiologic
  - Corrects to neutral alignment by age 2 ("bow-legged")
- Beyond age 2
  - Screen for Vitamin D deficiency for Rickets
  - Refer to pediatric ortho
- Outcome
  - Often requires surgery and increases risk of adulthood arthritis



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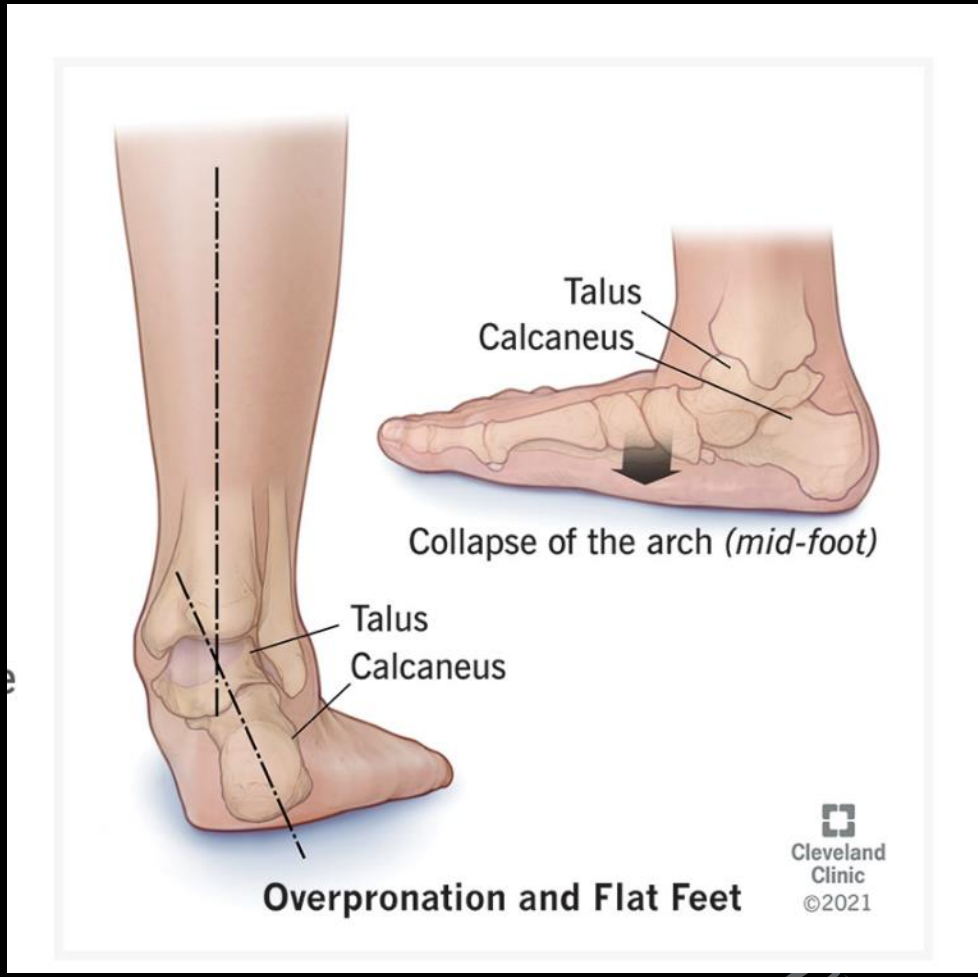
-Blount's Disease. Cleveland Clinic. Reviewed 2/25/22. https://my.clevelandclinic.org/health/diseases/22424-blounts-disease

Blount's

Pes Planus aka Flat feet

- Presentation
  - No arch seen when standing in a walking infant or older
  - Arches that do not form when standing on tip-toes
  - Heel points laterally and ankle rolls medially
  - Talus bone appears prominent
  - Pain
    - Foot, ankle, shin splints, knees



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-Flat feet (Pes Plants). Cleveland Clinic. Reviewed 11/17/24. https://my.clevelandclinic.org/health/diseases/flat-feet-pes-planus

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Pes Planus aka Flat feet

- Types
  - Flexible Flat foot
  - Rigid Flat foot
  - Congenital flat foot
  - Acquired flat foot
- Management:
  - If symptomatic (painful/stiff): Insoles, stretching, NSAIDs
  - Weight management
  - If not improving, refer to ortho

-Karkenny, A. How to recognize, manage orthopedic co-morbidities of obesity. 9/1/2023. AAP News. https://publications.aap.org/aapnews/news/25433/How-to-recognize-manage-orthopedic-co-morbidities accessed 1/1/25
-Flat feet (Pes Plants). Cleveland Clinic. Reviewed 11/17/24. https://my.clevelandclinic.org/health/diseases/flat-feet-pes-planus

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Pes Planus

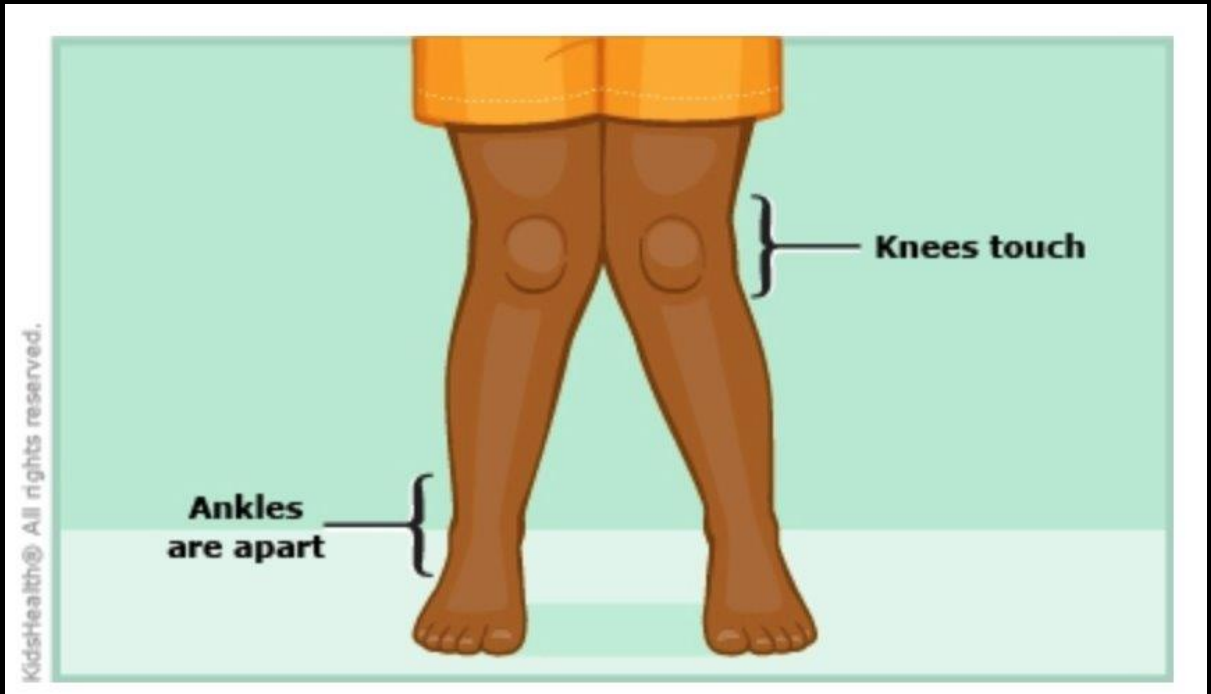
Pes Planus

Normal

Genu Valgum aka knock knees

- Etiology:
  - Physiologic:
    - Starting by age 2
    - Most prominent by age 3-4
    - Stable, slightly valgus position by age 7
  - Other:
    - Bilateral: Skeletal dysplasia, metabolic bone disease, lysosomal storage disease
    - Unilateral: post-traumatic, tumors, infection

-Karkenny, A. How to recognize, manage orthopedic co-morbidities of obesity. 9/1/2023. AAP News. https://publications.aap.org/aapnews/news/25433/How-to-recognize-manage-orthopedic-co-morbidities accessed 1/1/25
-Knock Knees (Genu Valgum). Nemours KidsHealth. Reviewed April 2020. https://kidshealth.org/en/parents/knock-knees.html



- Presentation:
  - Come to clinic age 3-5 with knocked knee appearance
  - Site of deformity typically distal femur
  - Usually not painful if physiologic

-Karkenny, A. How to recognize, manage orthopedic co-morbidities of obesity. 9/1/2023. AAP News. https://publications.aap.org/aapnews/news/25433/How-to-recognize-manage-orthopedic-co-morbidities accessed 1/1/25
-Knock Knees (Genu Valgum). Nemours KidsHealth. Reviewed April 2020. https://kidshealth.org/en/parents/knock-knees.html

- Management
  - If tibiofemoral angle <15° and less than age 6, monitor. If > 15° degrees, worsening or present past age 6, refer to ortho
  - Serial photos in EMR can document progression
- Outcome
  - Obesity increases risk of worsened disease
  - Increases stress on lateral knee which can increase risk of future arthritis

-Karkenny, A. How to recognize, manage orthopedic co-morbidities of obesity. 9/1/2023. AAP News. https://publications.aap.org/aapnews/news/25433/How-to-recognize-manage-orthopedic-co-morbidities accessed 1/1/25
-Knock Knees (Genu Valgum). Nemours KidsHealth. Reviewed April 2020. https://kidshealth.org/en/parents/knock-knees.html
-Patel M, Nelson R. Genu Valgum. [Updated 2023 May 29]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK559244/

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Genu Valgum

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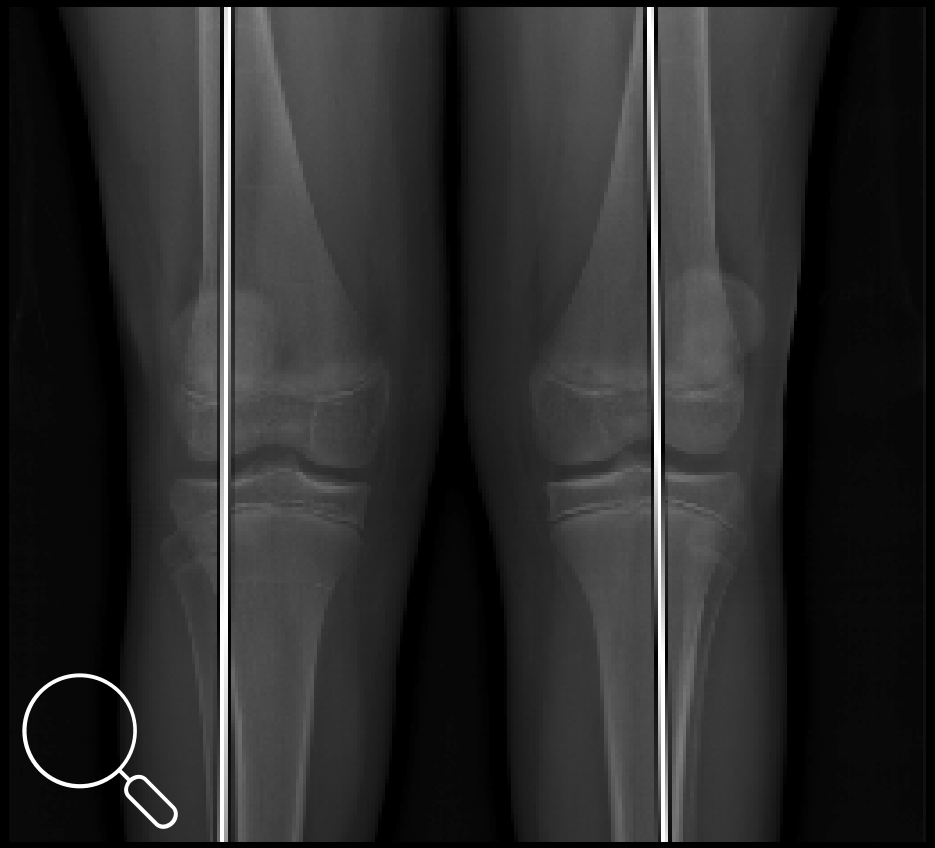
Genu Valgum



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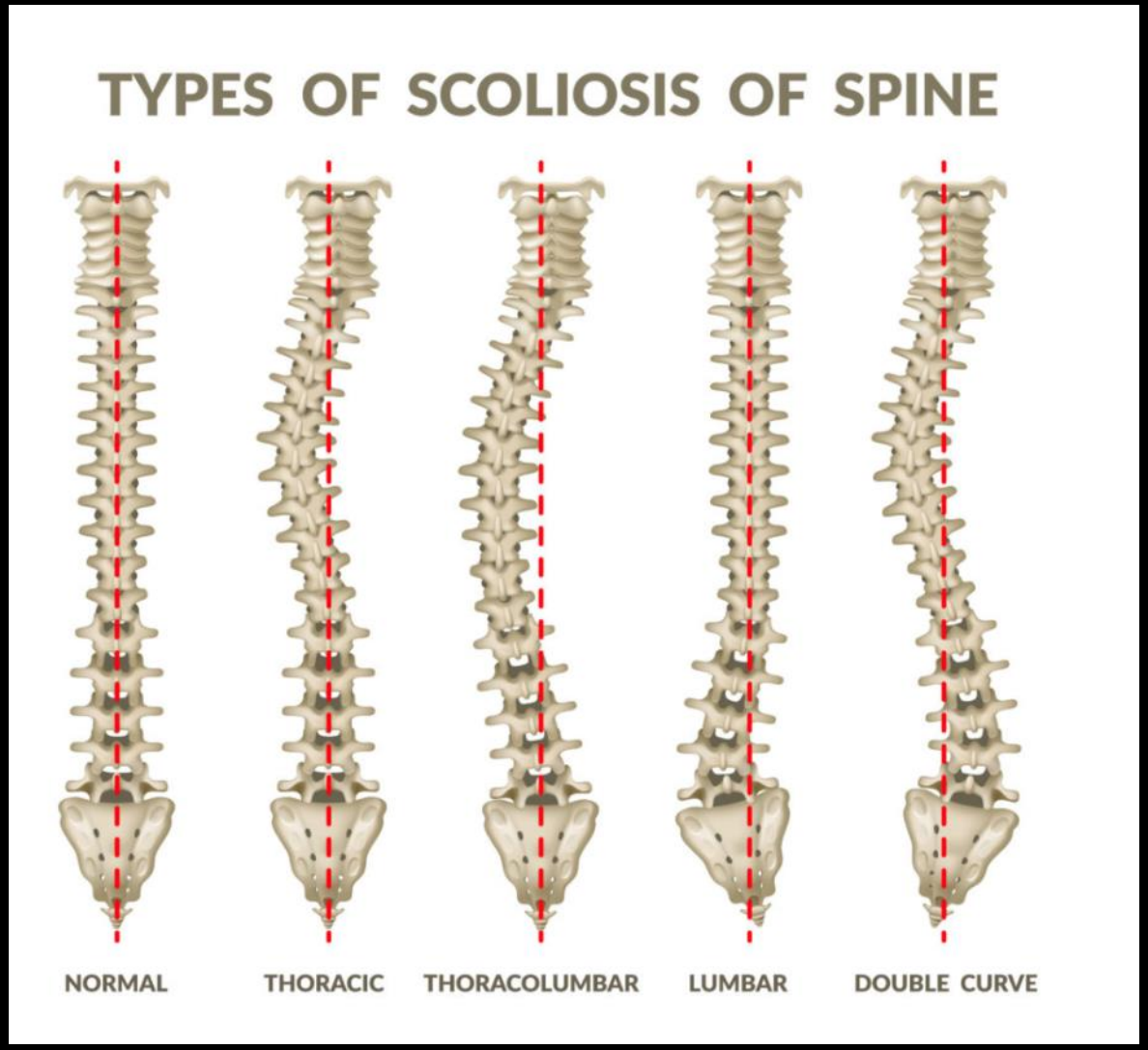
Scoliosis

- Lateral/rotational curvature of spine
  - Adolescent Idiopathic Scoliosis (AIS) most common ages 10-18
  - 1-3% prevalence ages 10-16
- AAP supports routine screening
  - Females at ages 10 & 12 (earlier if early puberty onset) and males at 13 & 14
  - AAFP & USPSTF state not enough evidence for screening

-Karkenny, A. How to recognize, manage orthopedic co-morbidities of obesity. 9/1/2023. AAP News. https://publications.aap.org/aapnews/news/25433/How-to-recognize-manage-orthopedic-co-morbidities accessed 1/1/25
-Robb Bowers M, Behar S. Adolescent Idiopathic Scoliosis. Primary Care RAP, HippoEducation. August 2024. Accessed 1/1/25. https://www.hippoed.com/



- Risk factors for severe disease
  - Obesity is a risk factor for more severe disease (weight does not impact prevalence) and less successful outcomes
  - Female

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-Robb Bowers M, Behar S. Adolescent Idiopathic Scoliosis. Primary Care RAP, HippoEducation. August 2024. Accessed 1/1/25. https://www.hippoed.com/
-Growing Pains in Children-Should you See a Physiotherapist? Palermo + Physiotherapy Wellness Centre. Accessed 1/19/25. https://palermophysio.ca/category/physiotherapy/paediatrics/

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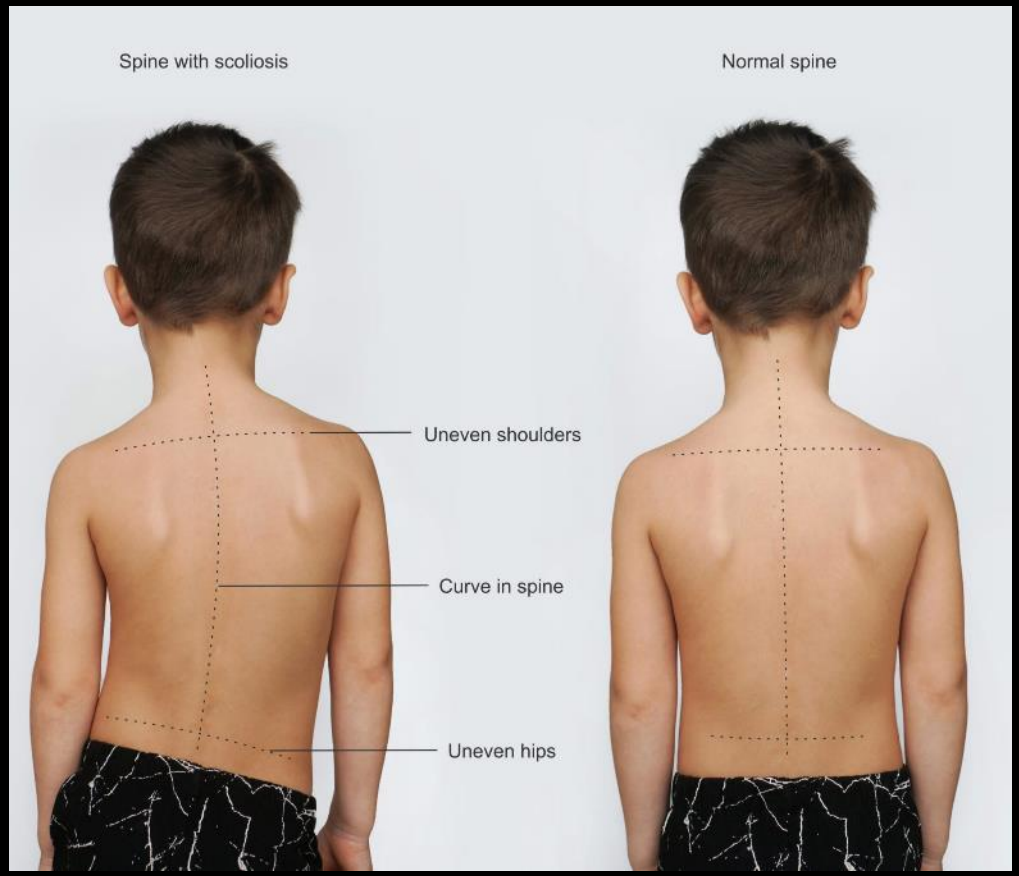
- Physical Exam Pearls
  - Head not centered
  - Uneven shoulders
  - Sideways leaning
  - Asymmetric hip height
  - Hand position uneven when arms at side
  - Rounding of upper back
  - Curvature direction matters
    - Thoracic curves almost always curve to the RIGHT
    - Lumbar curves almost always curve to the LEFT
    - Thoracic curve to the LEFT is more often associated with a non-idiopathic cause like cerebral palsy or spinal dysraphism or a tumor → get an MRI rather than just an x-ray



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-Growing Pains in Children-Should you See a Physiotherapist? Palermo + Physiotherapy Wellness Centre. Accessed 1/19/25. https://palermophysio.ca/category/physiotherapy/paediatrics/

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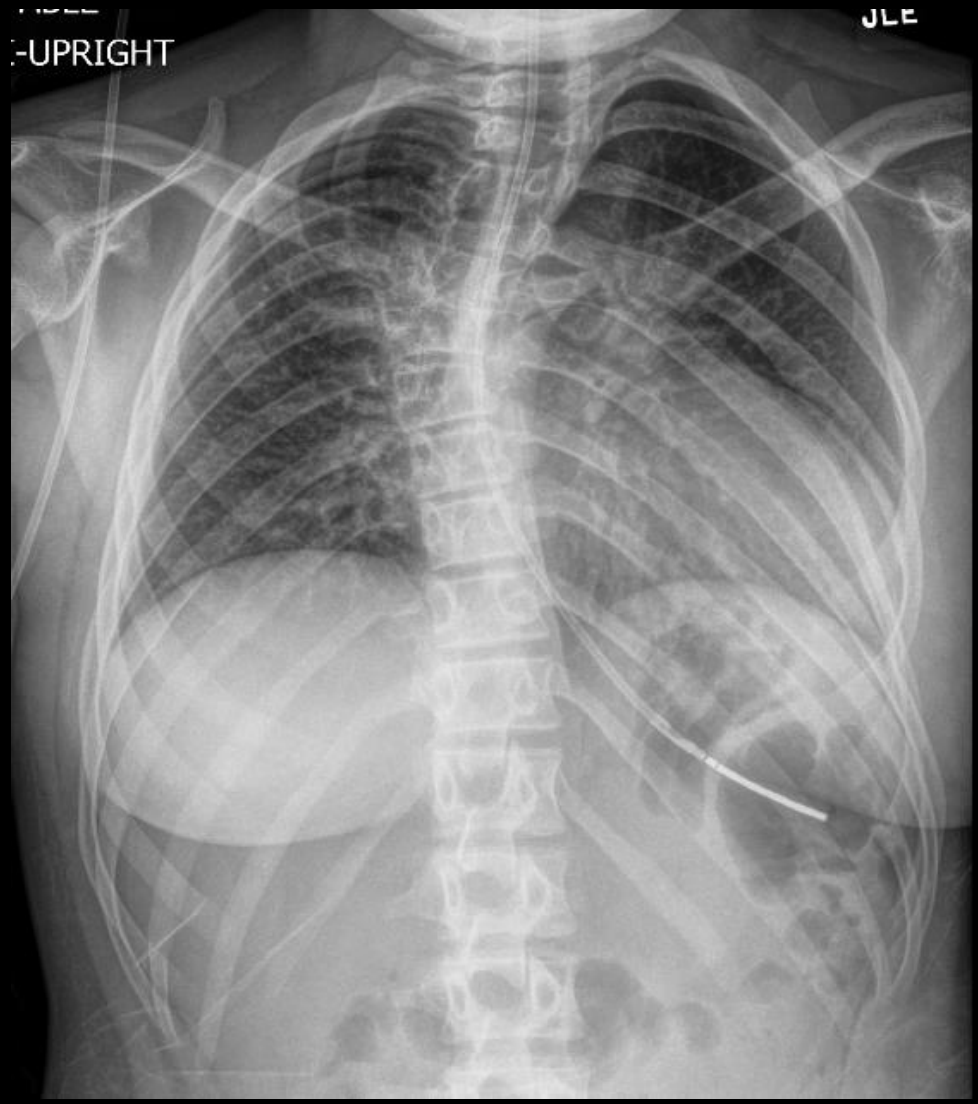
Scoliosis

Scoliosis - Congenital

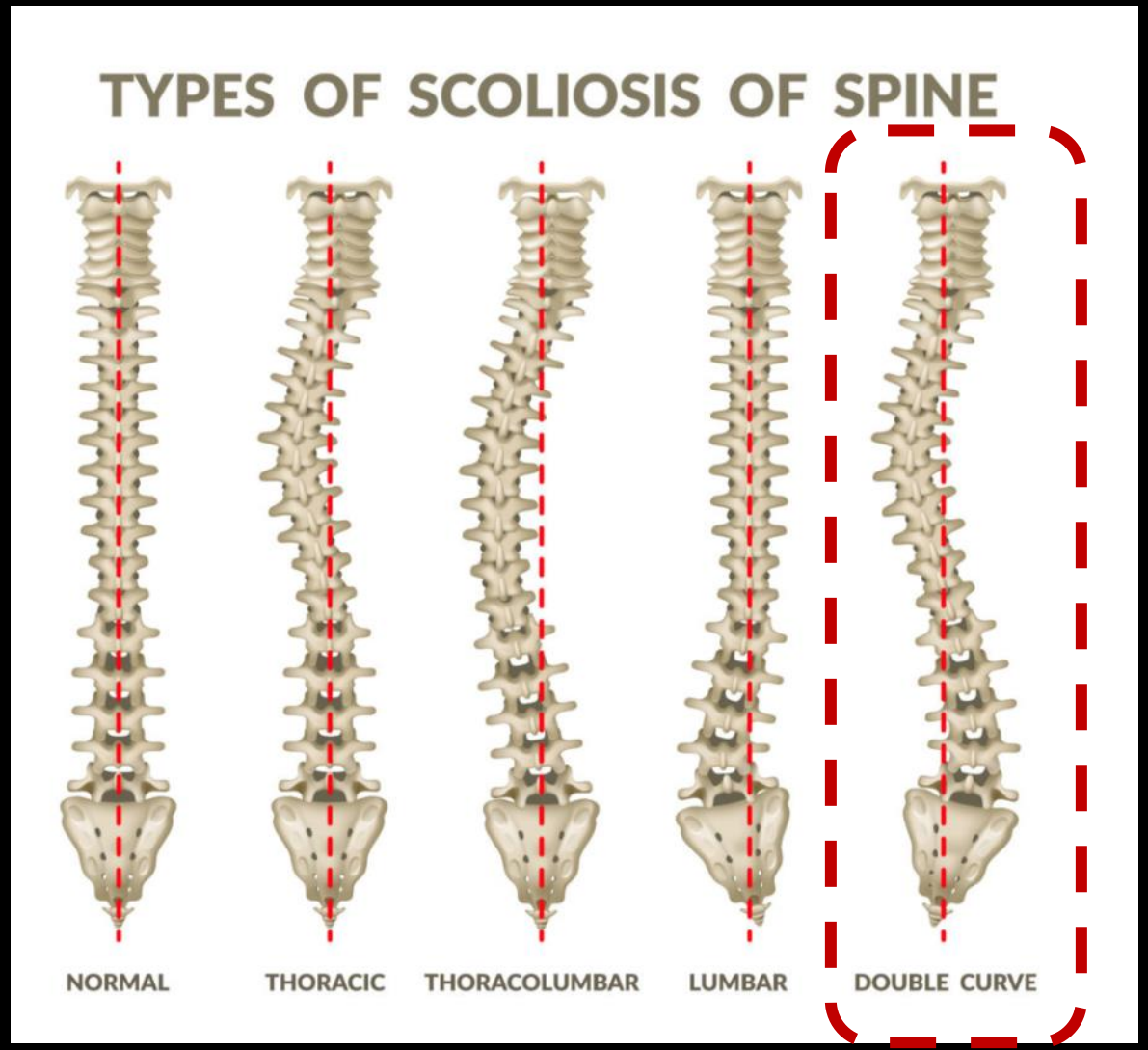
Scoliosis - Congenital



Scoliosis - Neuromuscular

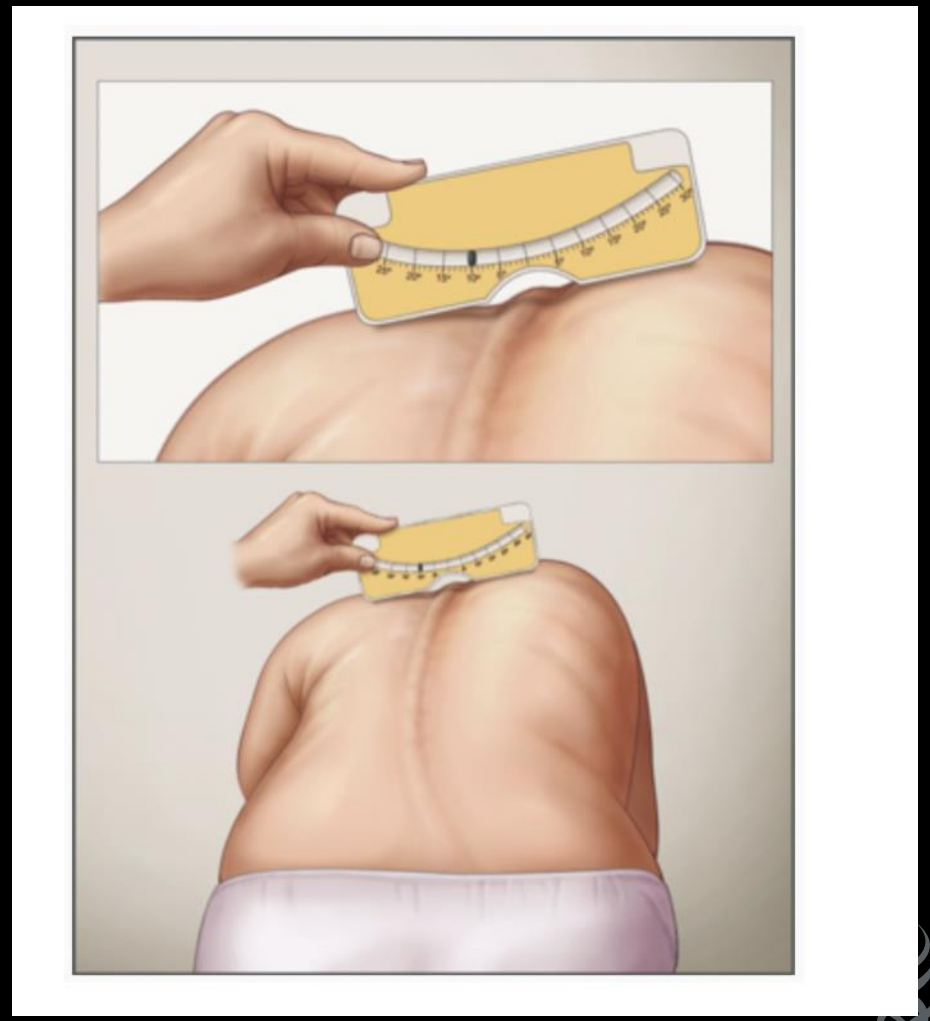
Scoliosis - Idiopathic

Scoliosis - Idiopathic



- Referral/Management

  - 10 degrees: Monitor annually with a scoliometer if skeletally immature; no further action if mature
  - 10-20 degrees: Monitor with a scoliometer every 6 months to a year; repeat imaging if ATR increases
  - 20-30 degrees: Refer to ortho if skeletally immature; monitor if mature, with rechecks every 6 months to a year
  - 30 degrees: Refer to ortho regardless of skeletal maturity
  - Management: PT/bracing/surgery



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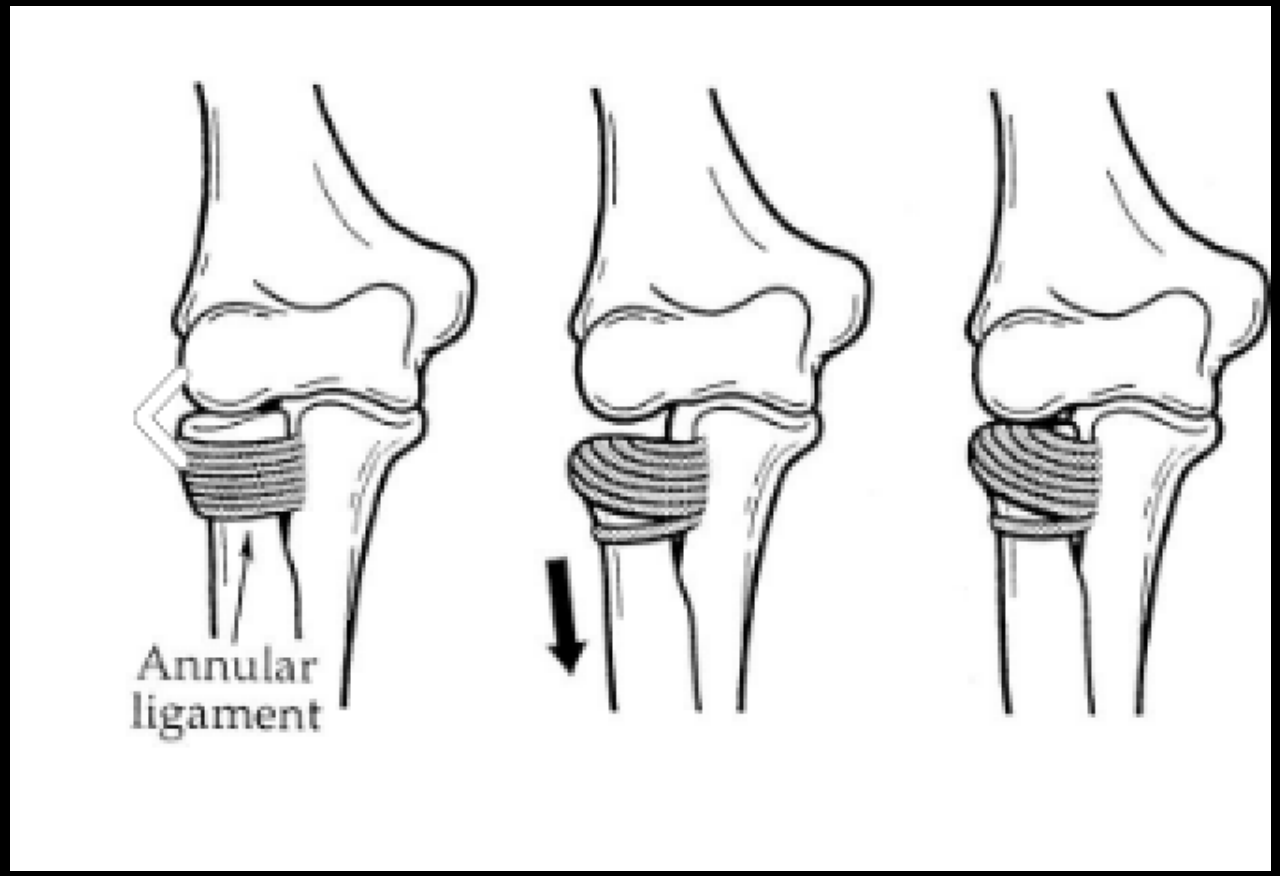
-Scoliosis: How to Use a Scoliometer. Brown Med-Peds. Accessed 1/19/25. https://brownmedpedsresidency.org/scoliosis/

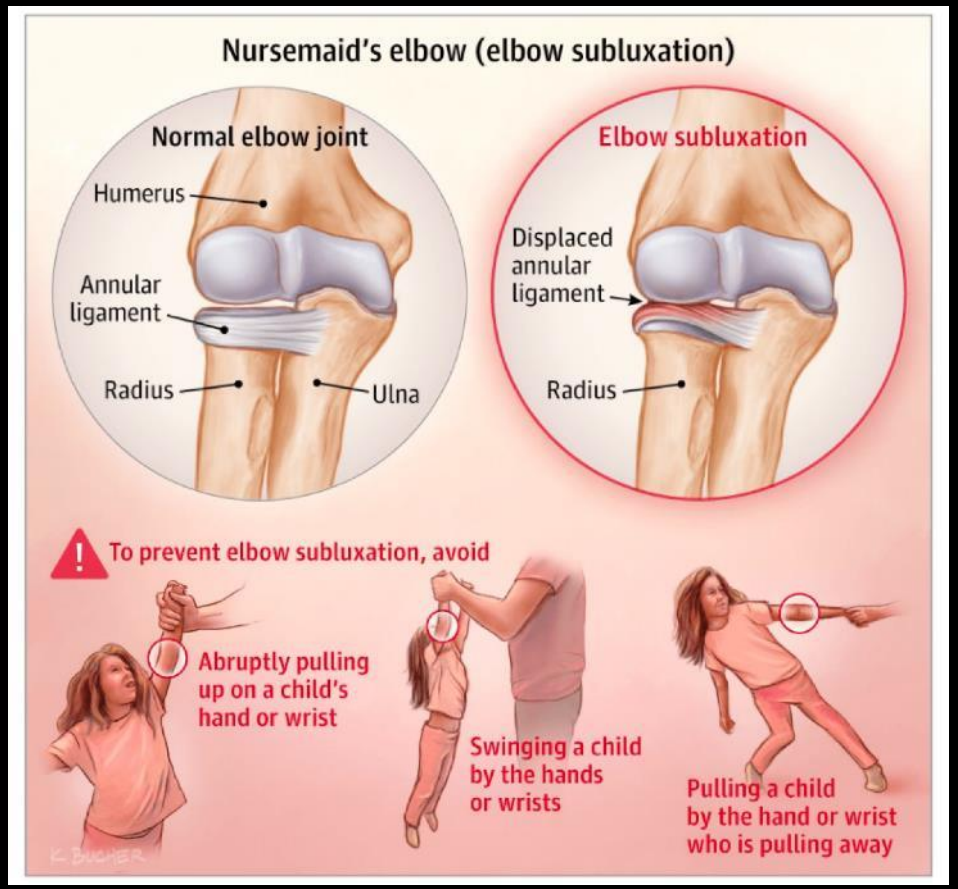

Traumatic

Nursemaid elbow/Radial head subluxation

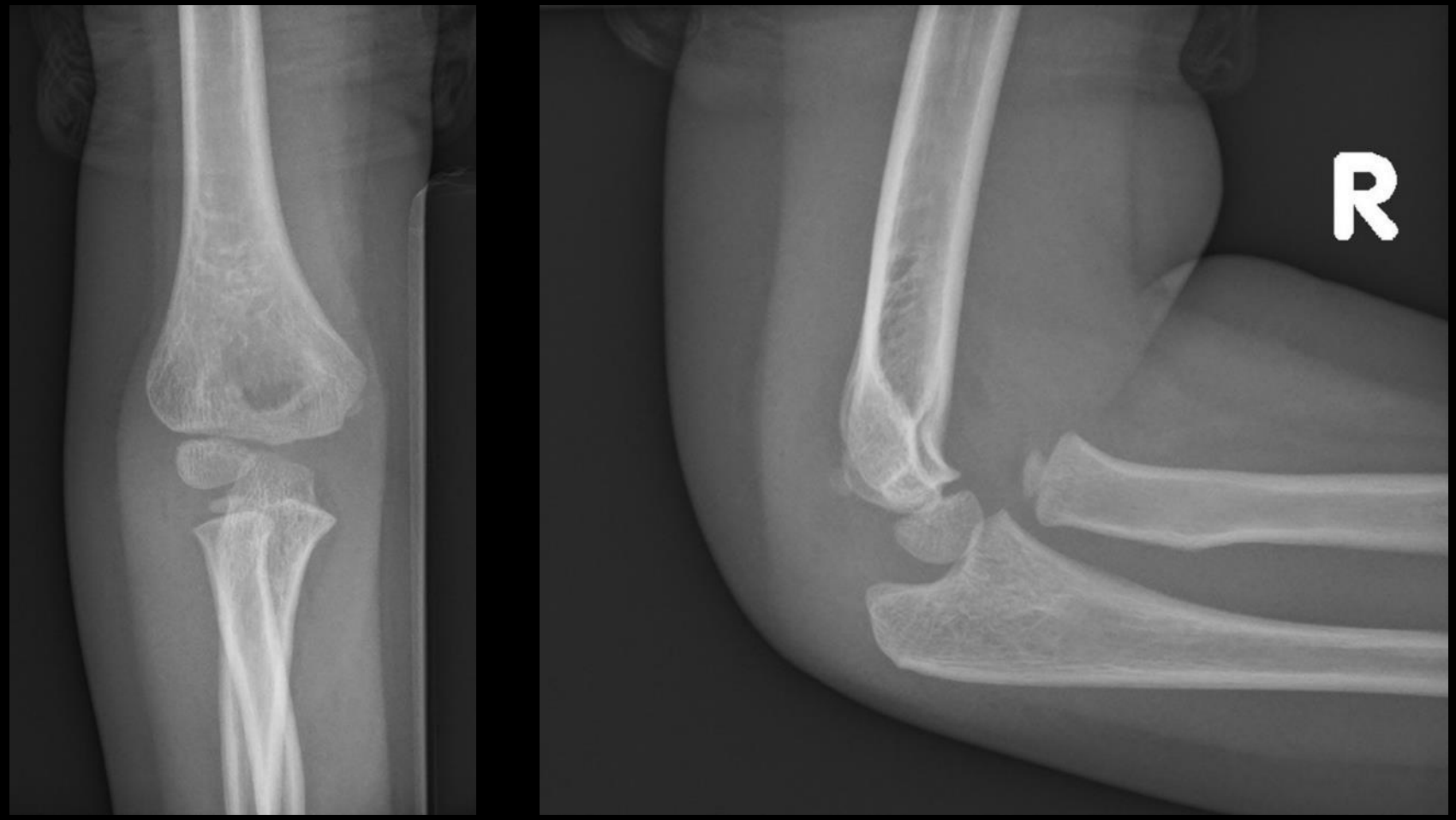
- Age
  - <7, peak incidence 2-3 years old.
  - More common in females
- Etiology
  - Sudden upward pull of arm, radius pulled through annular ligament
- Presentation
  - Slight click might be felt by person pulling arm.
  - Pain, tenderness at lateral aspect of elbow
  - Holding elbow in slight flexion, full ROM flexion/extension
- Differential
  - Fracture, contusion
  - Septic arthritis
  - Radial head dislocation

-Spiegel R, Kleist S. Hyperpronation Method for Reduction of Nursemaid's Elbow. Am Fam Physician. 2018;97(10)
-Shaath K, Shirley E. Nursemaid's Elbow. Ortho Bullets. August 21, 2022. Accessed 1/20/25.
https://www.orthobullets.com/pediatrics/4012/nursemaids-elbow





-Causes & Treatment of Nursemaid's Elbow. Fox Valley Orthopedics. Jan 9, 2019. Accessed 1/20/25. https://www.fvortho.com/blog/2019/january/causes-treatment-of-nursemaid-s-elbow/
-Shaath K, Shirley E. Nursemaid's Elbow. Ortho Bullets. August 21, 2022. Accessed 1/20/25. https://www.orthobullets.com/pediatrics/4012/nursemaids-elbow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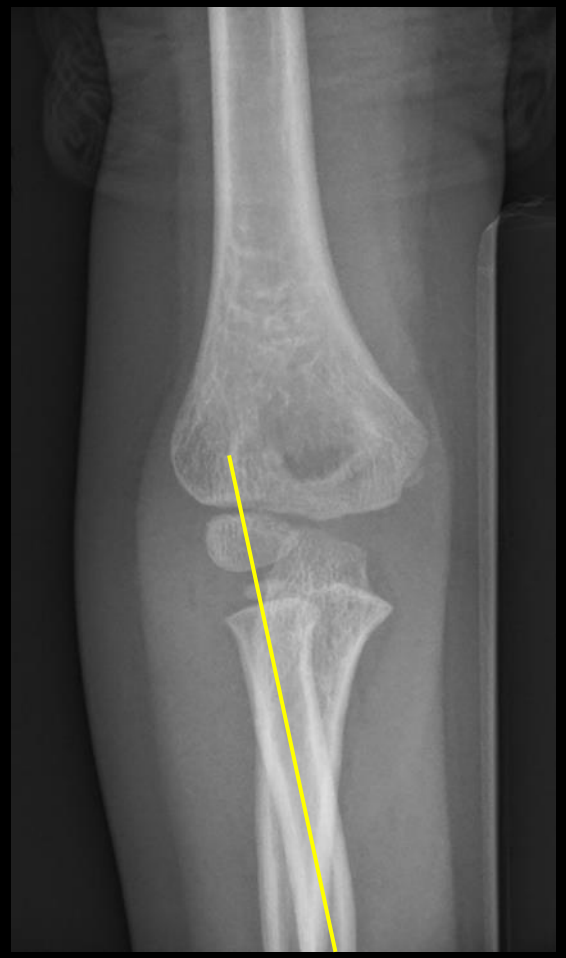
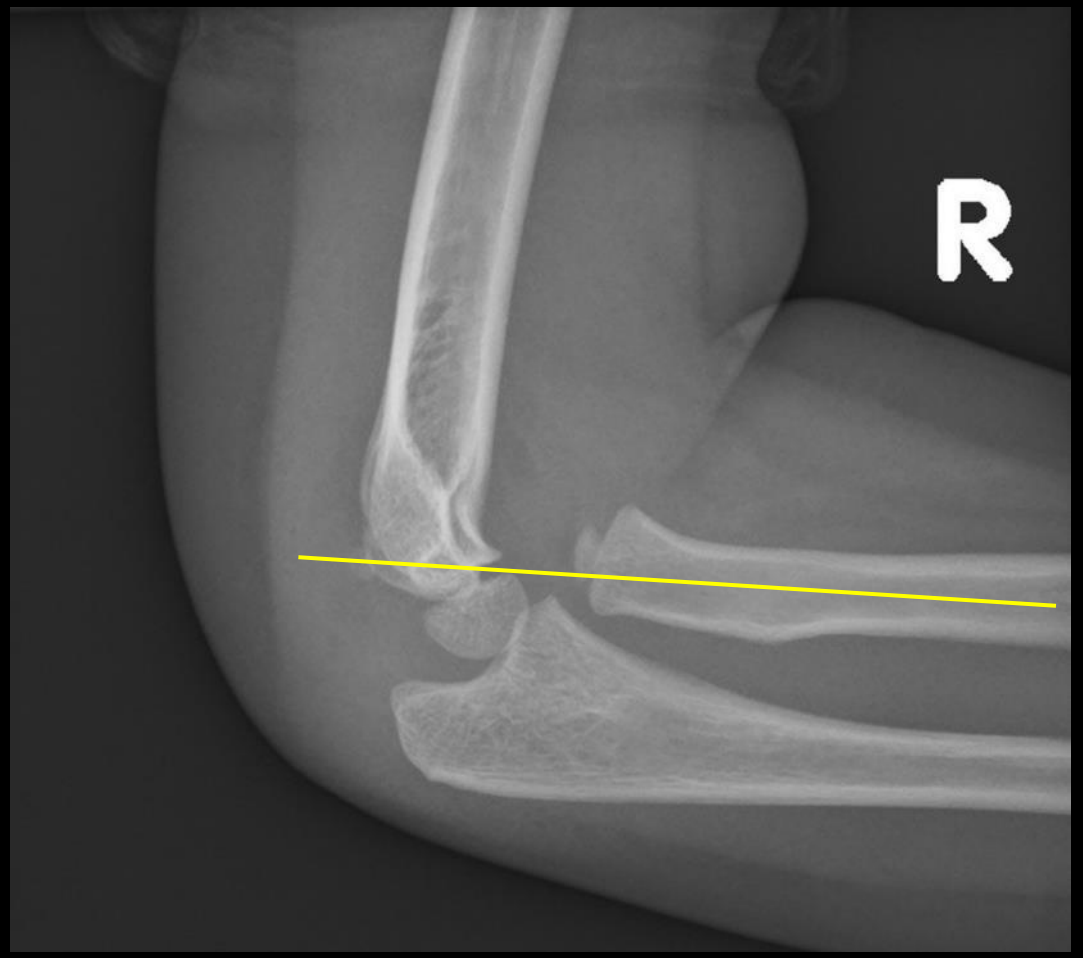
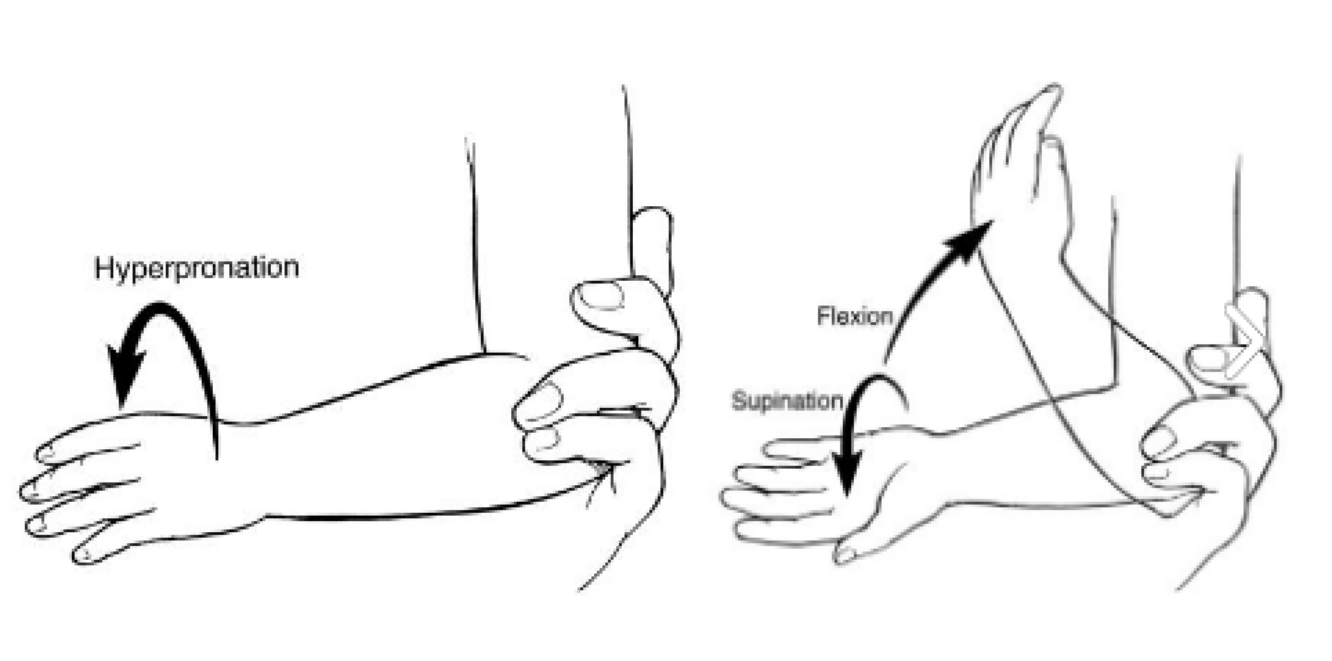
Disturbance of Alignment

Dislocation... with or without fracture





Treatment



- Non operative
  - Closed reduction
- Surgery rarely necessary
  - Chronic, symptomatic

-Shaath K, Shirley E. Nursemaid's Elbow. Ortho Bullets. August 21, 2022. Accessed 1/20/25. https://www.orthobullets.com/pediatrics/4012/nursemaids-elbow

Toddlers Fracture

- Age
  - Ambulatory infants and young children (9 months-3 years)
- Mechanism
  - Twisting injury while tripping, stumbling falling
- Presentation
  - Limping/refusing to walk, tenderness at site of fracture
- Treatment
  - Immobilization for 3-4 weeks

-Alqarni N, Goldman RD. Management of toddler's fractures. Can Fam Physician. 2018 Oct;64(10):740-741. PMID: 30315017; PMCID: PMC6184974. Accessed 1/1/25.

Toddler's Fracture

Toddler Fracture
healing

Toddler's Fracture
healing

Trampoline Fractures

- Approximately 100,000 ED visits per year
- 29% of pediatric fractures
- High risk for serious injuries (i.e. paralysis, fractures needing surgery, concussions)
- AAP recommends against trampolines except in settings with professional coaches, specialized equipment and avoiding trampolines under age 6

-Jeong C, Lee SU, Kim HG, Joo SY. Trampoline-related fractures of the proximal tibia in children. J Orthop Surg Res. 2021 Sep 8;16(1):551. doi: 10.1186/s13018-021-02707-9. PMID: 34496913; PMCID: PMC8424931. Accessed 1/1/25.
-Briskin, S. Are Trampolines Safe for Kids? 9/3/2024 Healthychildren.org AAP https://www.healthychildren.org/English/safety-prevention/at-play/Pages/Trampolines-What-You-Need-to-Know.aspx Accessed 1/1/25.

Trampoline Fracture

Trampoline Fracture

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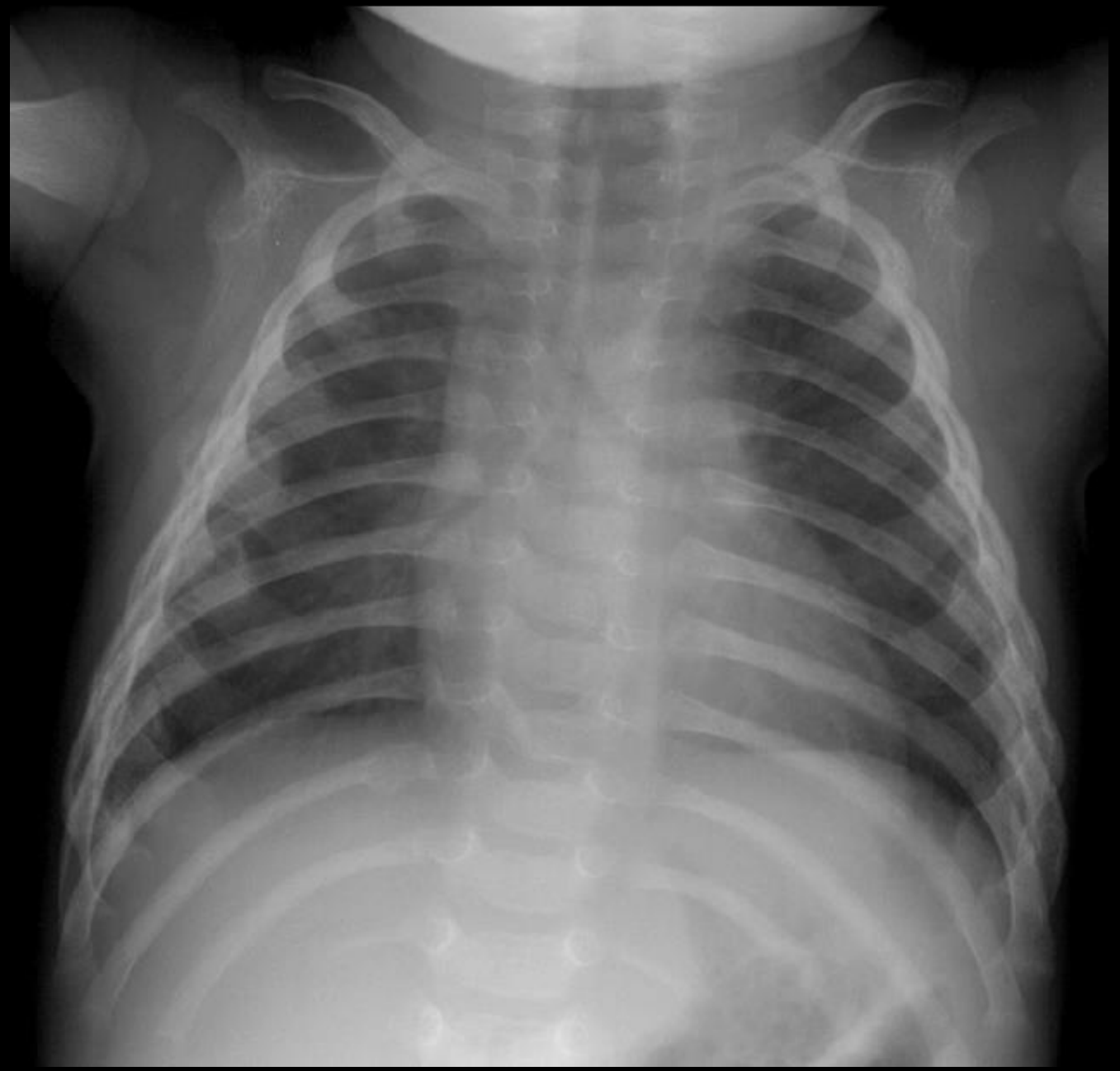
Trampoline Fracture

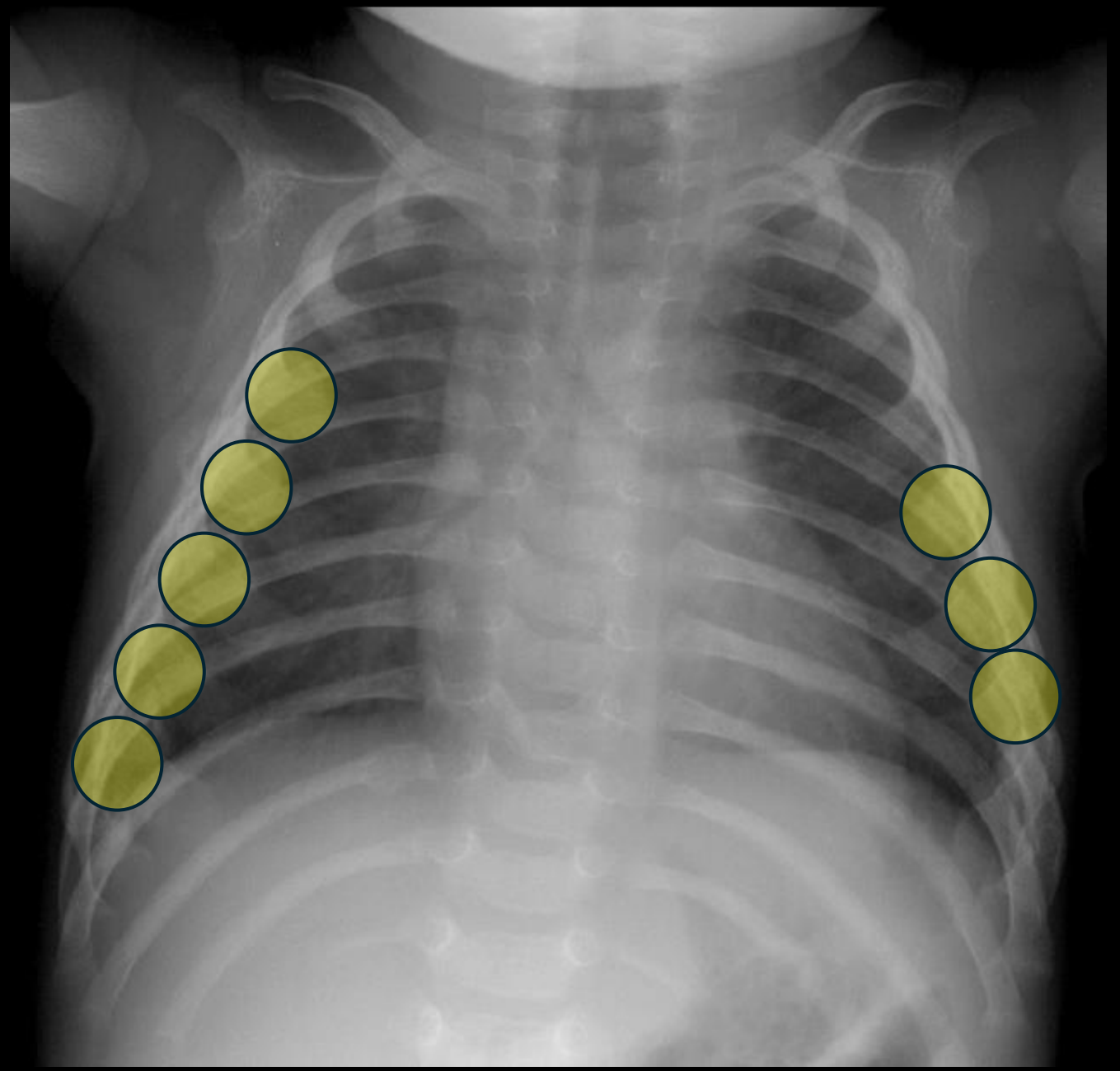
One month later

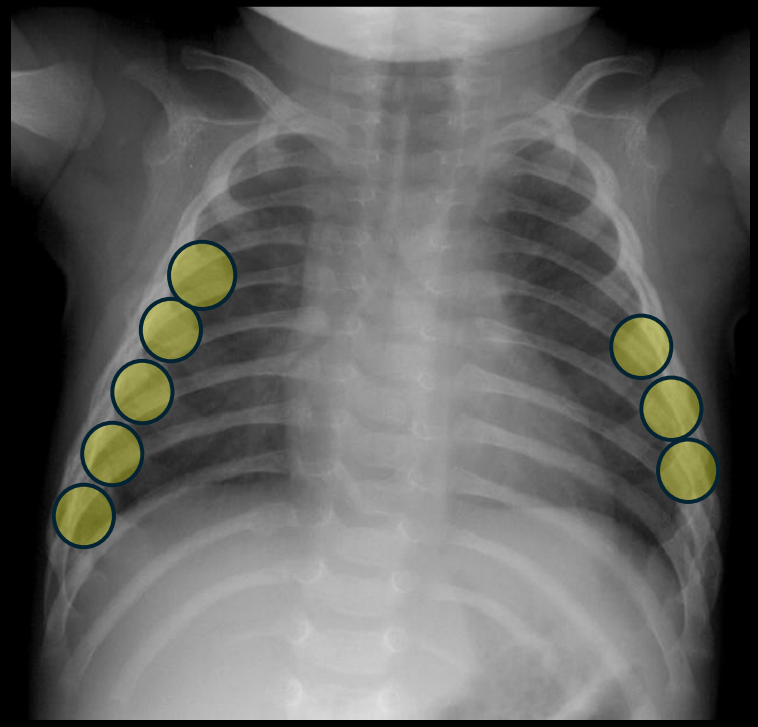
Non-Accidental Trauma-Can't Miss Diagnosis

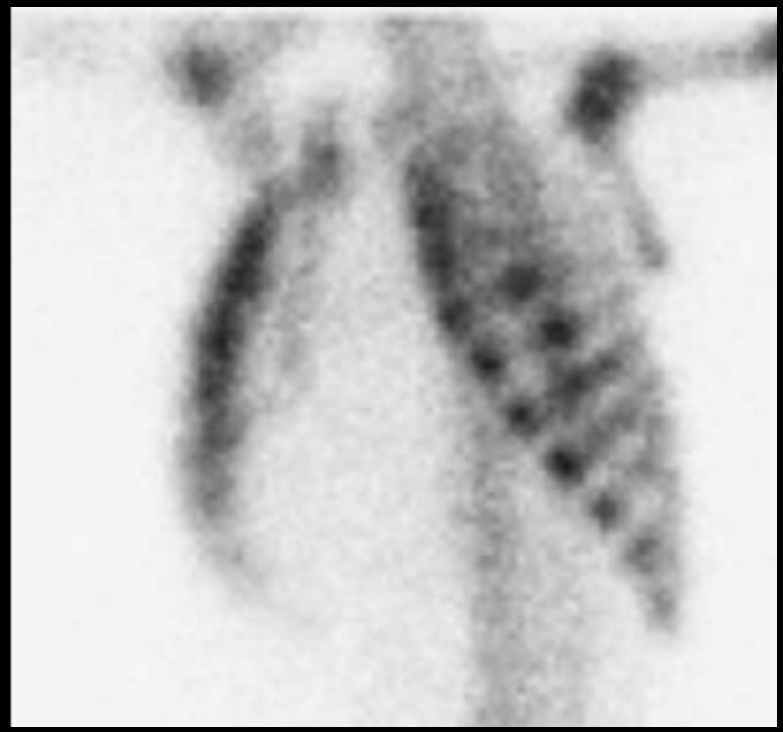
- Delays in seeking care
- Inconsistent history between caregivers
- Caregivers with inappropriate affect
- Bruising in non-mobile infant
- Pattern of injury that does not match history
- Child with history of injuries

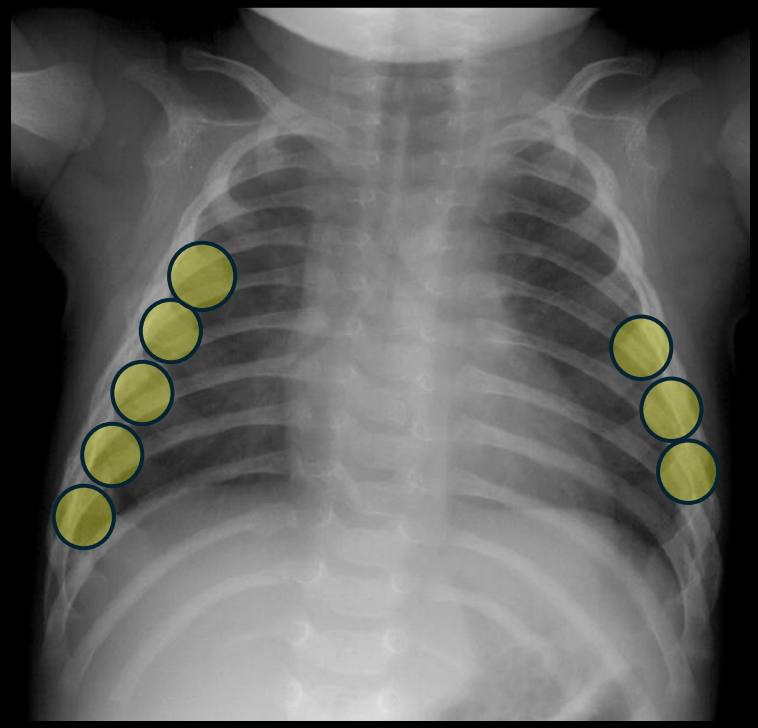
A Pediatric Perspective: Practical Guidelines for Identifying Non-Accidental Trauma in Children. Gillette Children's Specialty HealthCare. 2015, Volume 24, number 2. Accessed 1/1/25.
https://www.gillettechildrens.org/assets/uploads/for-medical-professionals/Guidelines_for_Non-Accidental_Trauma_Pediatric_Perspectives_Vol._24_No.2.pdf

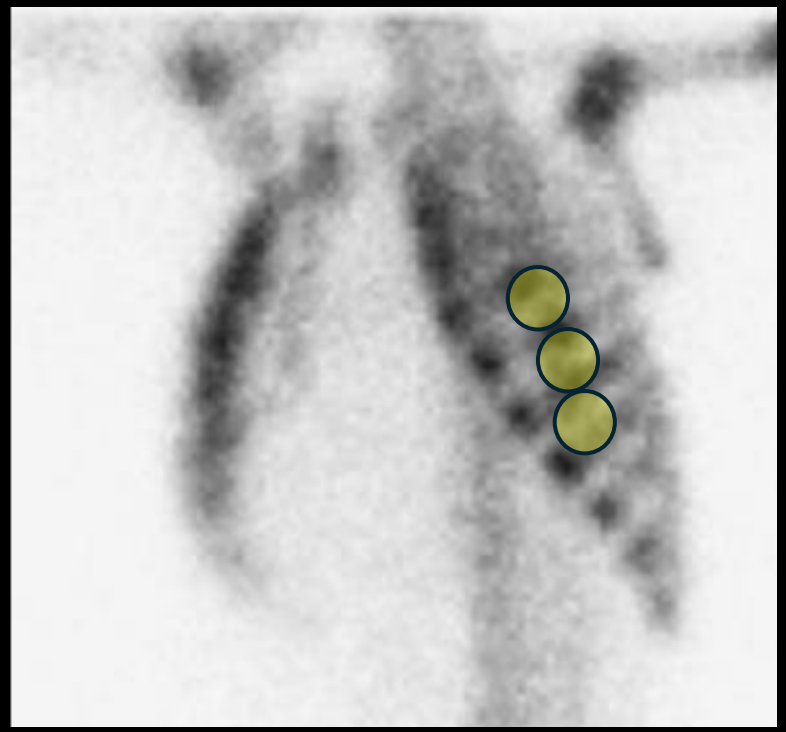


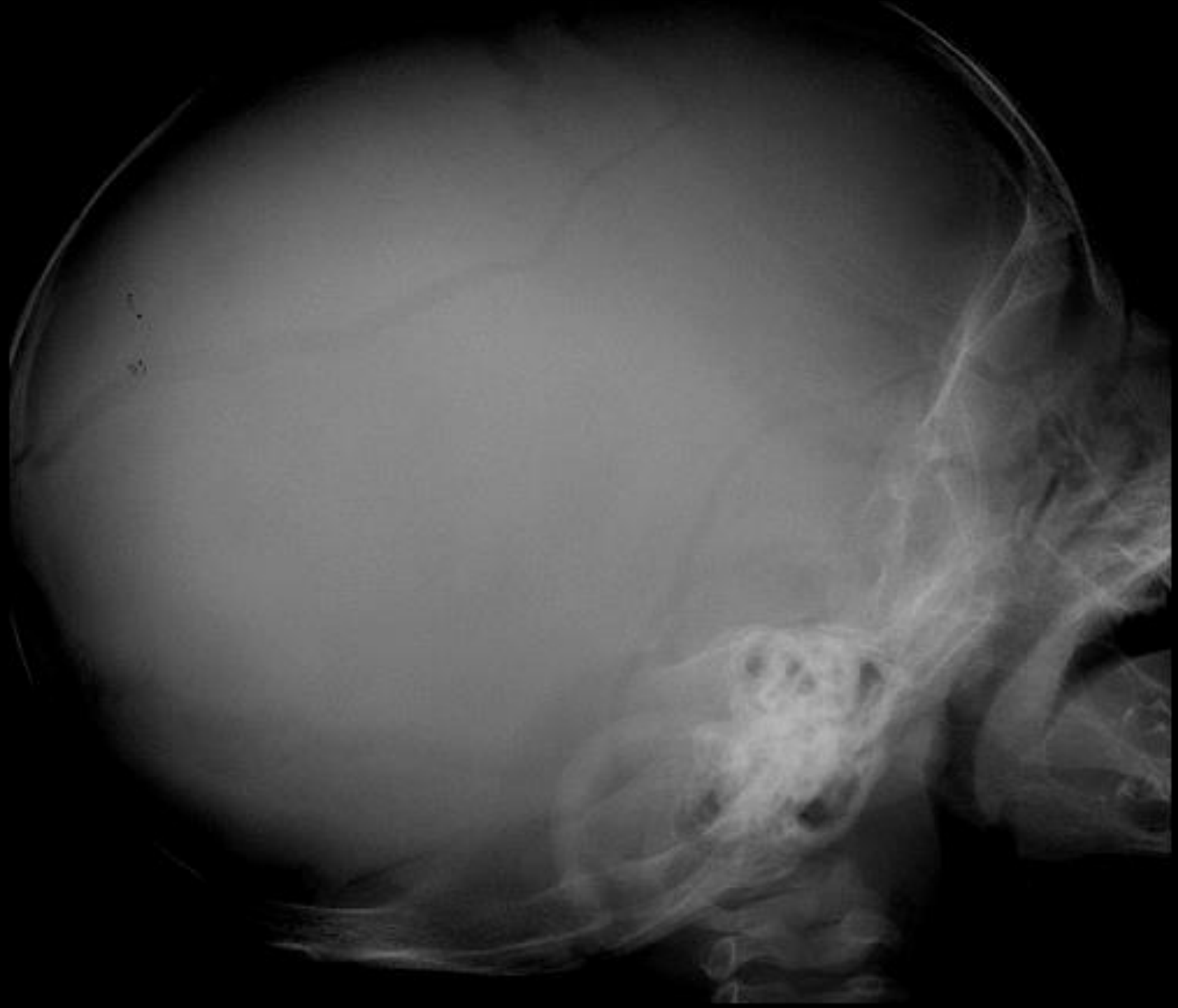


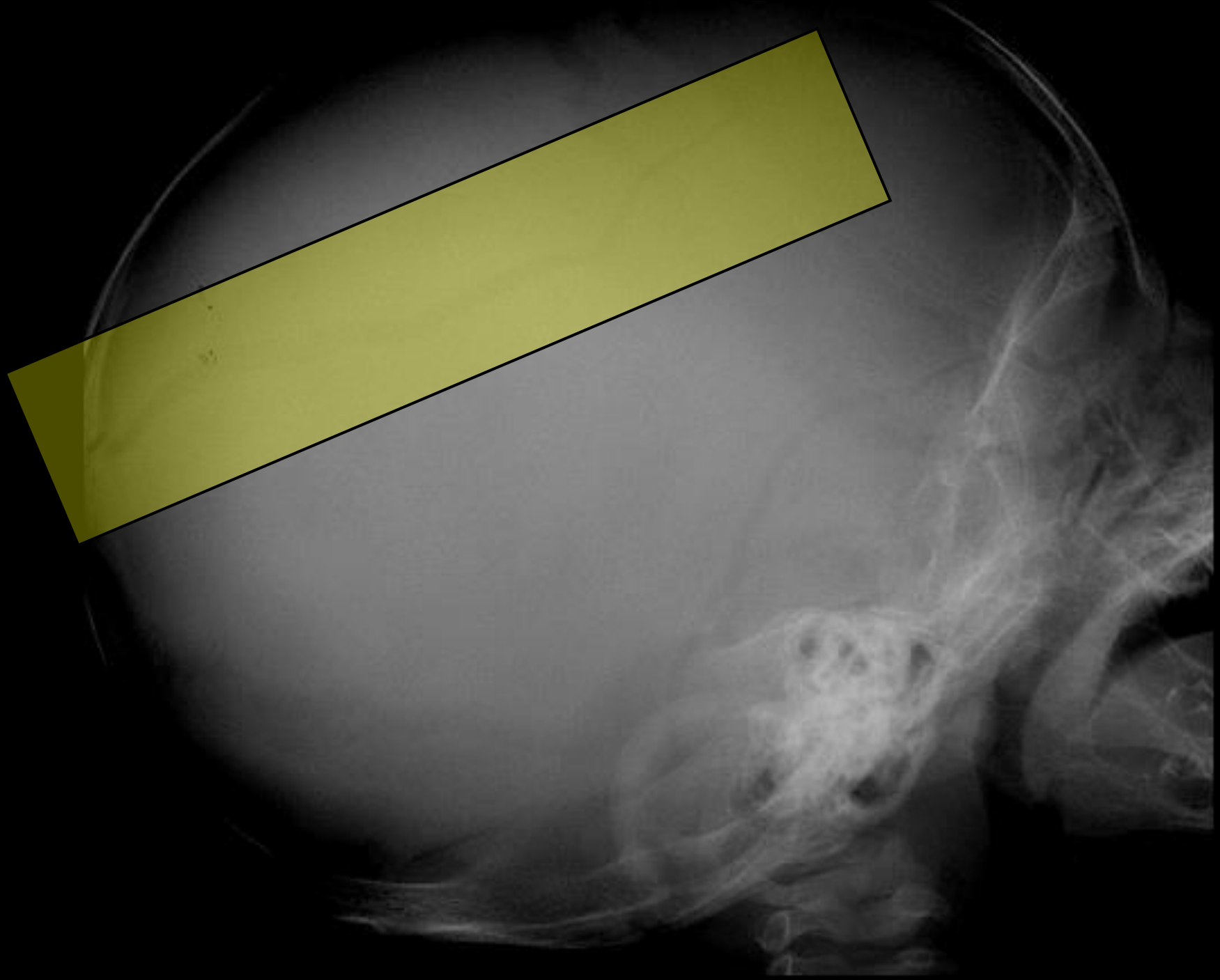


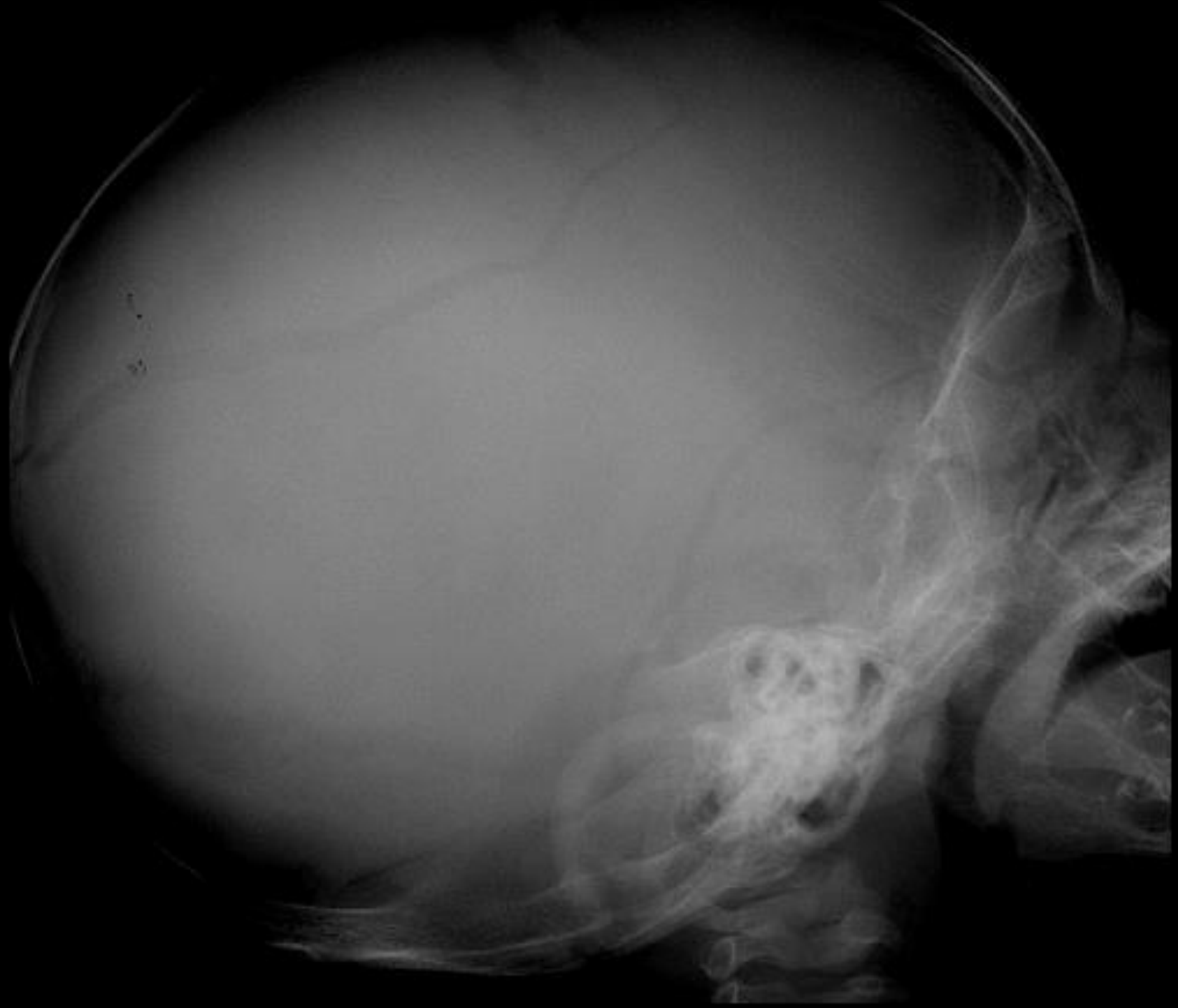












Fractures: School Age

Distal radius buckle fracture

- Mechanism of action:
  - Most commonly fall on outstretched hand
  - Buckling/folding of cortex (outer layer) of bone
- Incidence:
  - Most common type of fracture in childhood
  - 20% of all pediatric fractures
- Management:
  - Very stable fracture. Treatment aimed at pain reduction/prevention of further injury
  - Removable wrist splint given stability of fracture
  - Rarely is ortho intervention needed

-Koelink E, Schuh S, Howard A et al. Primary Care Physician Follow-up of Distal Radius Buckle Fractures. Pediatrics (2016) 137 (1): e20152262. https://doi.org/10.1542/peds.2015-2262
-Zwillinberg M, Esther K. Splint vs Cast for Forearm Buckle Fracture in Children. Am Fam Physician. 2022;105(4):online

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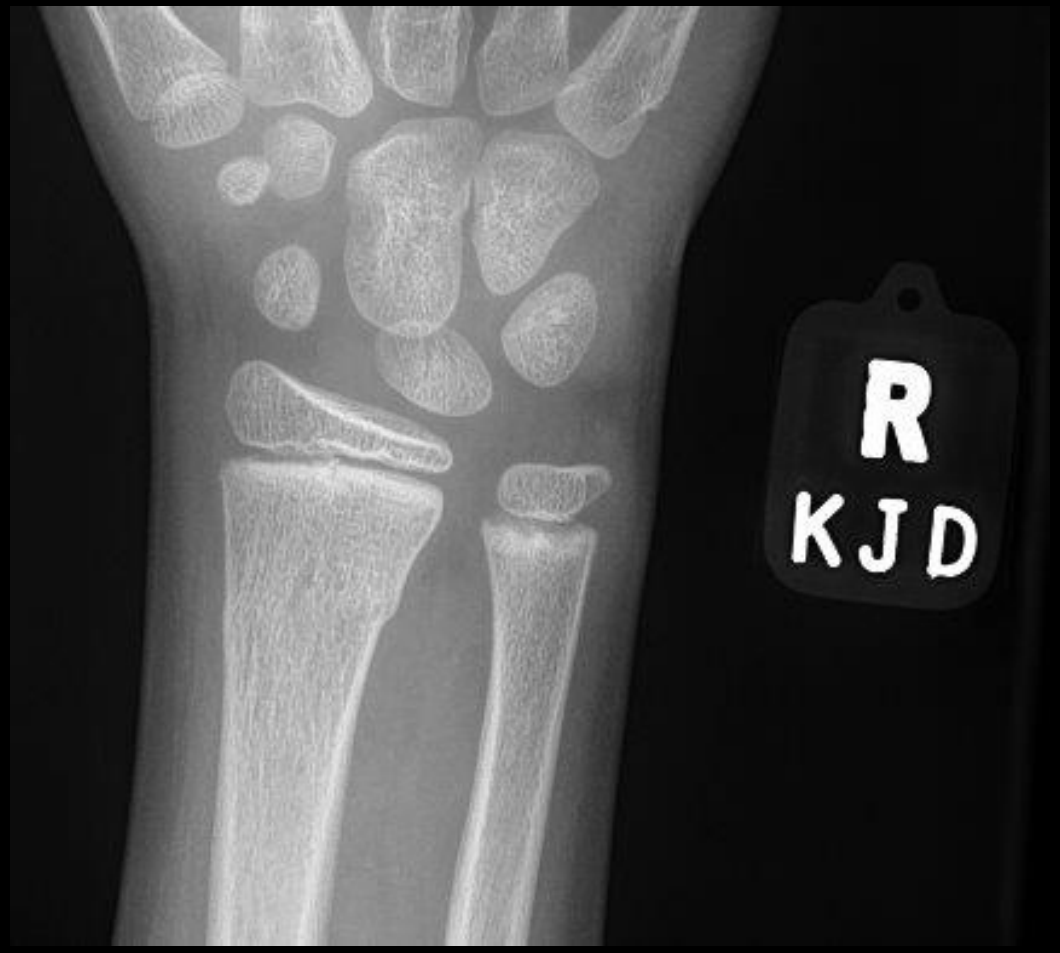
Buckle (Torus) Fracture

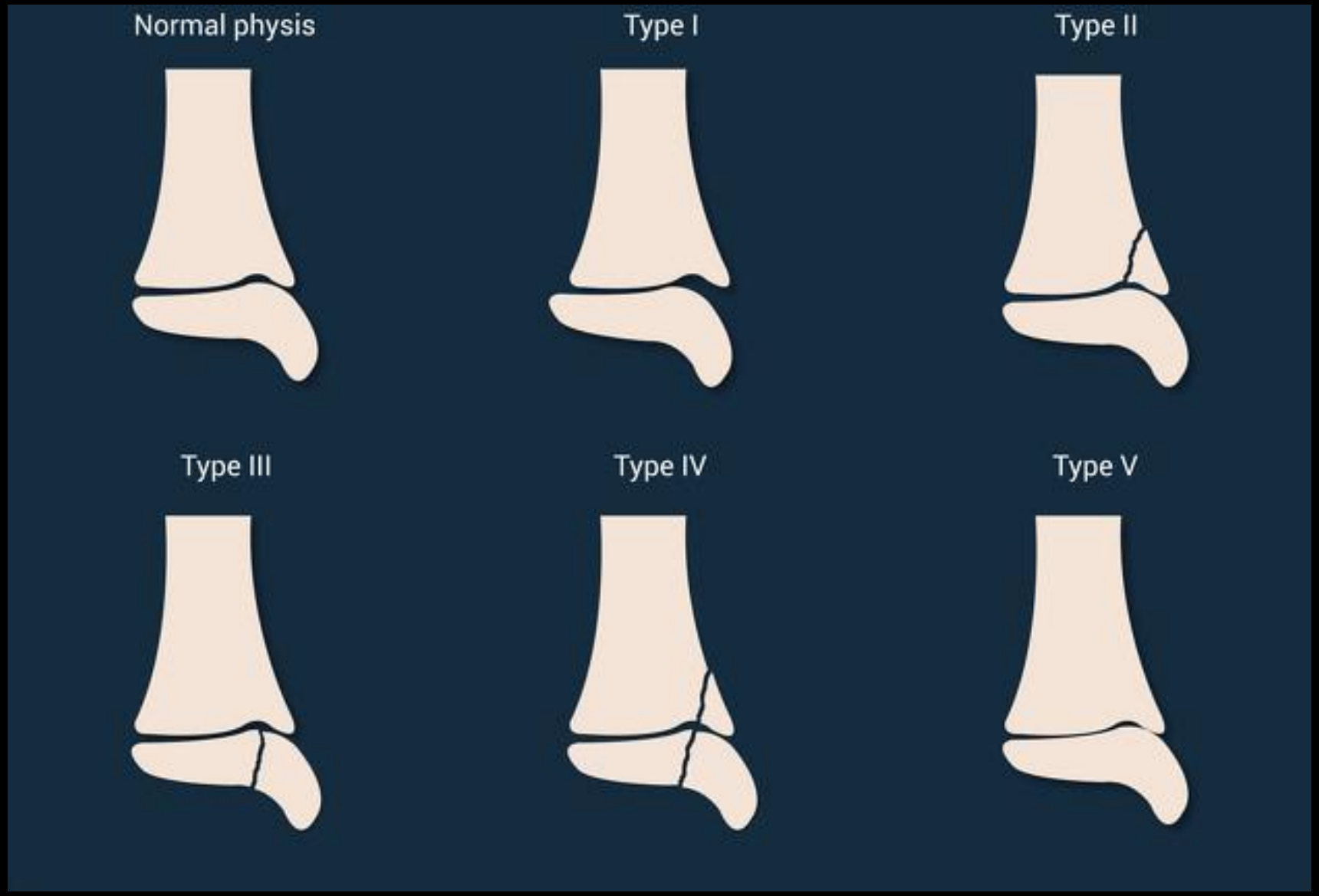


Salter Harris Fractures

- Growth plate fractures
  - Distal radius, distal tibia, distal fibula most common locations
- Incidence:
  - 20-35% of all pediatric fractures
  - More common in adolescents
  - Males>females 2:1 ratio
- Mechanism of Injury
  - Most common: a fall while running or playing
  - Less common: infection, repetitive stress, vascular insult, tumor
- Management:
  - Varies based on type of injury; from relative immobilization to surgical stabilization and immobilization

-Jones C, Wolf M, Herman M. Acute and Chronic Growth Plate Injuries. Pediatr Rev (2017) 38 (3): 129–138.
https://doi.org/10.1542/pir.2015-0160

Salter-Harris Fracture Classification: Transphyseal Fractures



Case courtesy of Leonardo Lustosa, Radiopaedia.org, rID: 97497

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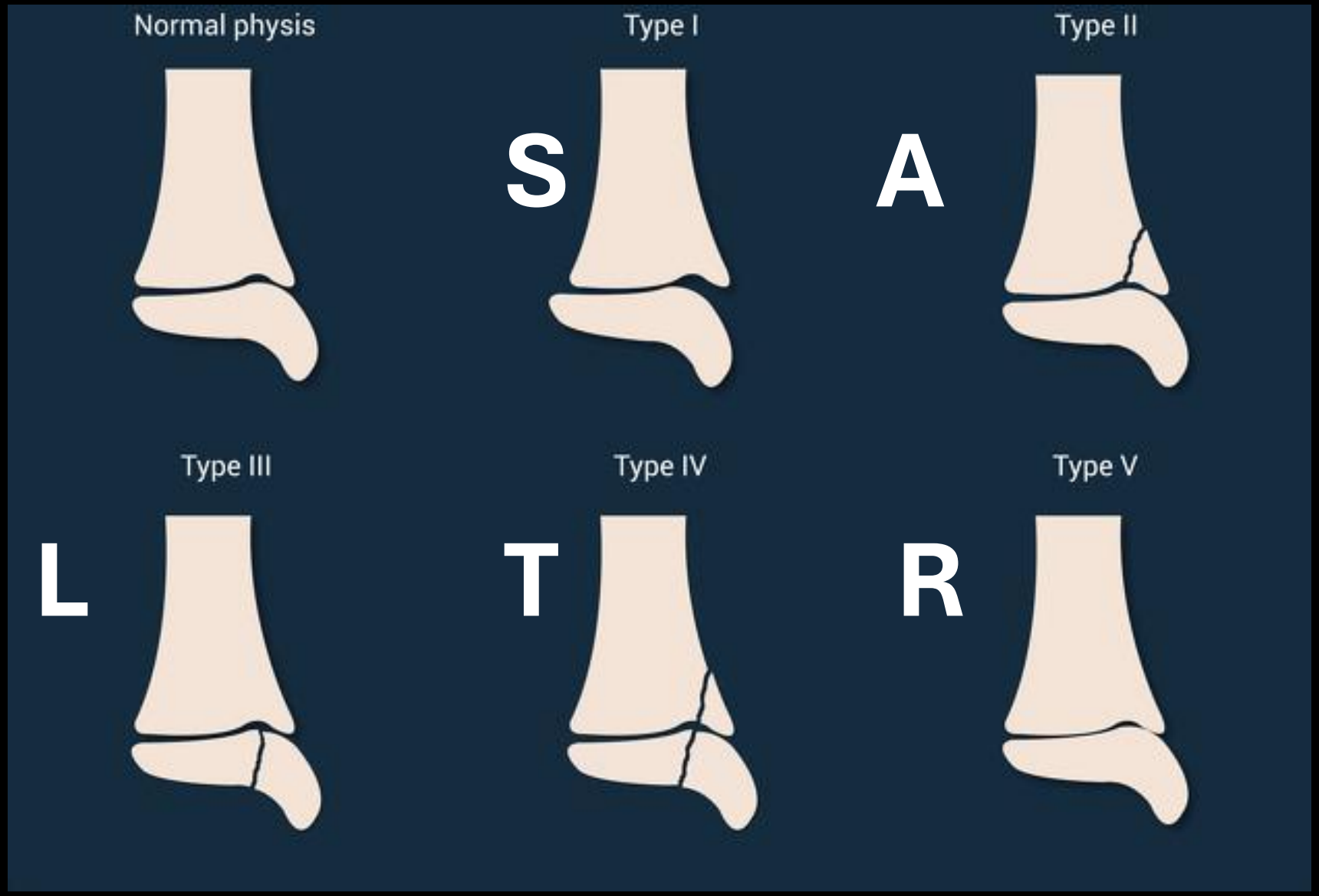
Salter-Harris Fracture Classification: Transphyseal Fractures



Case courtesy of Leonardo Lustosa, Radiopaedia.org, rID: 97497

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Salter Harris Spectrum: Beware the open physis!

I II III IV V

V

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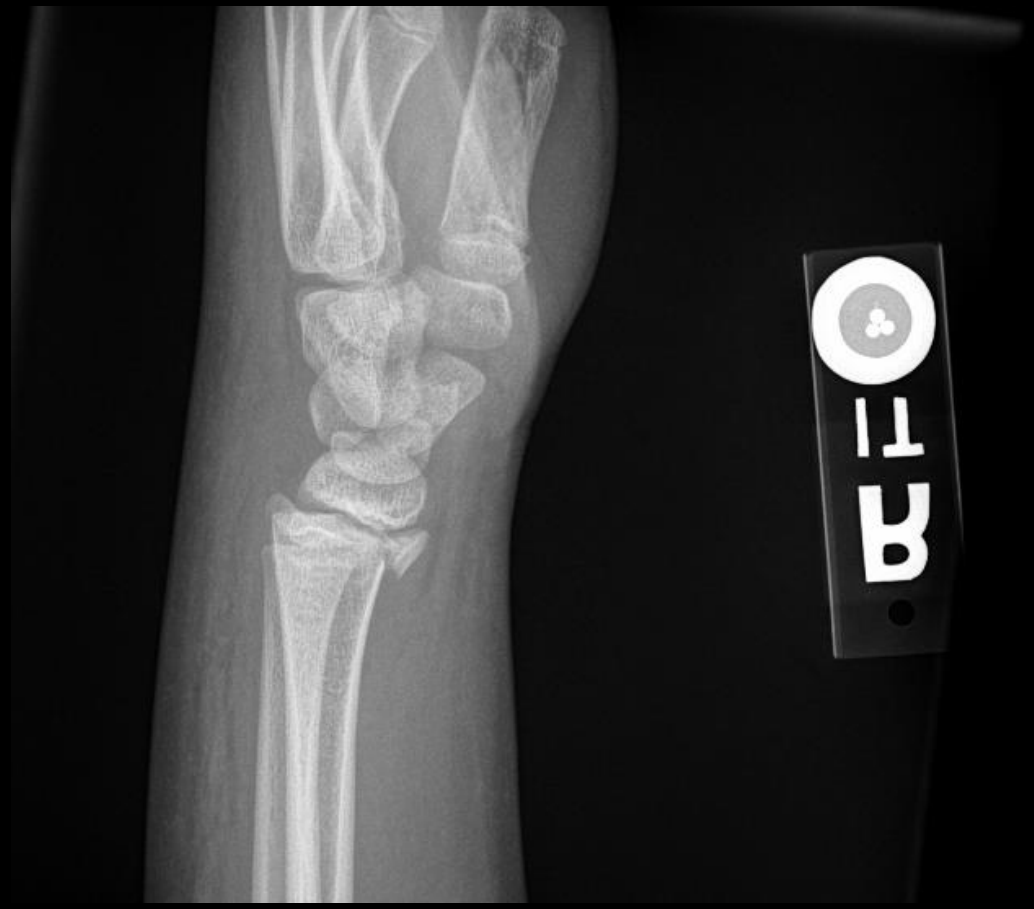
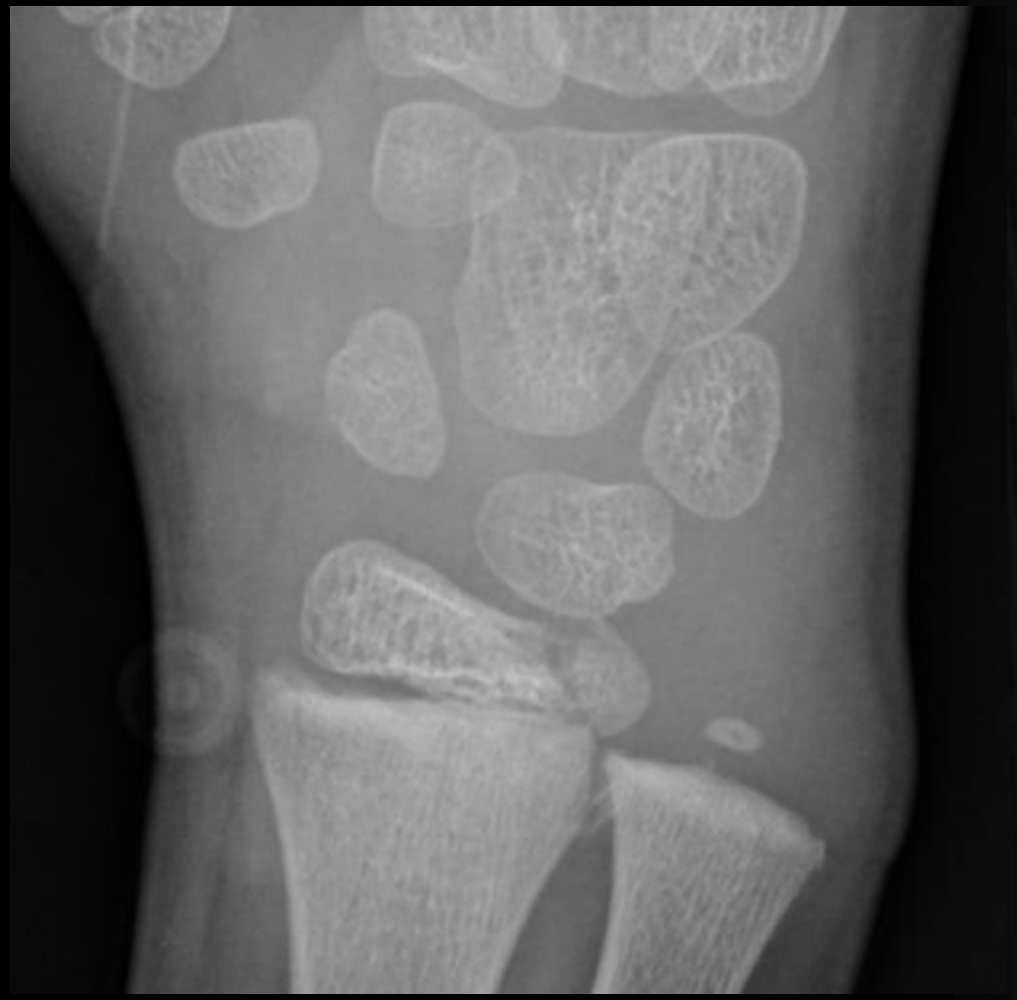
Salter Harris II

Salter Harris II



Buckle Fracture

Salter Harris IV



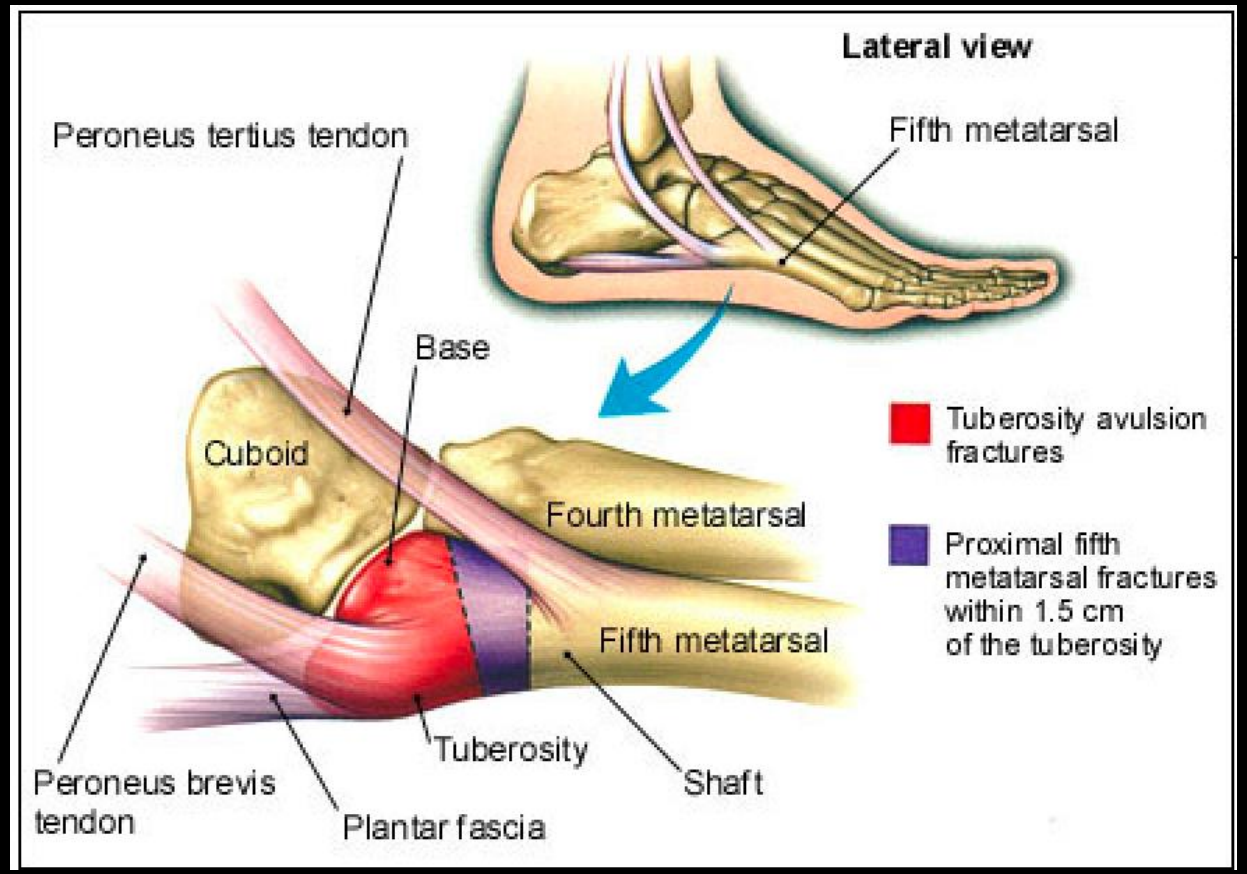
Salter-Harris I

Salter-Harris I

Salter-Harris I

5th Metatarsal Fractures-3 types

- Avulsion
  - Presentation: Sudden onset of pain after forced inversion with foot/ankle in plantar flexion, Swelling & bruising
  - Treatment: Conservative, Referral to ortho if fracture displaced
- Stress
  - Presentation: Prodromal pain with weight bearing/activity, athletes early in training season, swelling ecchymosis.
  - Treatment: Usually conservative. Treat as acute fracture if within 1.5 cm of tuberosity and refer to ortho
- Jones
  - Presentation: Acute incident, laterally directed force on forefoot with ankle in plantar flexion
  - Treatment: Variable healing potential—can result in osteonecrosis. Refer to ortho



-Strayer et al. Fractures of the Proximal Fifth Metatarsal. Am Fam Physician. 1999;59(9):2516-2522

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Tour de 5th metatarsal

Normal or abnormal?

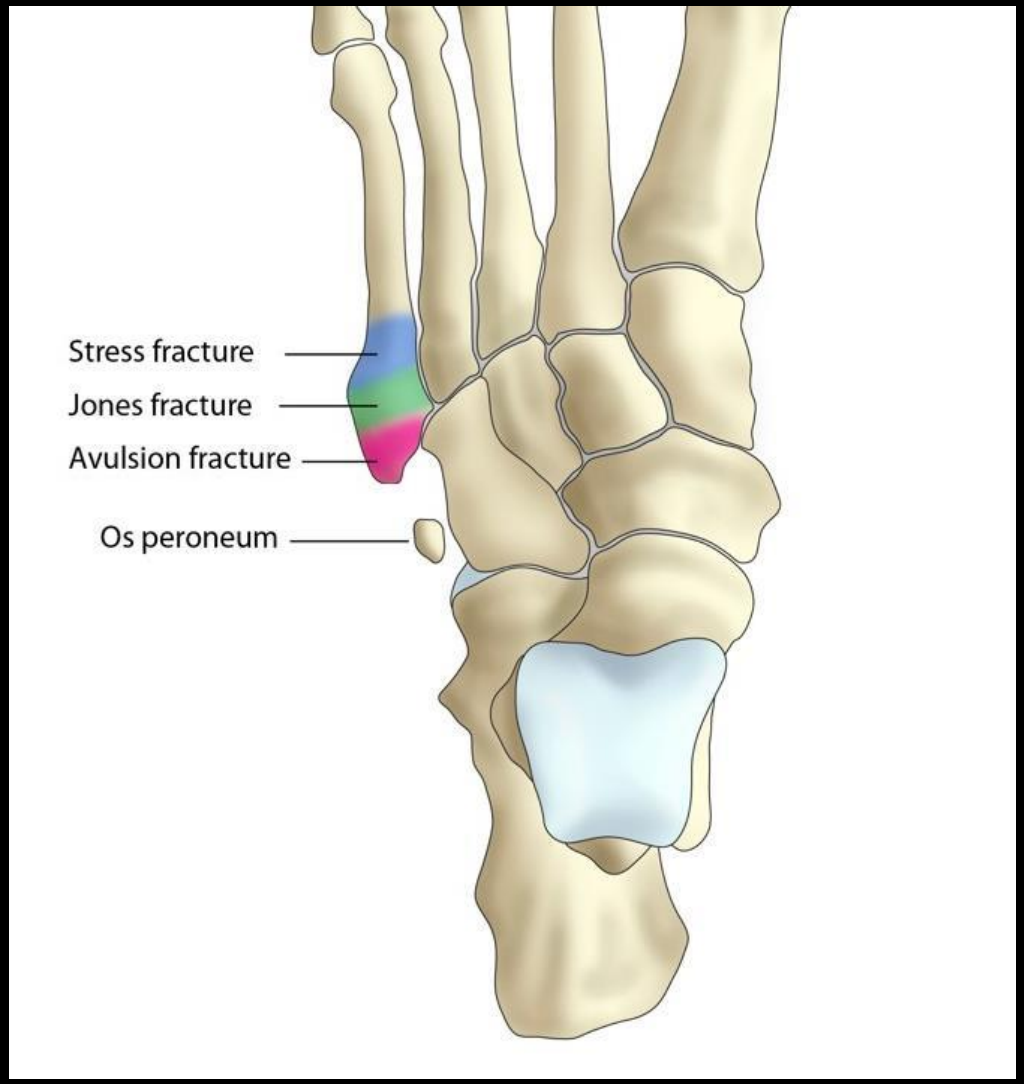
Normal! Apophysis

Tour de 5th metatarsal – Avulsion Fracture

Tour de 5th metatarsal – Jones fracture

Tour de 5th metatarsal – stress fracture

Tour de 5th metatarsal



Fractures are transverse, apophysis is longitudinal

Proximal -> Distal = A -> Z
Avulsion -> Jones -> Stress

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Case courtesy of Frank Gaillard, Radiopaedia.org, rID: 7644

Slipped capital femoral epiphysis (SCFE)

- Age
  - School age/adolescents with open growth plate
- Location
  - Proximal femoral physis (growth plate)
- Risk factors
  - Strongly associated with obesity
    - Increasing BMI increases risk and reduces age on onset
- Presentation
  - Hip, thigh, knee pain (can be referred)
  - Limp
  - Out-toeing
    - New onset and/or asymmetric
- Management
  - Imaging
  - Referral to ortho
  - Surgery
  - Weight management to reduce contralateral disease

-Karkenny, A. How to recognize, manage orthopedic co-morbidities of obesity. 9/1/2023. AAP News. https://publications.aap.org/aapnews/news/25433/How-to-recognize-manage-orthopedic-co-morbidities accessed 1/1/25

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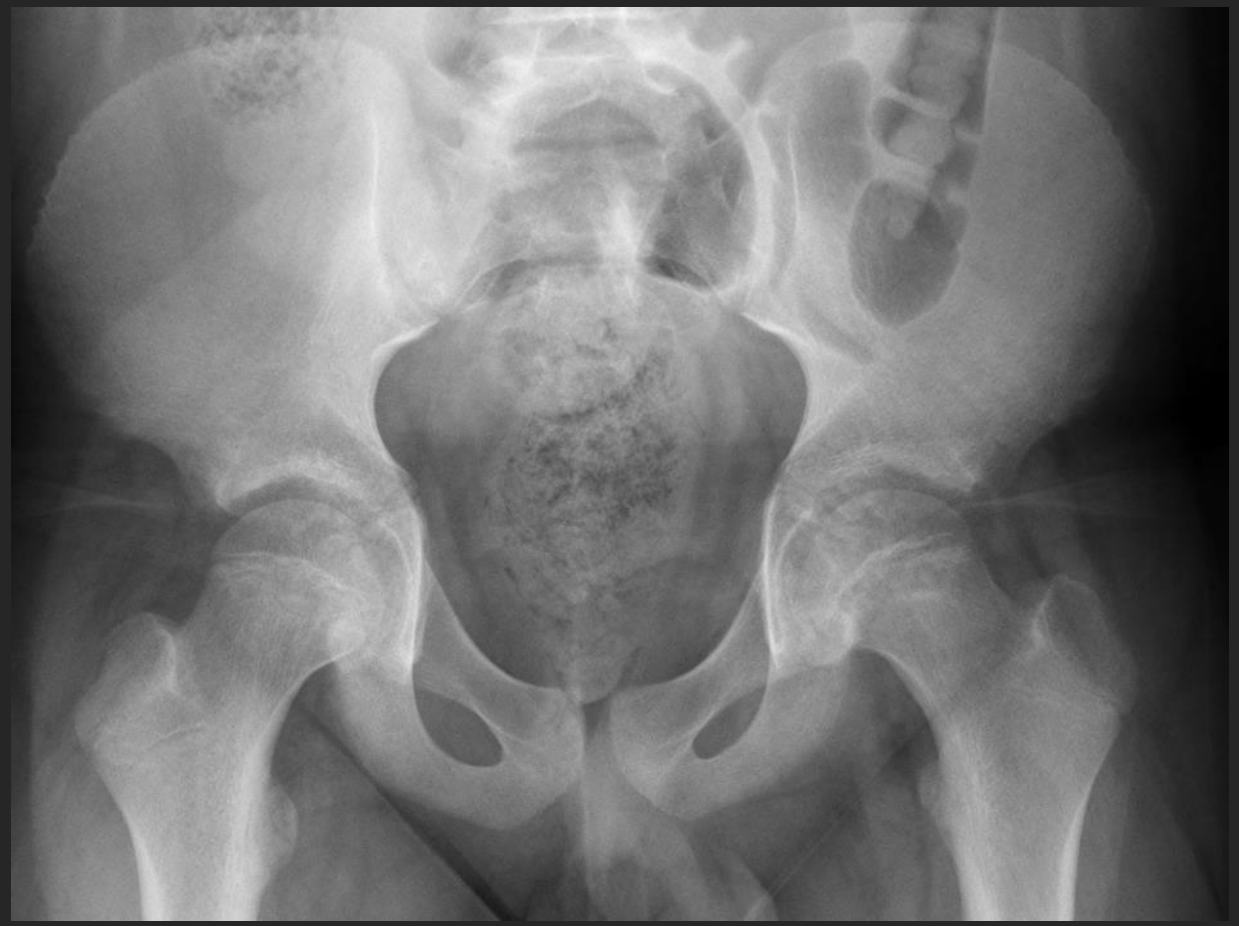
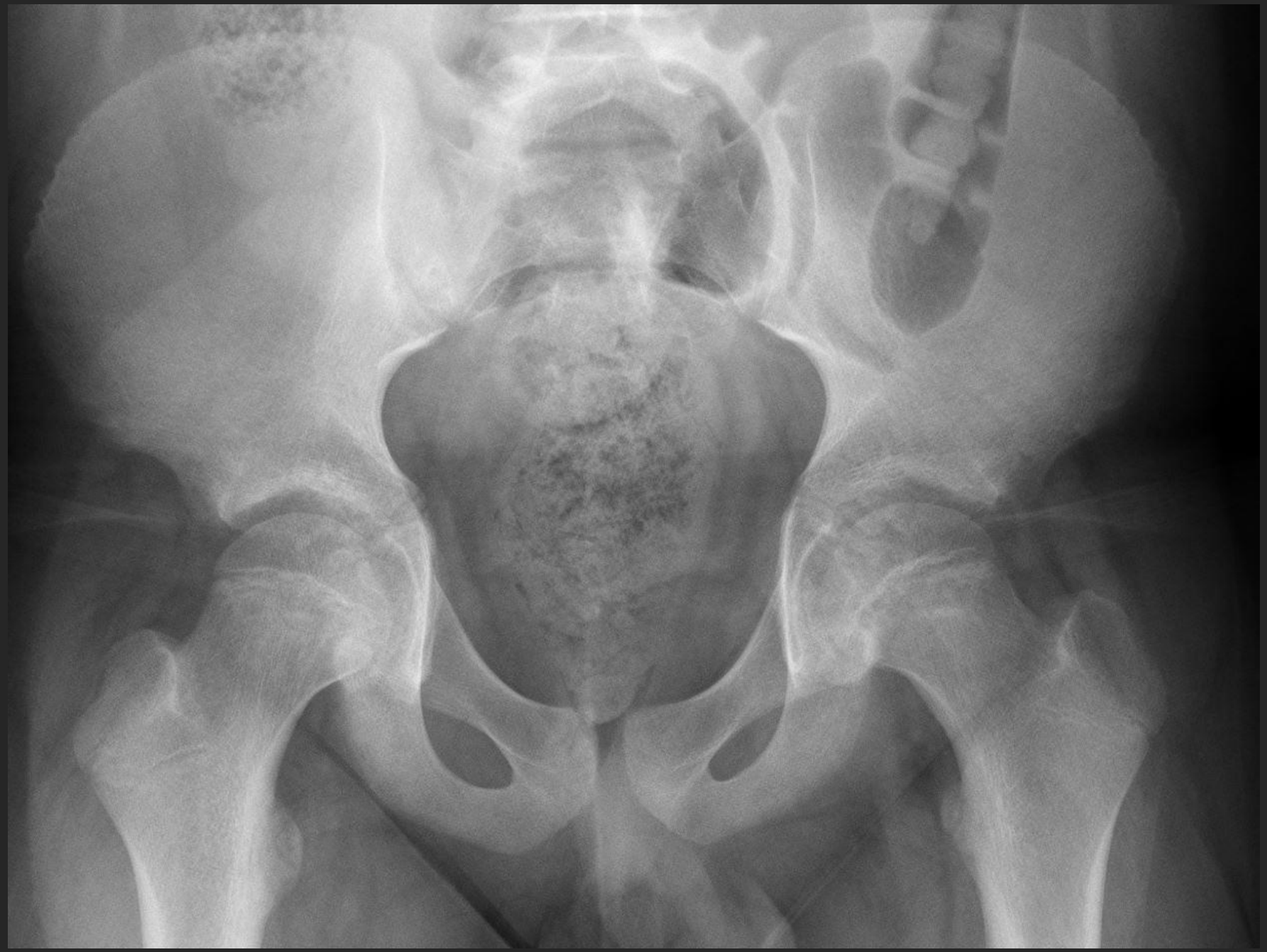
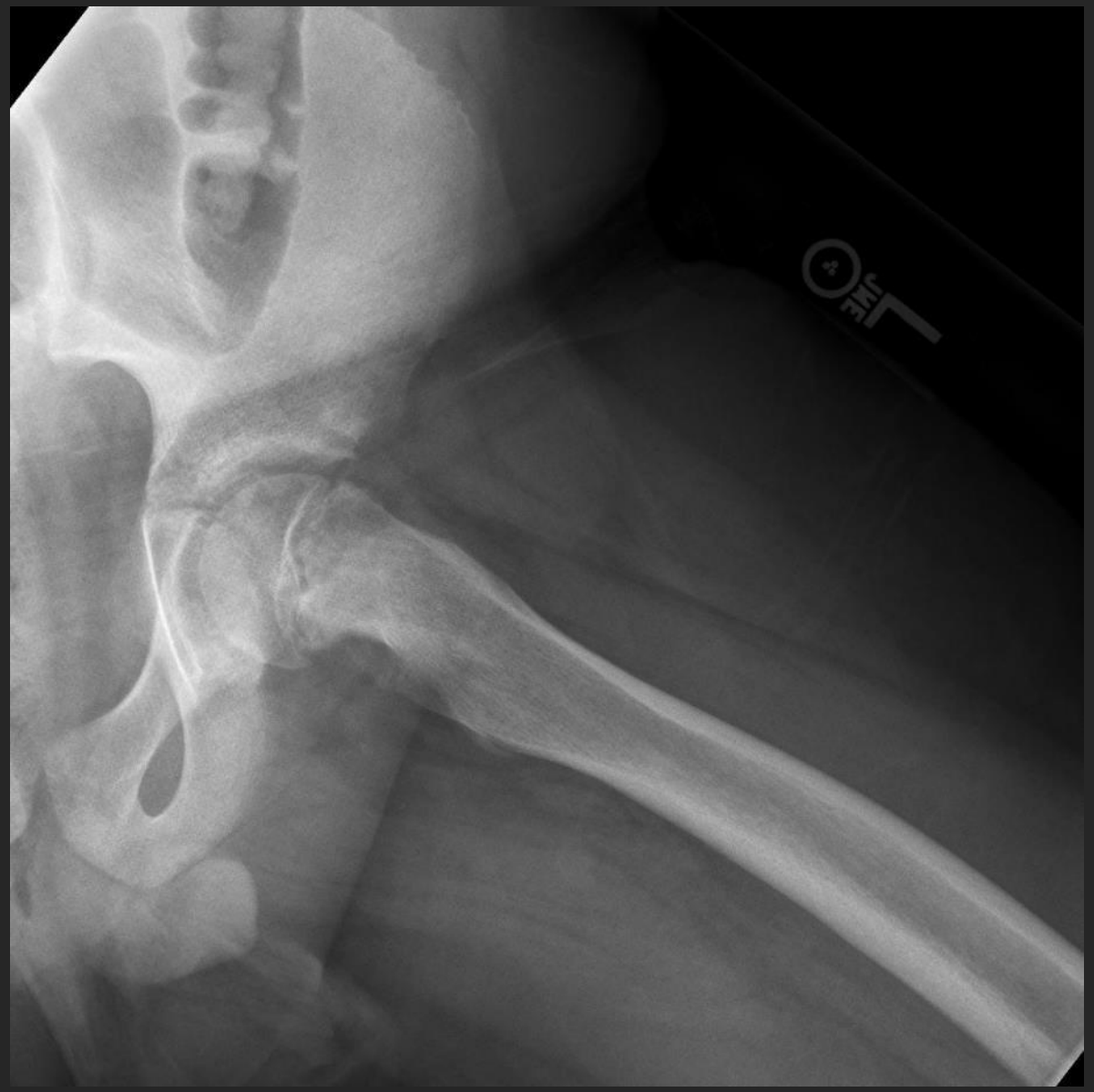
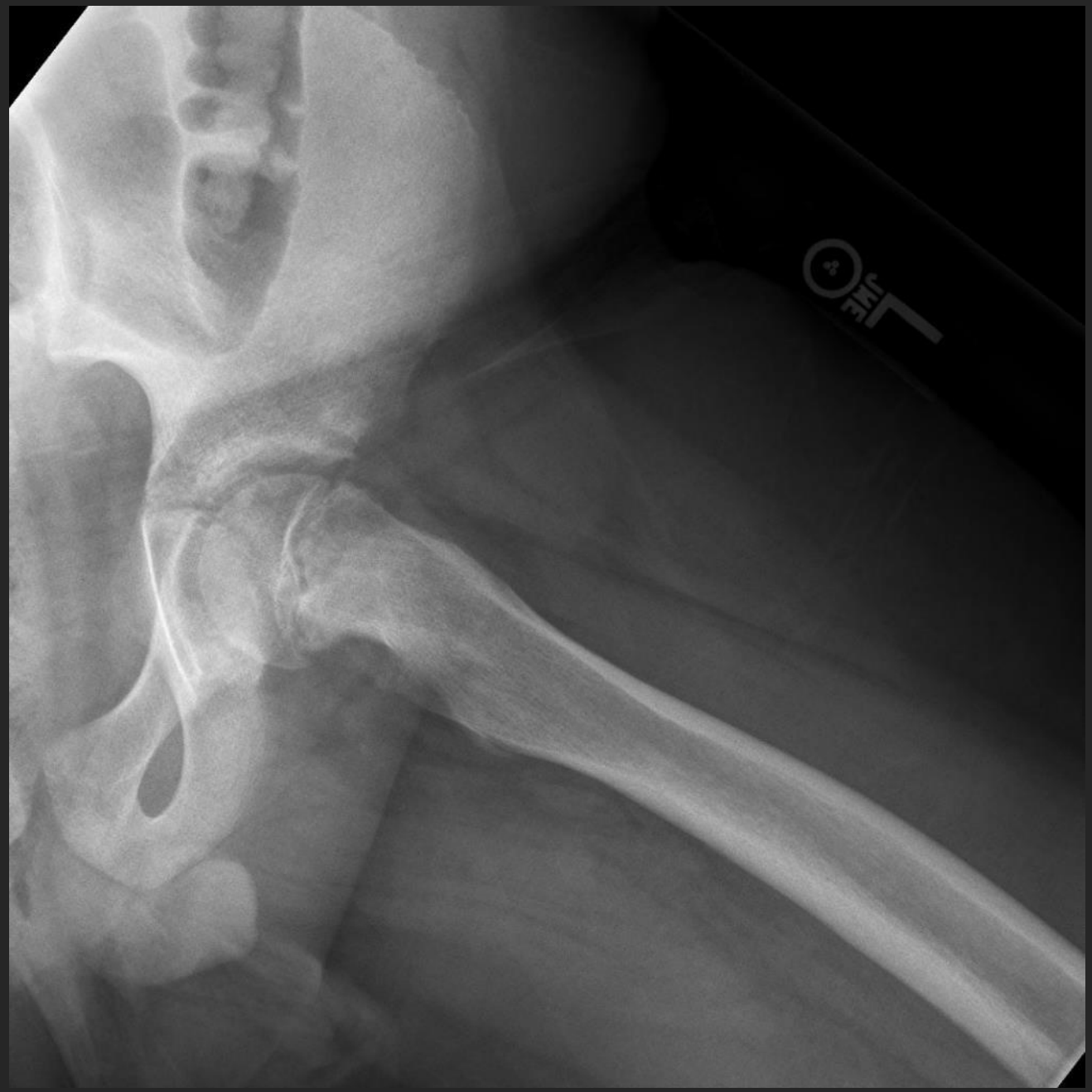
Normal or abnormal?

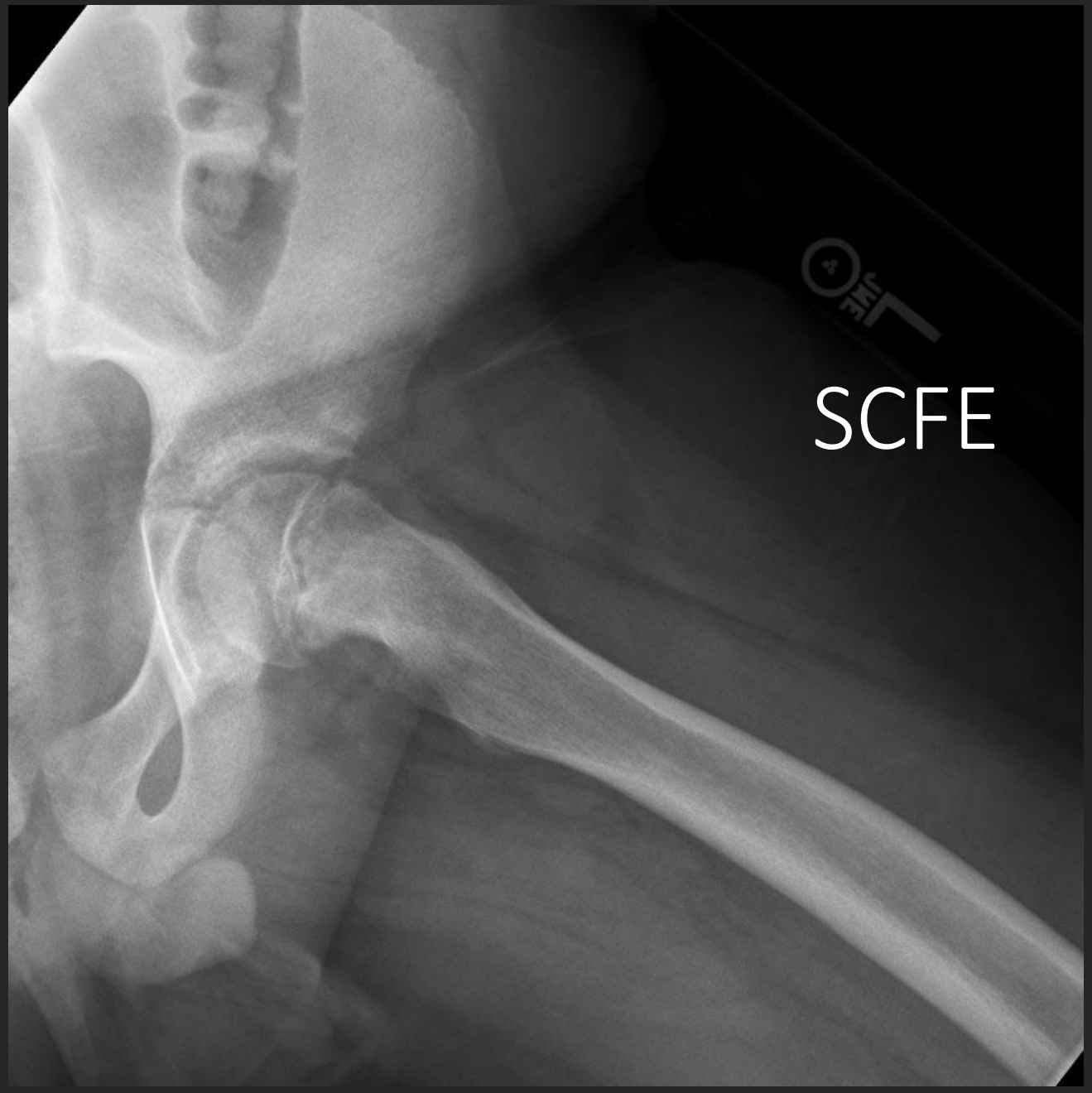




SCFE





SCFE

Normal

Fractures Teens

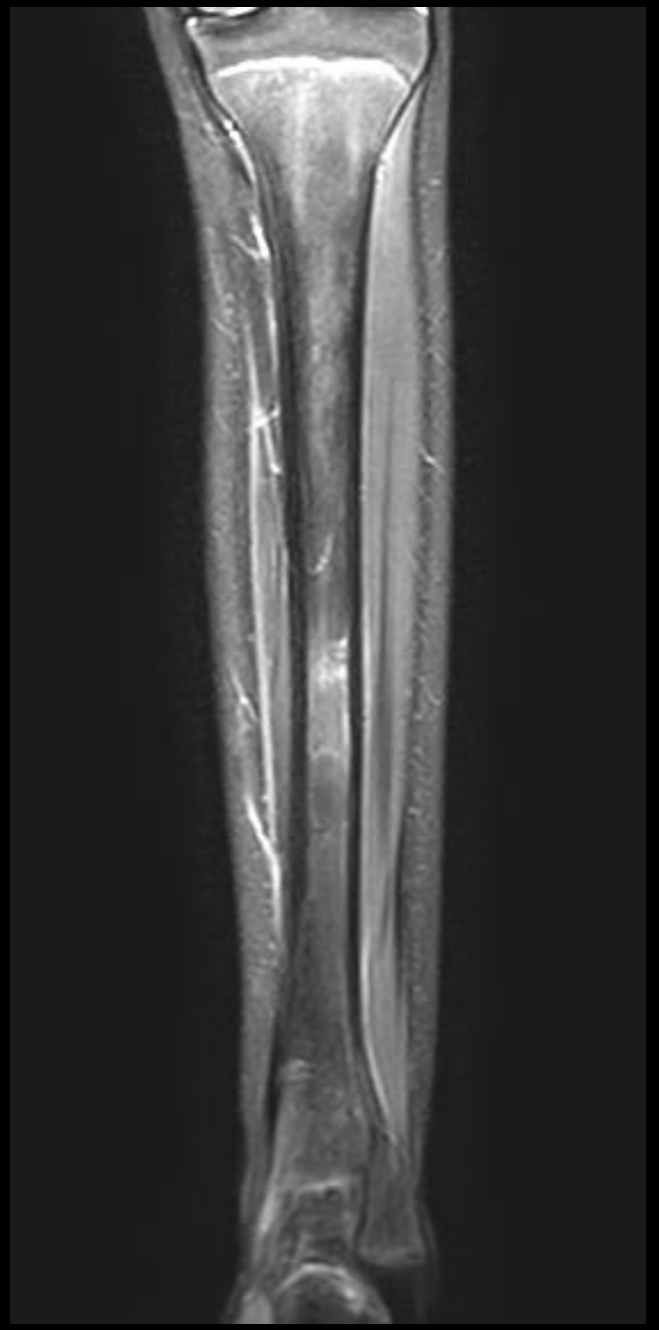
Stress fractures-Teen Athletes

- Epidemiology:
  - Less than 5% of athletes
- Presentation:
  - Insidious
  - Tenderness over fracture site
  - Often a history of rapid increase in activity
- Mechanism of action:
  - Overuse injury with repetitive stress and microfractures
- Risk factors:
  - Runners, dancers, military recruits (10% of recruits)
  - Female, particularly low BMI with female athlete triad
  - BMI >30 also increases risk
  - Low vitamin D (optimal level unknown)
  - Chronic NSAIDs-possible interference with bone remodeling

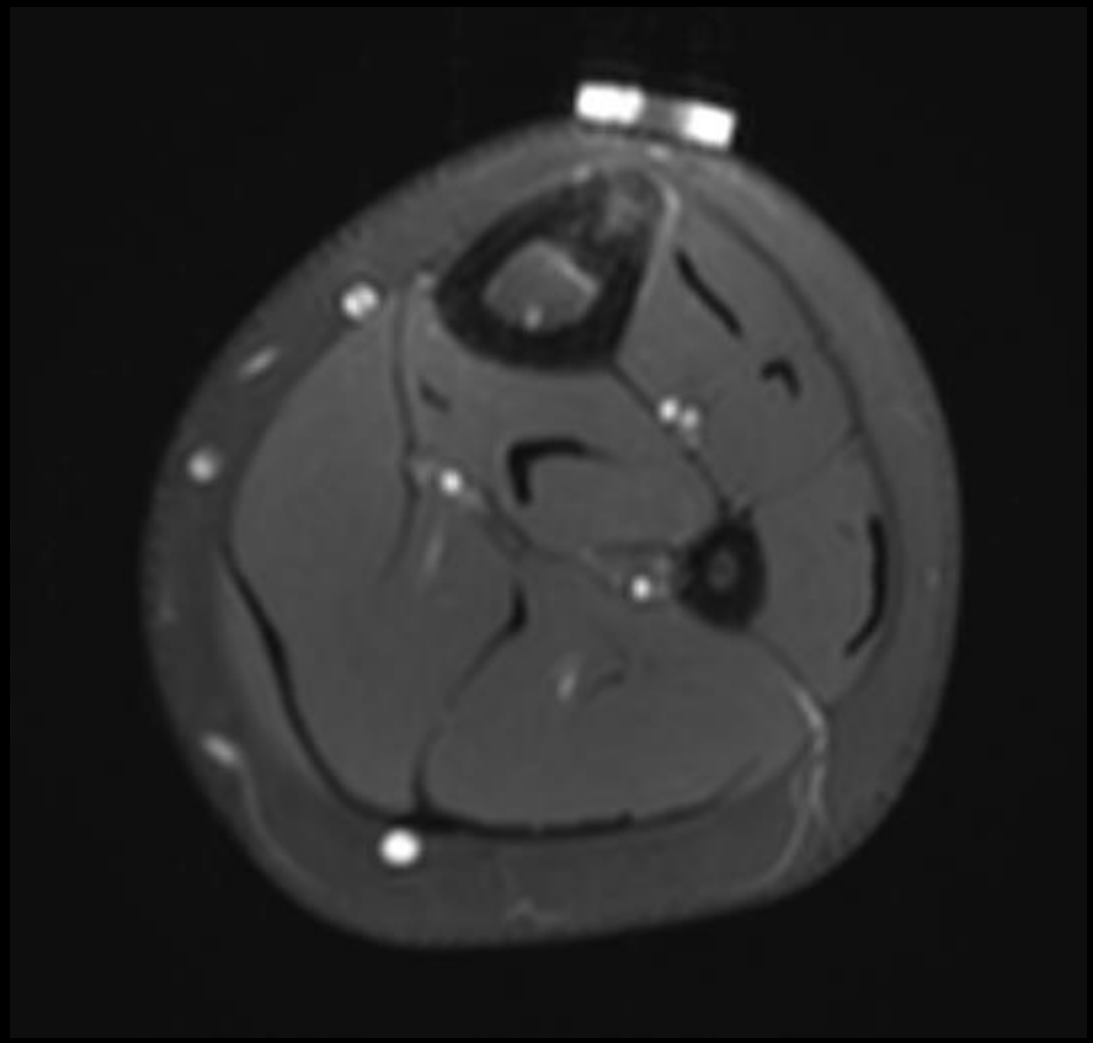
McKean J. Tibial Shaft Stress Fractures. Ortho Bullets. June 5, 2023. Accessed 1/20/25. https://www.orthobullets.com/knee-and-sports/3112/tibial-shaft-stress-fractures
-Schroeder J, Trigt S, Capo Dosal G. Bone Stress Injuries: Diagnosis and Management. Am Fam Physician. 2024;110(6):592-600

Tibia stress fracture

Tibia stress fracture



Tibia stress fracture



- Management
  - Usually conservative:
    - Low risk sites: fibular, posteromedial tibial shaft
      - Activity restriction with protected weight bearing (crutches) to maintain pain at 3/10
      - Gradual return to activity, maintaining pain at 3/10
      - Follow-up every 1-3 weeks
      - Repeating imaging/referral if symptoms >3 months
    - High risk sites: femoral neck, tarsal navicular
      - Refer to sports med/ortho
  - Acetaminophen and ice
    - Avoid NSAIDs-controversial-may delay healing
  - Optimize nutrition

McKean J. Tibial Shaft Stress Fractures. Ortho Bullets. June 5, 2023. Accessed 1/20/25. https://www.orthobullets.com/knee-and-sports/3112/tibial-shaft-stress-fractures
-Schroeder J, Trigt S, Capo Dosal G. Bone Stress Injuries: Diagnosis and Management. Am Fam Physician. 2024;110(6):592-600

Apophyseal Avulsion Fractures

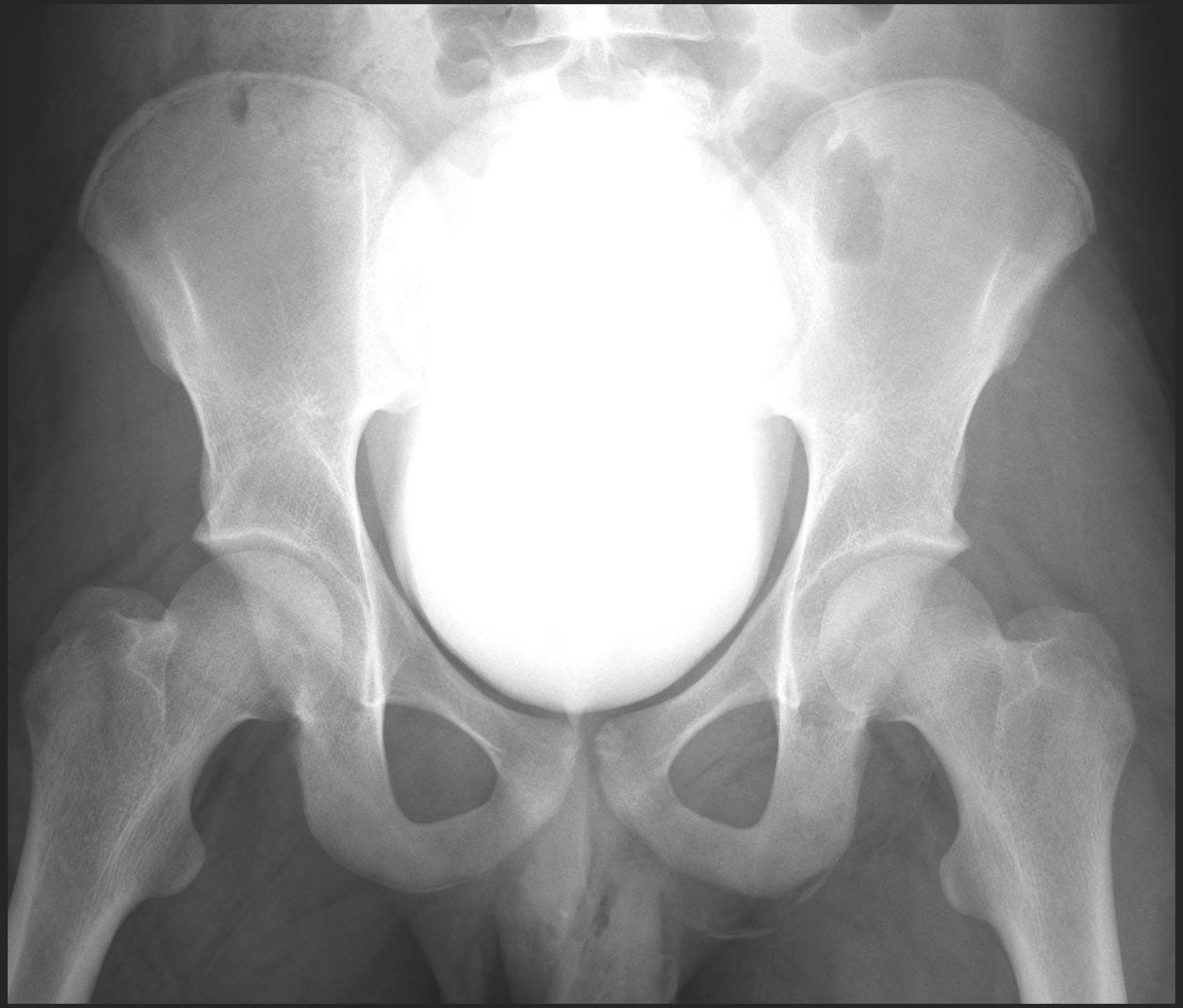
- Epidemiology:
  - Adolescent athletes
    - 14-25
- Mechanism of action
  - Sudden, forceful contraction of muscle attached to the apophysis
  - Kicking sports like soccer, gymnastics and running
- Location:
  - Hip and pelvis
    - Ischial tuberosity-46%
    - Anterior Superior Iliac Spine (ASIS)-32%
    - Super corner of pubic symphysis-12%
    - Iliac crest-11%

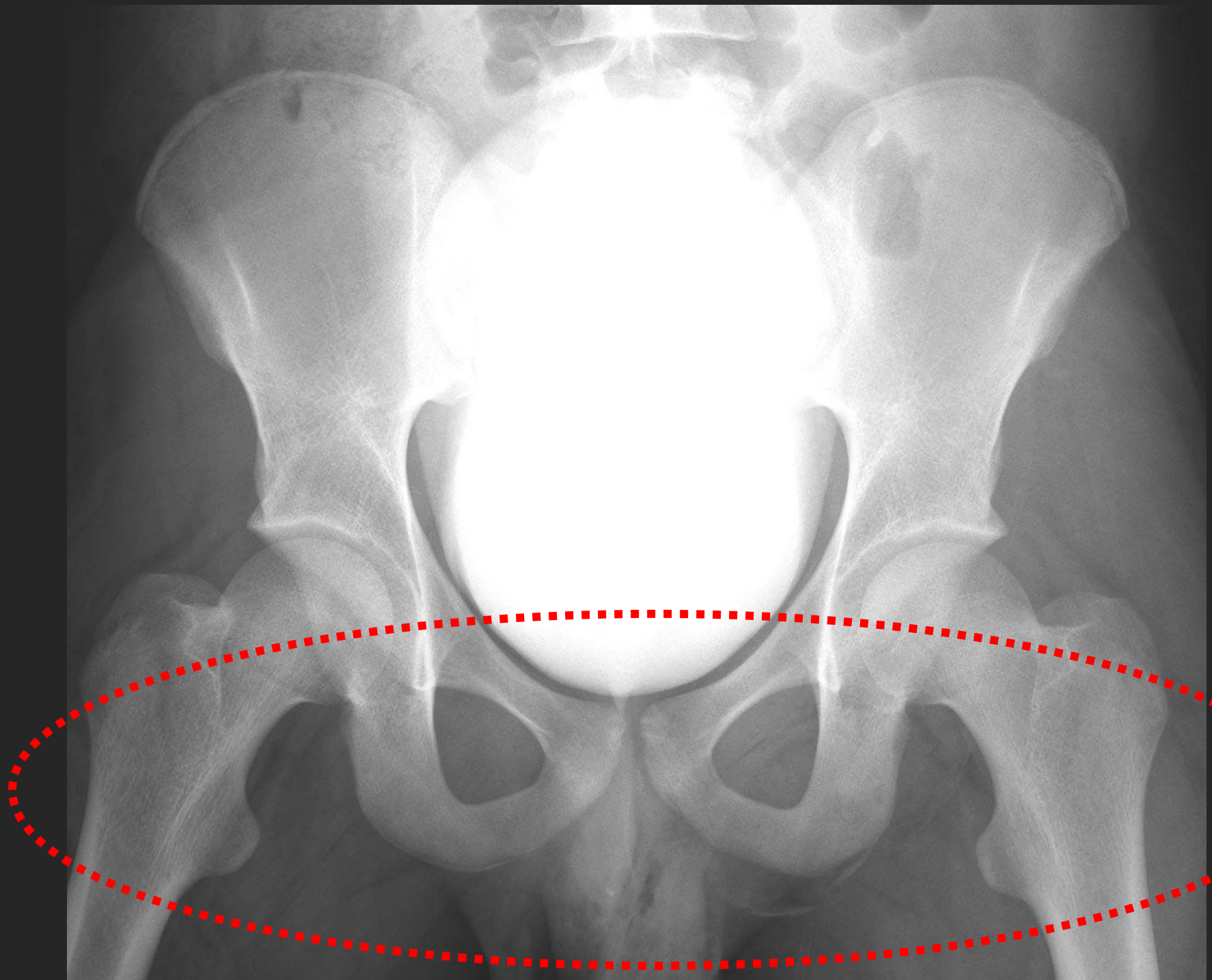
-McKinney BI, Nelson C, Carrion W. Apophyseal avulsion fractures of the hip and pelvis. Orthopedics. 2009 Jan;32(1):42. doi: 10.3928/01477447-20090101-12. PMID: 19226032.
-Porr J, Lucaciu C, Birkett S. Avulsion fractures of the pelvis - a qualitative systematic review of the literature. J Can Chiropr Assoc. 2011 Dec;55(4):247-55. PMID: 22131561; PMCID: PMC3222700.
-Calderazzi F, Nosenzo A, Galavotti C, Menozzi M, Pogliacomi F, Ceccarelli F. Apophyseal avulsion fractures of the pelvis. A review. Acta Biomed. 2018 Nov 15;89(4):470-476. doi: 10.23750/abm.v89i4.7632. PMID: 30657114; PMCID: PMC6502104.

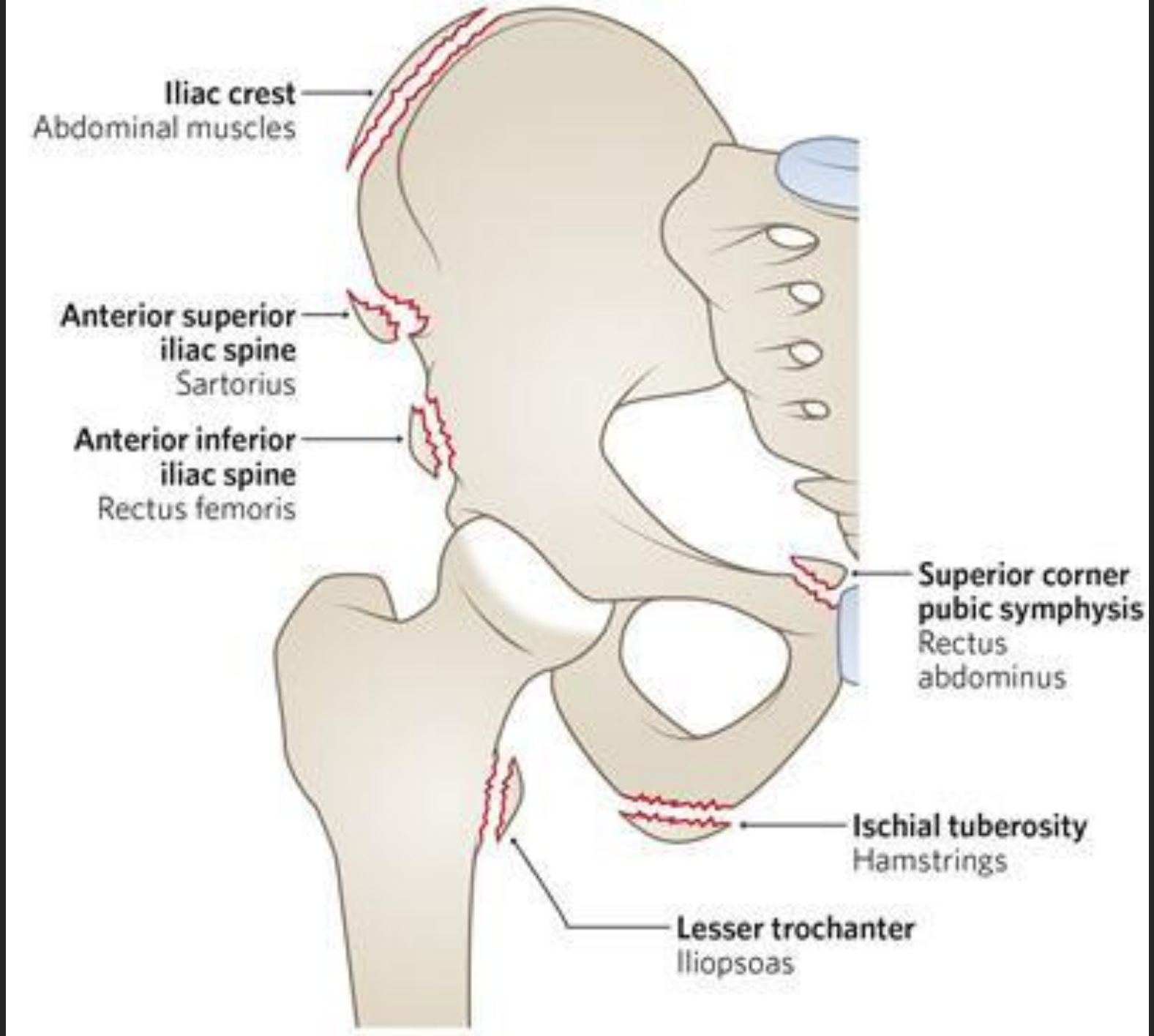
- Presentation
  - Sudden pain during activity, improved with rest
    - Swelling, local tenderness, bruising
  - Weakness
    - Knee, hip, flexion/extension depending on location of fracture

- Management
  - Conservative vs surgical
    - Some controversy about when surgery indicated
      - possibly when >2 cm in size
      - Some indications of improved outcome
    - Conservative: rest and gradual return to activity over 6 weeks

-McKinney BI, Nelson C, Carrion W. Apophyseal avulsion fractures of the hip and pelvis. Orthopedics. 2009 Jan;32(1):42. doi: 10.3928/01477447-20090101-12. PMID: 19226032.
-Porr J, Lucaciu C, Birkett S. Avulsion fractures of the pelvis - a qualitative systematic review of the literature. J Can Chiropr Assoc. 2011 Dec;55(4):247-55. PMID: 22131561; PMCID: PMC3222700.
-Calderazzi F, Nosenzo A, Galavotti C, Menozzi M, Pogliacomi F, Ceccarelli F. Apophyseal avulsion fractures of



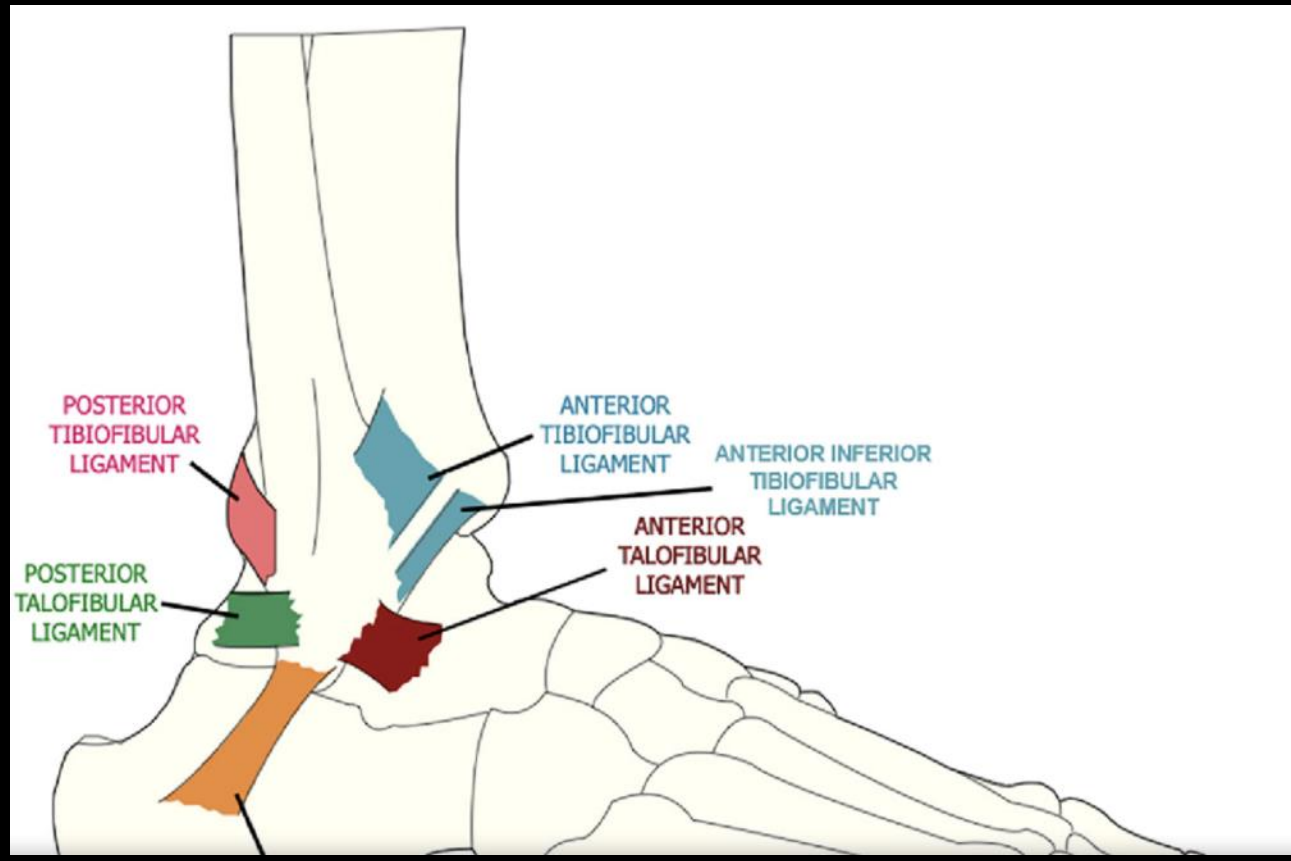




https://www.rch.org.au/clinicalguide/guideline_index/fractures/Pelvic_Avulsion_Injuries_%E2%80%93_Emergency_Department/

Juvenile Tillaux Fracture

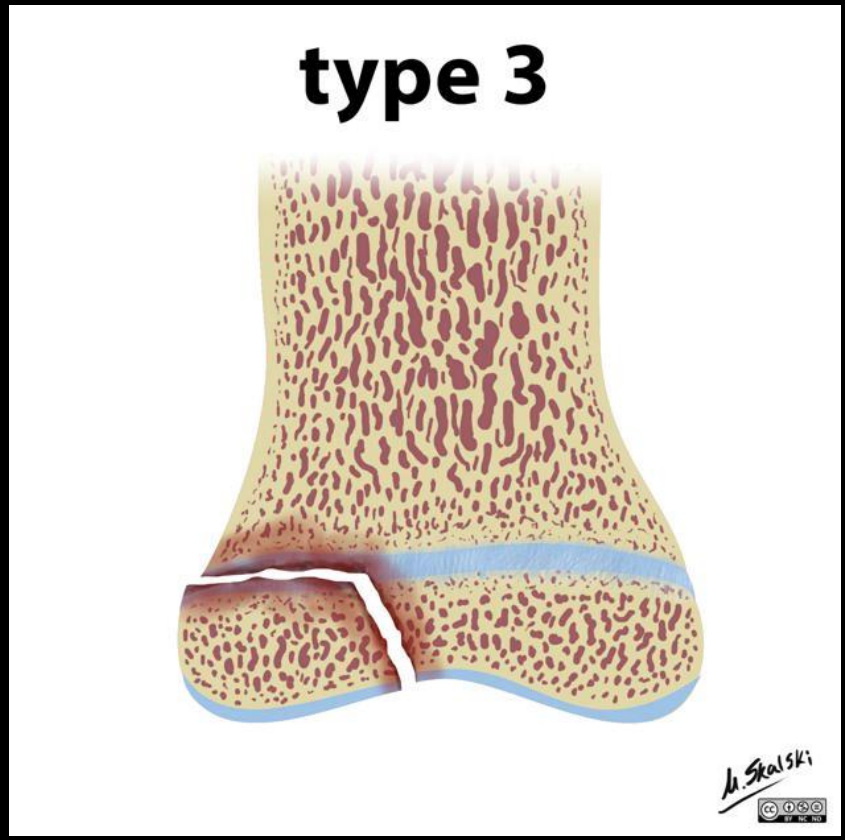
- Epidemiology
  - Age 12-14, rarely in adults
  - Primarily girls
- Incidence
  - 3-5% pediatric ankle fractures
- Etiology:
  - Avulsion of anterior inferior tibiofibular ligament
  - Supination-external rotation injury
    - skating/sliding
- Presentation
  - Pain, inability to bear weight
  - Minimal swelling
  - Tenderness at anterolateral joint line



-Kanal, S., Saif, M., Scher, C.E., & Davis, L.C. (2020). Ultrasound and MRI Evaluation of the Lateral Ankle.
-Ahn L, Williams B. Tillaux Fractures. Ortho Bullets. Feb 19, 2022. Accessed 1/23/25. https://www.orthobullets.com/pediatrics/4028/tillaux-fractures
-Habusta SF, Ponnarasu S, Mabrouk A, et al. Tillaux Fracture. [Updated 2023 Apr 22]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK482332/

Juvenile Tillaux Fracture

- Salter Harris III
- Anterolateral distal tibia epiphysis
- Physeal closure pattern: central > anteromedial > posteromedial > lateral
- Best seen on mortise view

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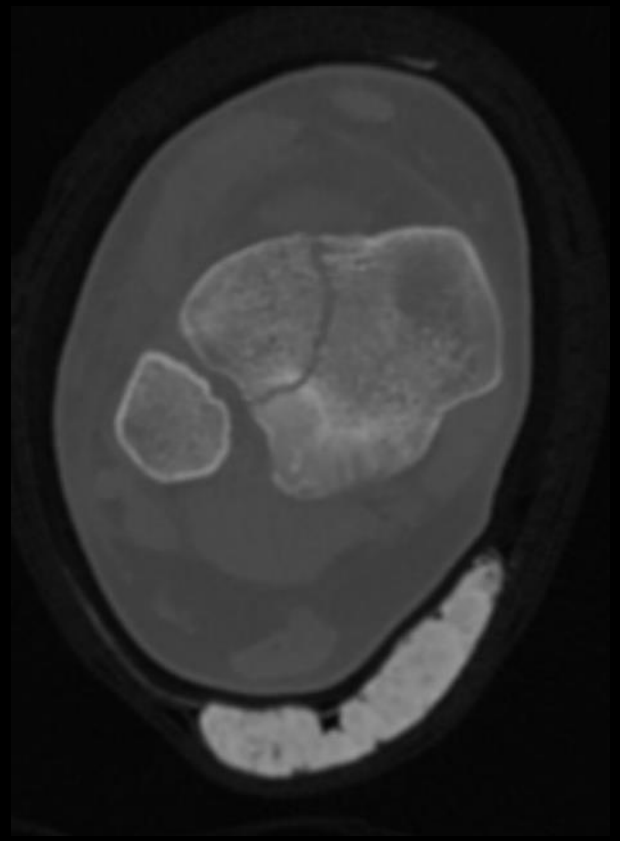
PO



Juvenile Tillaux Fracture

- Treatment:
  - Non-operative: closed reduction and casting with <2 mm remaining displacement
  - Operative: Indicated if >2 mm remaining displacement remains after reduction

-Ahn L, Williams B. Tillaux Fractures. Ortho Bullets. Feb 19, 2022. Accessed 1/23/25. https://www.orthobullets.com/pediatrics/4028/tillaux-fractures
--Habusta SF, Ponnarasu S, Mabrouk A, et al. Tillaux Fracture. [Updated 2023 Apr 22]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from:

Triplane Ankle Fracture

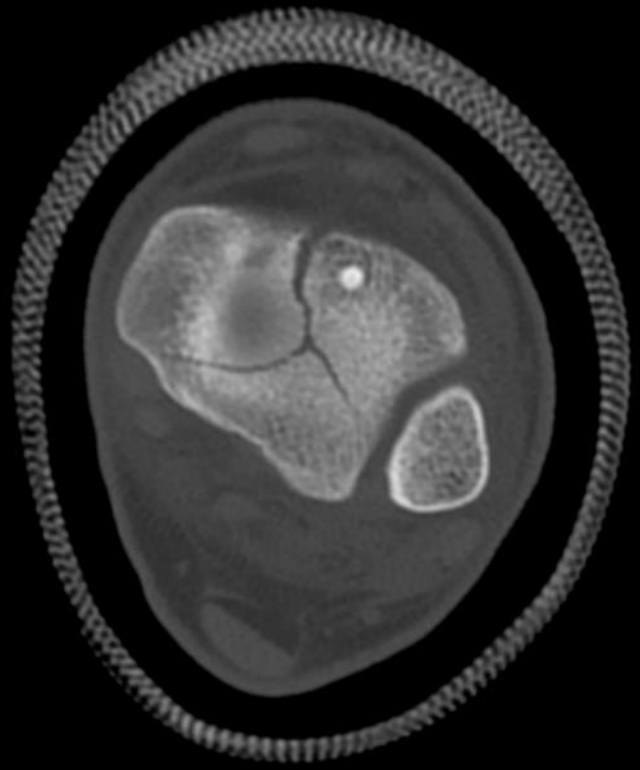
- Epidemiology:
  - Age 10-17
  - More common in males
- Incidence:
  - 5-15% of pediatric ankle fractures
- Etiology:
  - Supination-external rotation injury
- Presentation:
  - Pain, focal tenderness, inability to bear weight, deformity, swelling, bruising

-Ahn L, Williams B. Triplane Fractures. OrthoBullets. June 27, 2023. Accessed 1/23/25. https://www.orthobullets.com/pediatrics/4029/triplane-fractures
-Shamrock AG, Varacallo MA. Triplane Ankle Fracture. [Updated 2023 Aug 4]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK547737/

Triplane Ankle Fracture

- Salter Harris IV
- Classic triplane pattern:
  - Coronal fracture plane through posterior distal tibial metaphysis & diaphysis
  - Transverse fracture plane through physis
  - Sagittal fracture plane through epiphysis
- Fibula fracture in 50%


A
GLH



Triplane Fracture

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  - Operative: Indicated if >2 mm remaining displacement remains after reduction

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-Shamrock AG, Varacallo MA. Triplane Ankle Fracture. [Updated 2023 Aug 4]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK547737/

Infectious/Inflammatory

Osteomyelitis

- Etiology
  - Hematogenous bacterial spread to metaphysis
    - *Staph aureus* (MRSA or MSSA), *strep pyogenes* (group A), *strep pneumoniae*
    - *Haemophilus influenzae* rare due to vaccination
    - *K kingae* (Gram negative) common <age 3
    - *Salmonella* should be considered in children with underlying hemoglobinopathies (often multifocal/symmetric)
    - No organism found in 55%
  - Contiguous spread less common (i.e. adjacent septic arthritis)
  - Direct inoculation (i.e. trauma or procedures)

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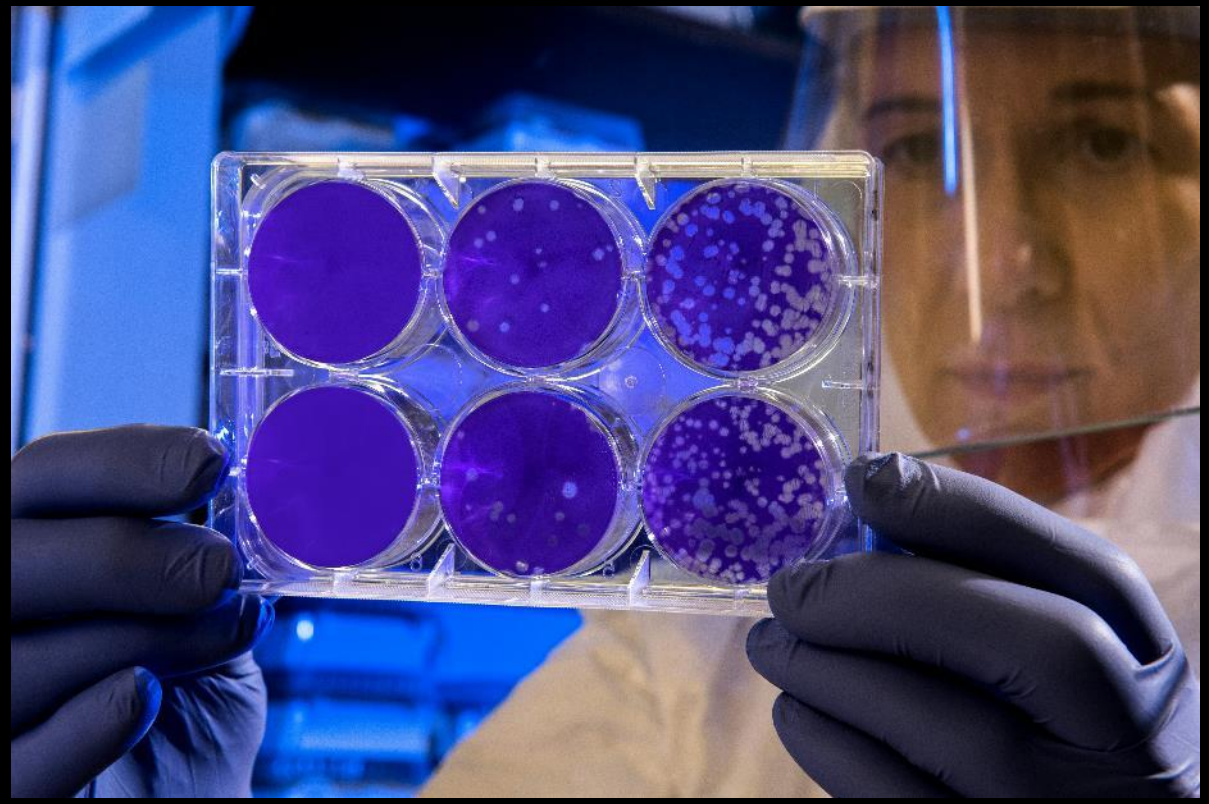
-Abuali M. Osteomyelitis. Quick References (2023) https://doi.org/10.1542/aap.ppcqr.396206

- Epidemiology:
  - 1.2-1.3 per 100,000 people (children and adults)
  - Half of cases <5 years old
  - Boys affected twice as often after age 1
  - Long bones primarily affected-femur then tibia
    - 10-25% of infections in short bones (i.e. pelvis/vertebrae)
    - 5% in multiple bones
- Risk Factors:
  - Trauma
  - Hardware
  - Young age-vessel anatomy
  - Hemoglobinopathies (i.e. sickle cell)
  - Immunocompromised
  - Preterm



-Abuali M. Osteomyelitis. Quick References (2023)
https://doi.org/10.1542/aap.ppcqr.396206

- Presentation
  - Fever
  - Limp, pain (can be referred), refusal to bear weight, decreased range of motion
  - Exam: subtle warmth, erythema, swelling. Focal tenderness often out of proportion to exam
  - Irritability in young age
- Differential
  - Very broad

-Abuali M. Osteomyelitis. Quick References (2023)
https://doi.org/10.1542/aap.ppcqr.396206

- Management:
  - High index of suspicion should prompt lab and imaging evaluation
    - Blood cultures before antibiotics
    - CBC, ESR, CRP limited utility, but CRP most useful
  - Antibiotics
    - Empiric therapy to cover Staph/Strep, neonates include GBS/gram negative coverage, H flu in unvaccinated patients, salmonella with sickle cell
  - +/- Surgery-consult ortho inpatient

-Abuali M. Osteomyelitis. Quick References (2023) https://doi.org/10.1542/aap.ppcqr.396206

40 Inch SID
70kvp@3.2mas
resus


40 Inch SID
70kvp@3.2mas
resus
R
CM


R
EAH

Post-traumatic/post-surgical osteomyelitis


R
OD
PORTABLE
SUPINE


R
HEO


R
HEO


L
EEF
11.1mm[proj]
L

Chronic Recurrent Multifocal Osteomyelitis (CRMO) aka non-infectious osteomyelitis

- Etiology
  - Autoinflammatory disease
  - Sterile chronic nonbacterial osteitis
- Epidemiology
  - Ages 7-10
  - Twice as common in females
  - Can be associated with other autoimmune diseases
- Incidence
  - 4 per million children
- Presentation:
  - Unifocal or multifocal osteolytic/osteosclerotic lesions
  - +/- inflammatory/systemic features
    - Can mimic osteomyelitis and osteosarcoma
  - Chronic, intermittent painful flares into adulthood

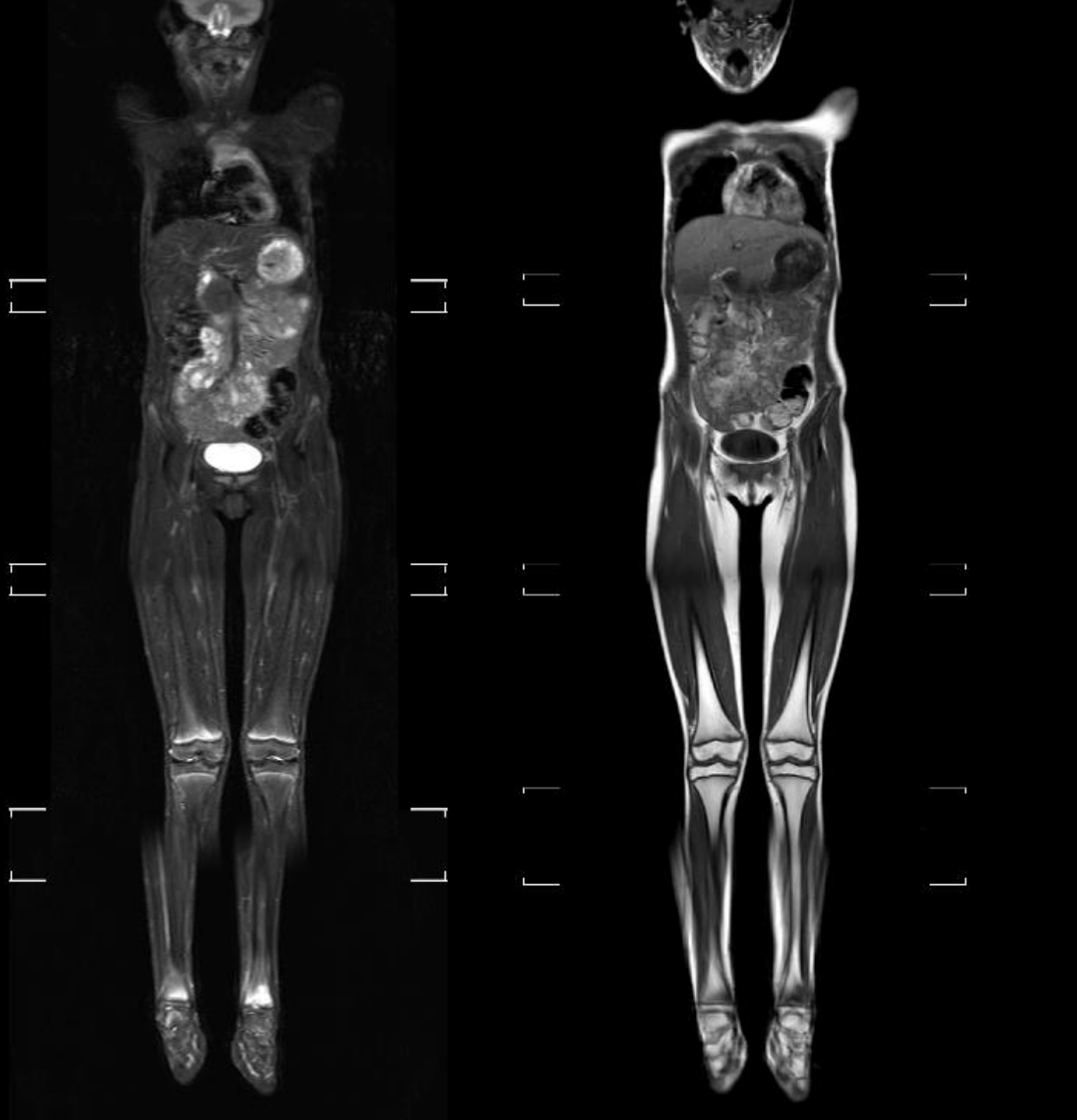
Huynh K et al. Chronic Recurrent Multifocal Osteomyelitis Involving the Spine, Sternum and Lower Extremities: A Case Report. Pediatrics (2024) 154 (4): e2024067527. https://doi.org/10.1542/peds.2024-067527

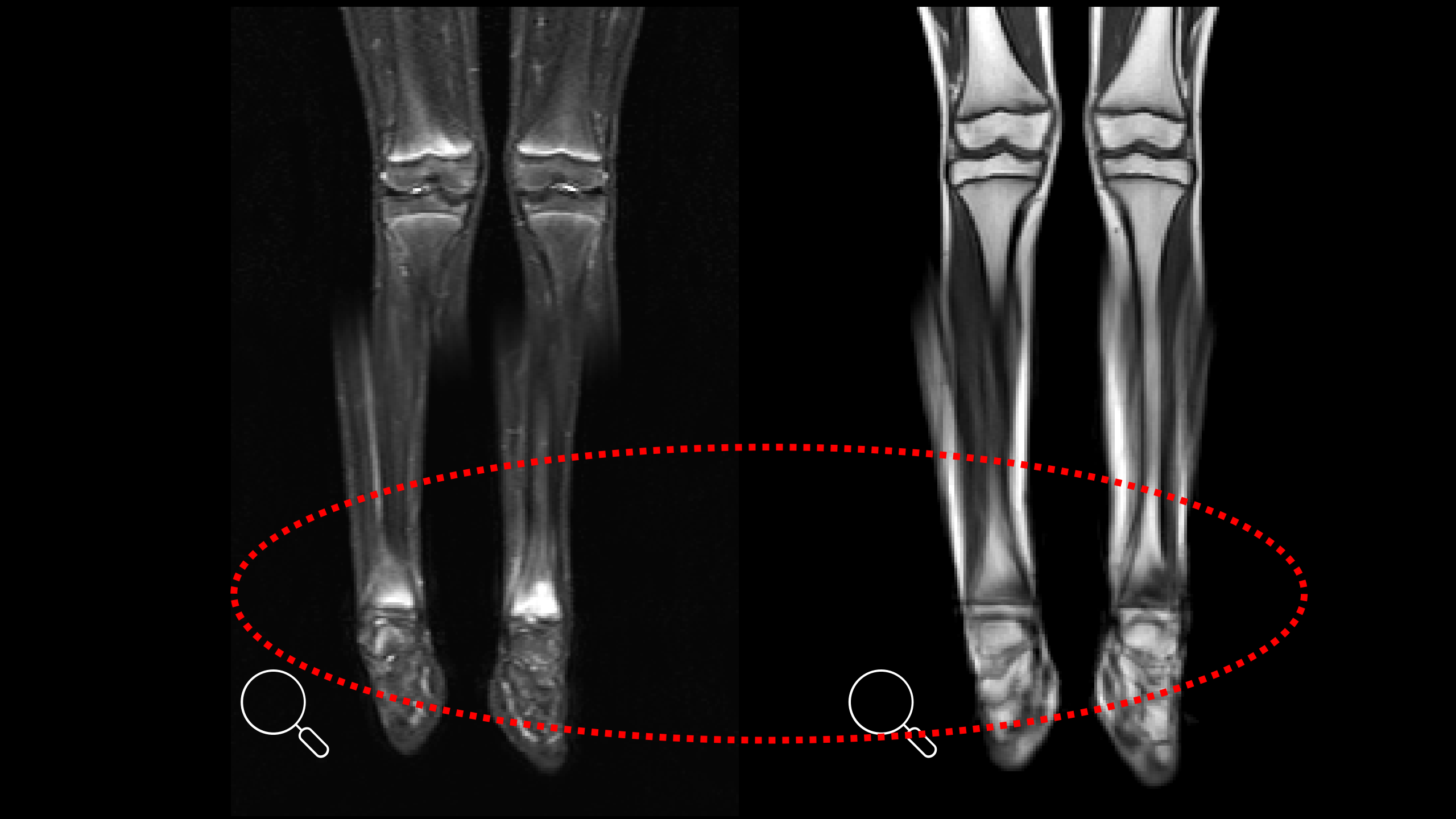
Chronic Recurrent Multifocal Osteomyelitis (CRMO) aka non-infectious osteomyelitis

- Diagnosis of exclusion
- Management
  - No structural/vertebral involvement (60% remission)
    - NSAIDs first line therapy
    - Biologics
  - Vertebral/jaw involvement/refractory
    - Bisphosphanates
- Untreated:
  - Risks of pathologic fractures, chronic pain, MSK deformity

Huynh K et al. Chronic Recurrent Multifocal Osteomyelitis Involving the Spine, Sternum and Lower Extremities: A Case Report. Pediatrics (2024) 154 (4): e2024067527. https://doi.org/10.1542/peds.2024-067527

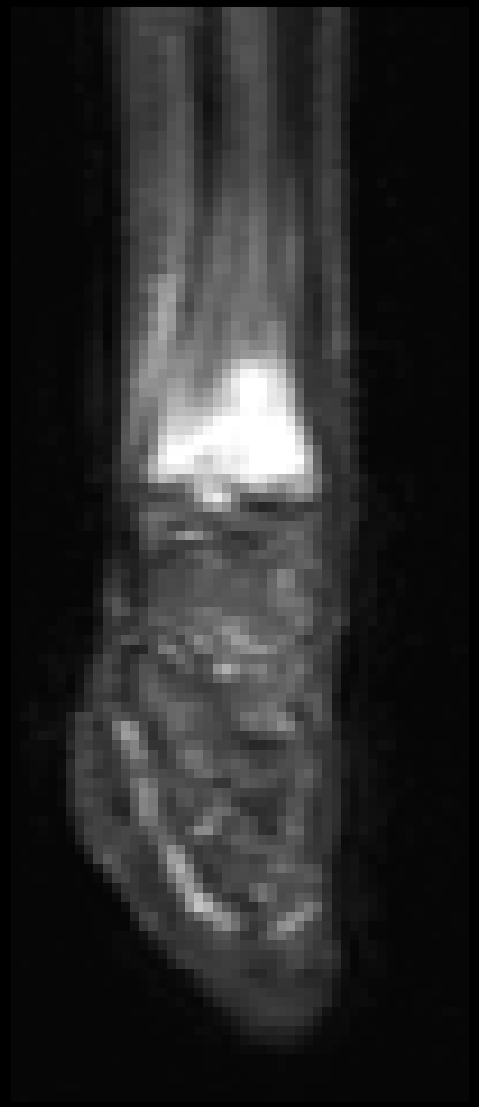
CRMO
a.k.a CNO





Why MRI for CRMO?

Why MRI for CRMO?




Oncologic

Leukemia

- Epidemiology:
  - 30% of childhood cancers
    - Acute lymphoblastic leukemia (ALL)-80%
    - Acute myelogenous leukemia (AML)-18%
    - Chronic myelogenous leukemia (CML)-least common, primarily adolescents
- Common Presentation:
  - Bone pain, limp, leg/back pain, headache, symptoms of anemia/thrombocytopenia, abnormal CBC, B symptoms

-Kaplan, J. Leukemia in Children. Pediatr Rev (2019) 40 (7): 319–331. Accessed 1/5/25. https://doi.org/10.1542/pir.2018-0192
-Chennamadhavuni A, Lyengar V, Mukkamalla SKR, et al. Leukemia. [Updated 2023 Jan 17]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK560490/
Accessed 15/25

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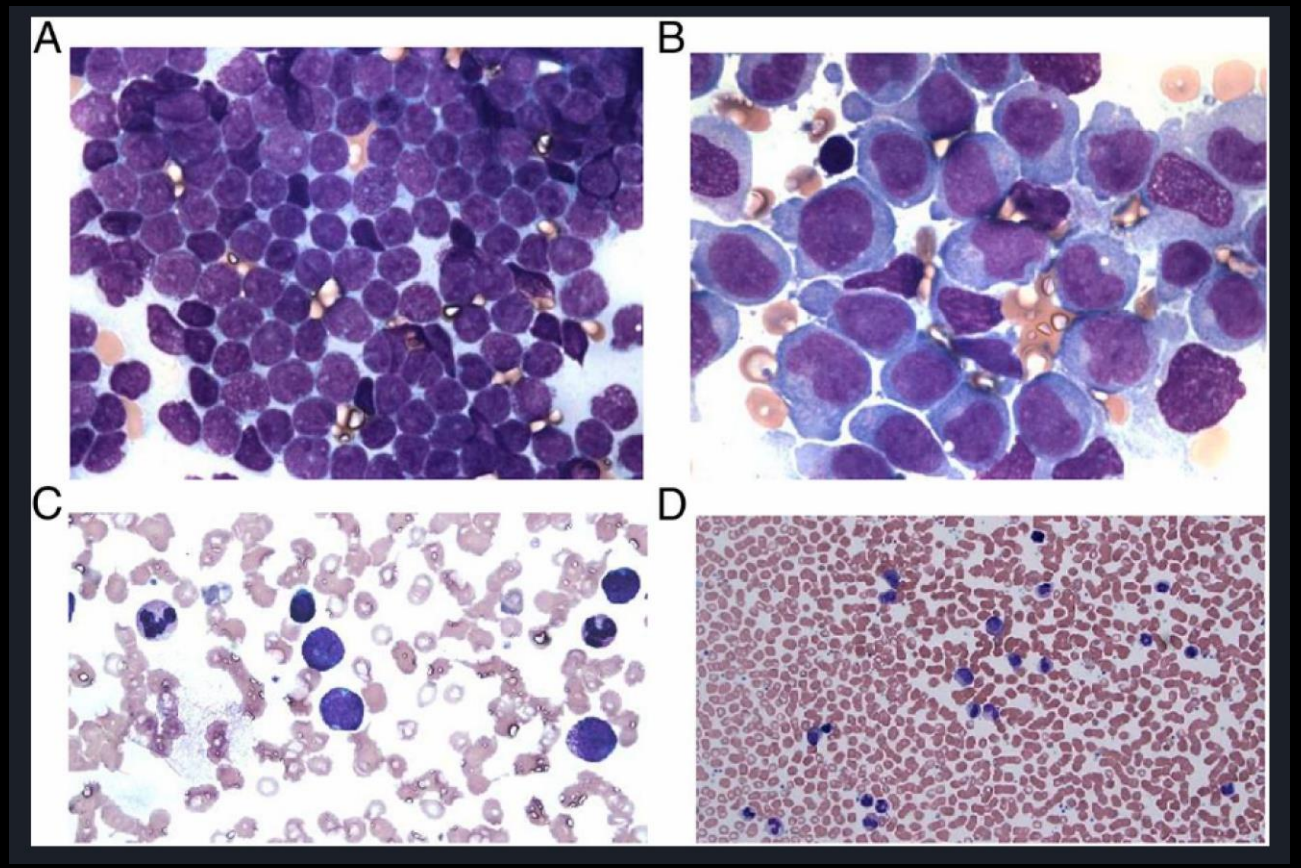
- Risk factors
  - Ionizing radiation
  - Chemo for other cancer
  - Benzene-chronic exposure-AML
  - Monozygotic twins 10-15% concordance
  - Down syndrome (15x), Klinefelter, Fanconi syndrome
  - Obesity
  - Hepatitis C-CLL
  - Another leukemia-30% of patients with myelodysplastic syndrome develop 2nd leukemia
  - NOT hair dye
- Work-up:
  - CBC with differential
    - Blasts=Bad
  - CMP, coag studies
    - Greater number of cell lines affected increases concern for leukemia
  - Imaging
  - Bone marrow biopsy

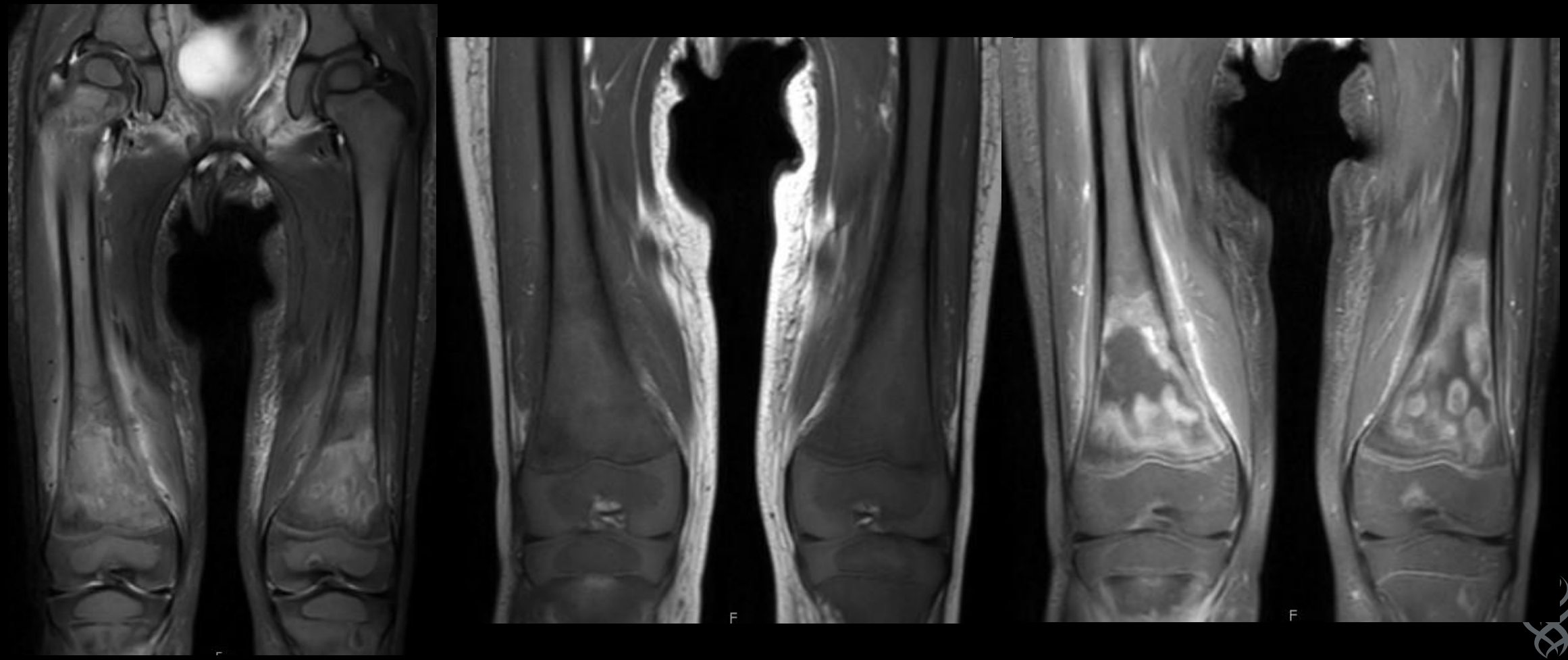


-Kaplan, J. Leukemia in Children. Pediatr Rev (2019) 40 (7): 319–331. Accessed 1/5/25. https://doi.org/10.1542/pir.2018-0192
-Gbenjo J, McCrary G, Wilson S. Leukemia: What Primary Care Physicians Need to Know. *Am Fam Physician. Volume 107, Number 4. April 2023*

- Differential:
  - Overlapping presenting symptoms with many common chief concerns—have a high index of suspicion and low threshold for CBC with diff
- Management:
  - Oncology referral
  - Do not typically present with fractures or need orthopedics

-Kaplan, J. Leukemia in Children. Pediatr Rev (2019) 40 (7): 319–331. Accessed 1/5/25. https://doi.org/10.1542/pir.2018-0192

Leukemia



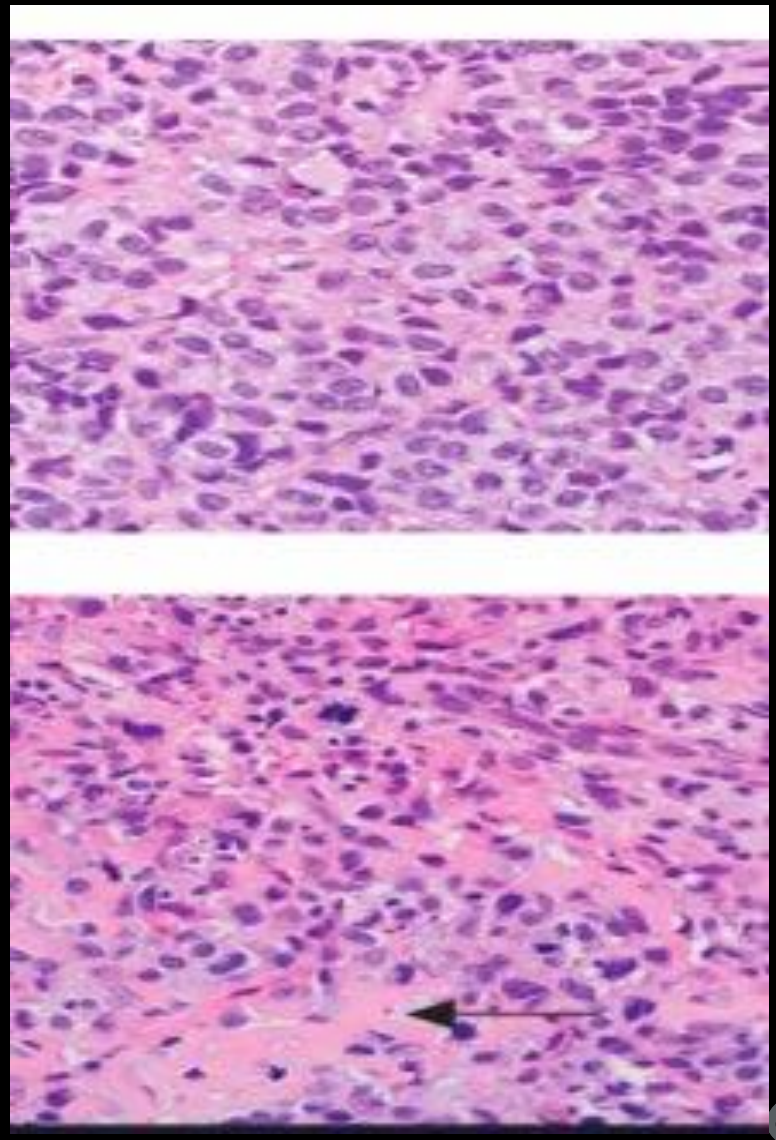
Leukemia: treatment complication

Primary Bone Cancers

- Epidemiology
  - Both osteosarcoma/Ewing slightly more predominant in males at 55% of cases
  - 800 cases per year, about 4% of pediatric cancers
    - 0-14: 450 cases (rare in ages 0-4)
    - 15-19: 350 cases
    - Second peak age >65, often with Paget's disease
- Presentation:
  - Non-specific pain/swelling at primary disease site
  - Pain often with activity or after sports injury, which can complicate diagnosis
  - Can also have pain at rest or at night

Self, C. Osteosarcoma/Ewing Sarcoma. Pediatr Rev (2022) 43 (5): 256–265. https://doi.org/10.1542/pir.2021-005065

- Risk Factors:
  - Environmental factors (i.e. Ionizing radiation)
  - Genetic factors
  - Most arise spontaneously
  - Ewing
    - In children, higher rate in African, Hispanic ancestry
  - Osteosarcoma
    - 9x more prevalent in European descent, much lower in African descent



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Pediatr Rev. 2022;43(5):256-265. doi:10.1542/pir.2021-005065

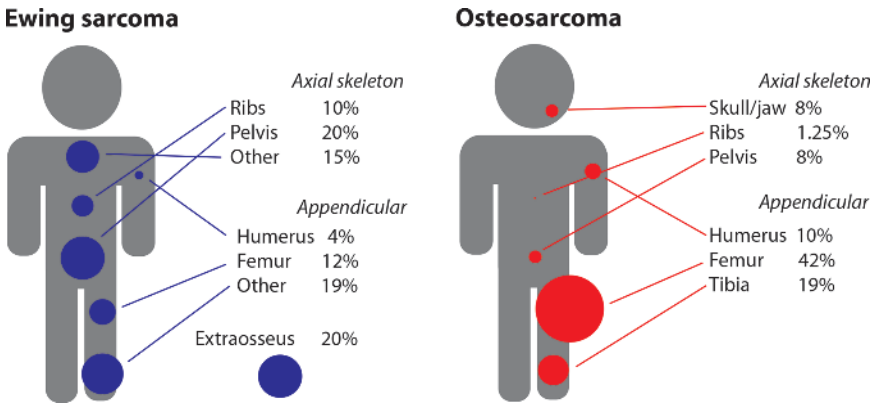

Figure Legend:

Sites of disease involvement.

- Work up:
  - High index of suspicion
    - Particularly: Pain that is persistent day/night, weeks-months, not associated with trauma/activity
  - Labs
    - BMP, CBC with diff, LFTs usually normal
    - LDH and alk phos often elevated
  - Imaging
- Management:
  - Medical and surgical oncology
    - Osteosarcoma
      - Neoadjuvant chemo with methotrexate, doxorubicin (Adriamycin), cisPlatin
      - Surgery
      - Adjuvant chemo
    - Ewing
      - Neoadjuvant chemo
      - Surgery or radiotherapy
      - Adjuvant chemo

Self, C. Osteosarcoma/Ewing Sarcoma. Pediatr Rev (2022) 43 (5): 256–265. https://doi.org/10.1542/pir.2021-005065

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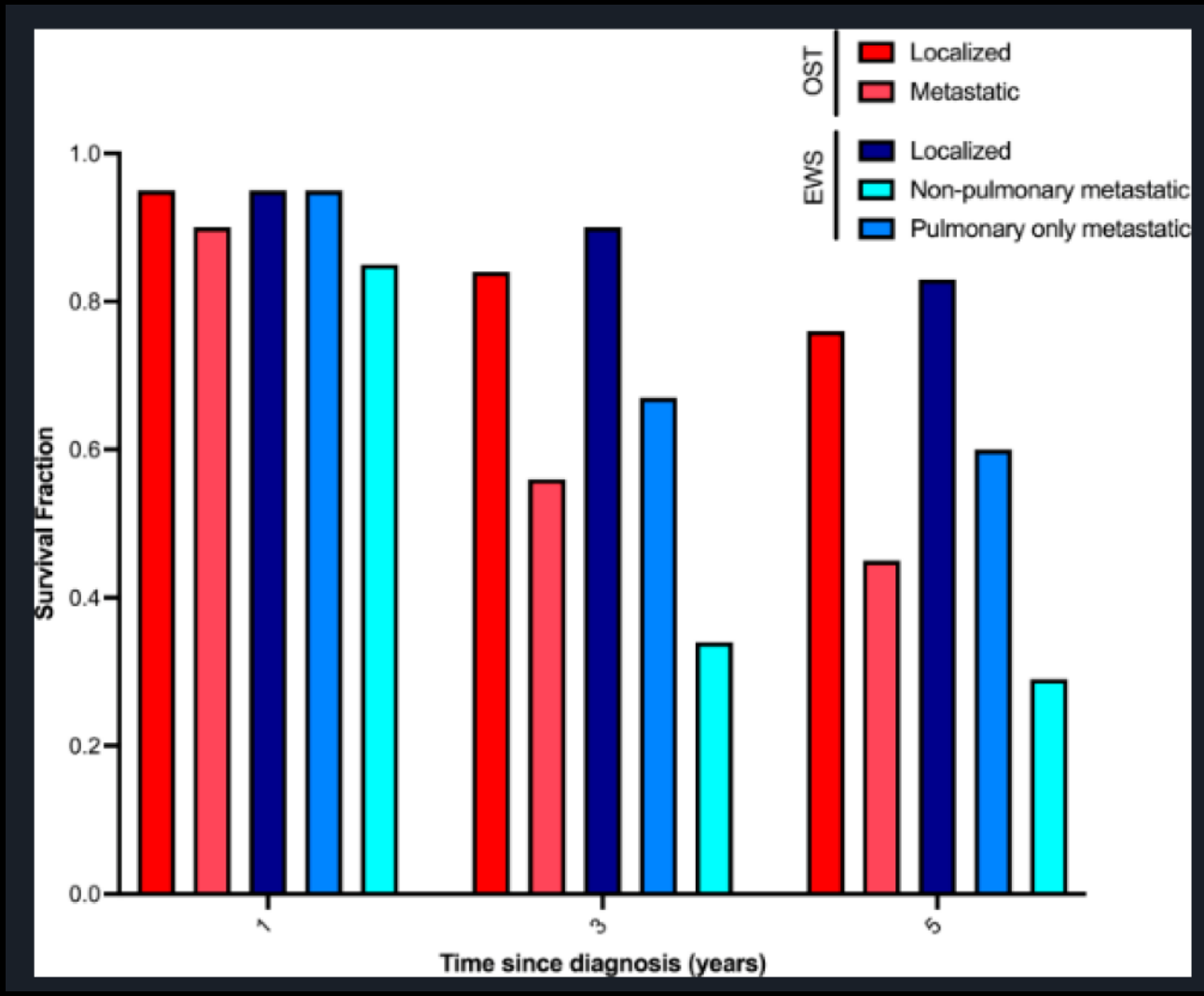
- Prognosis, 5 year survival
  - Osteosarcoma
    - Localized/completely resectable- 70%
    - Unresectable/metastatic about 45%
  - Ewing
    - Localized, >80%
    - Non-pulmonary metastatic, about 30%
    - Pulmonary only metastatic, about 60%



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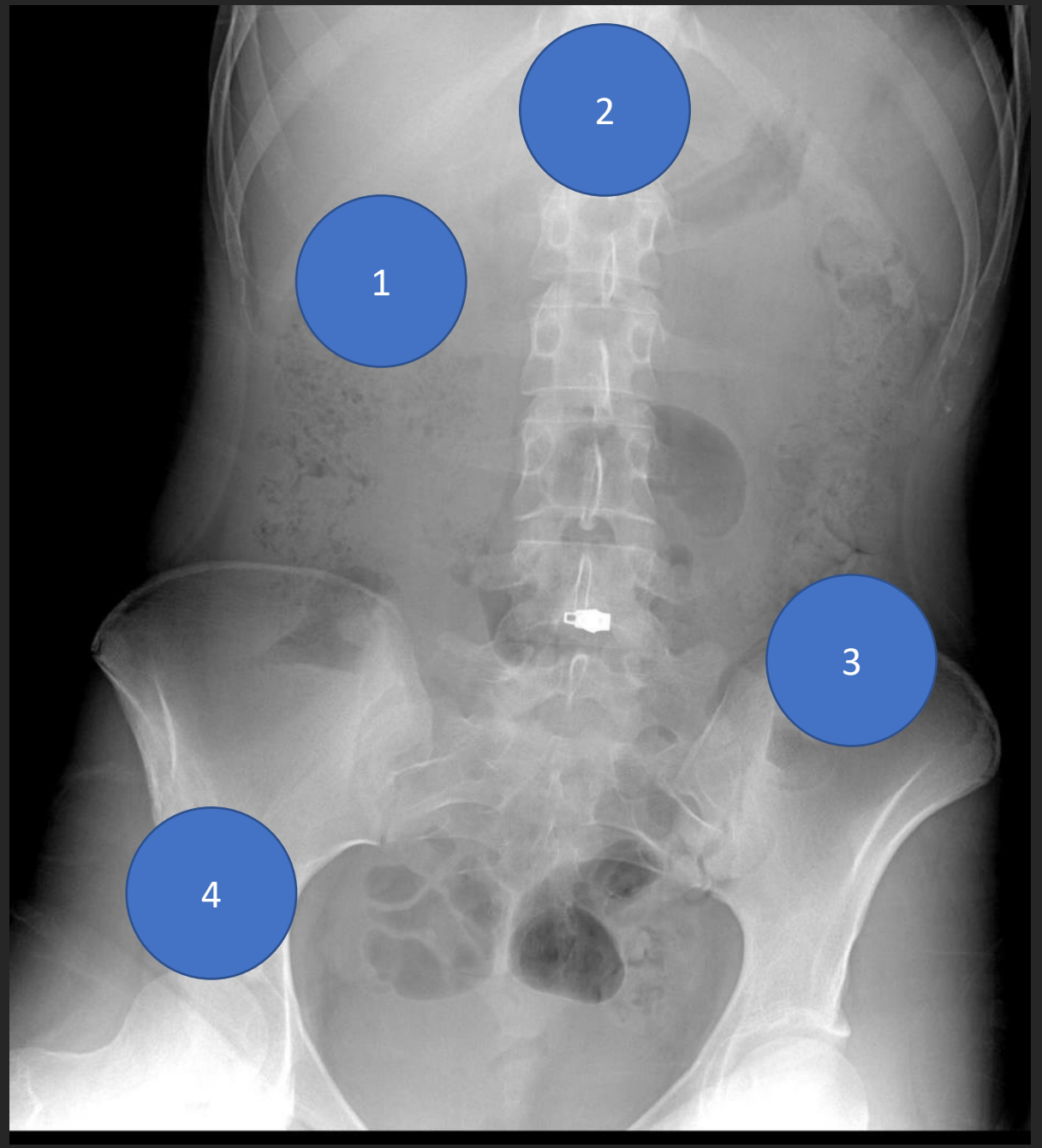
2
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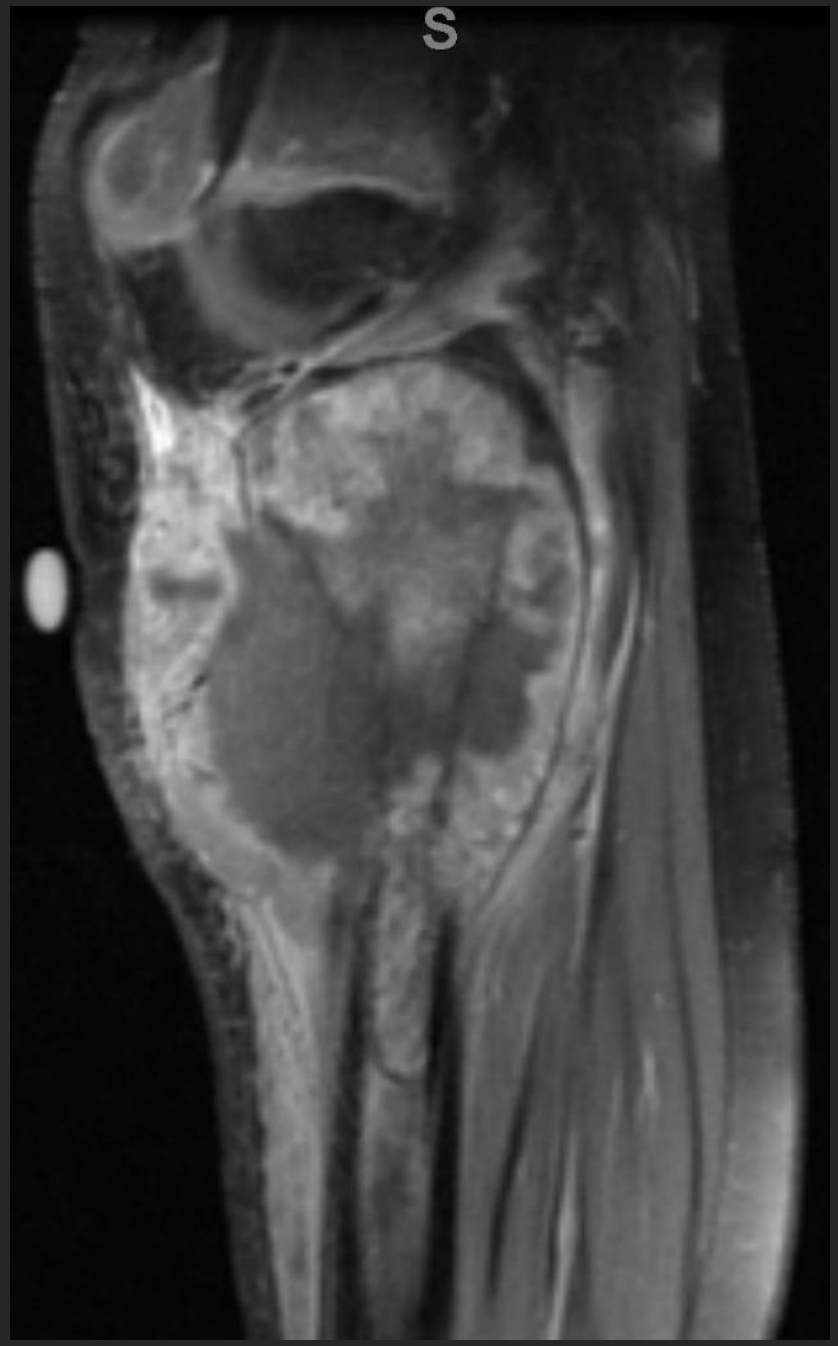
4

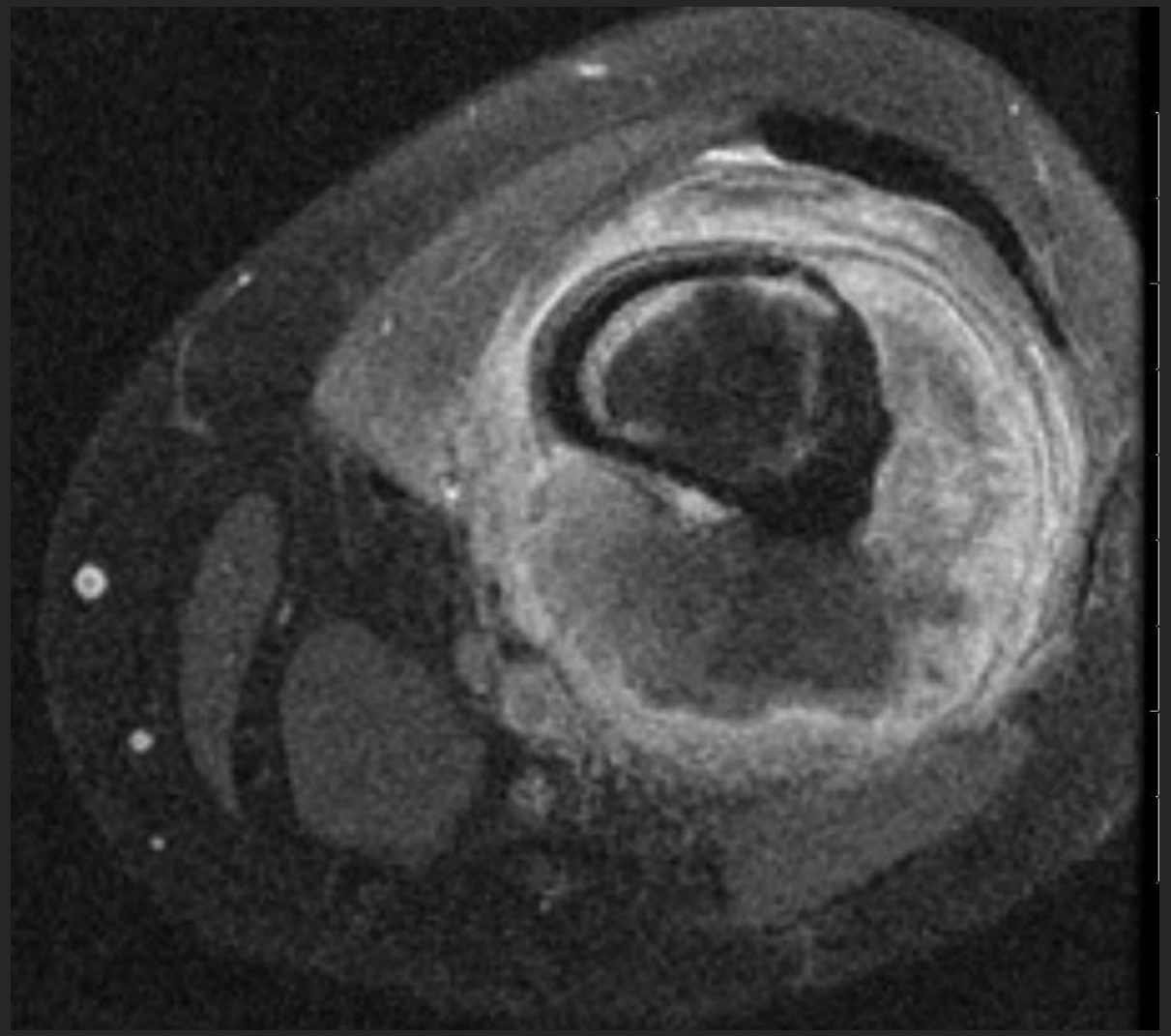
Ewings Sarcoma

- Permeative lesion
- Codman’s triangle – aggressive periosteal reaction
- Metaphyseal long bone

Osteosarcoma



Osteosarcoma



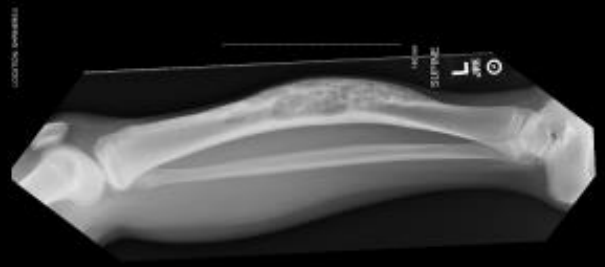
Both Osteosarcoma

Bone

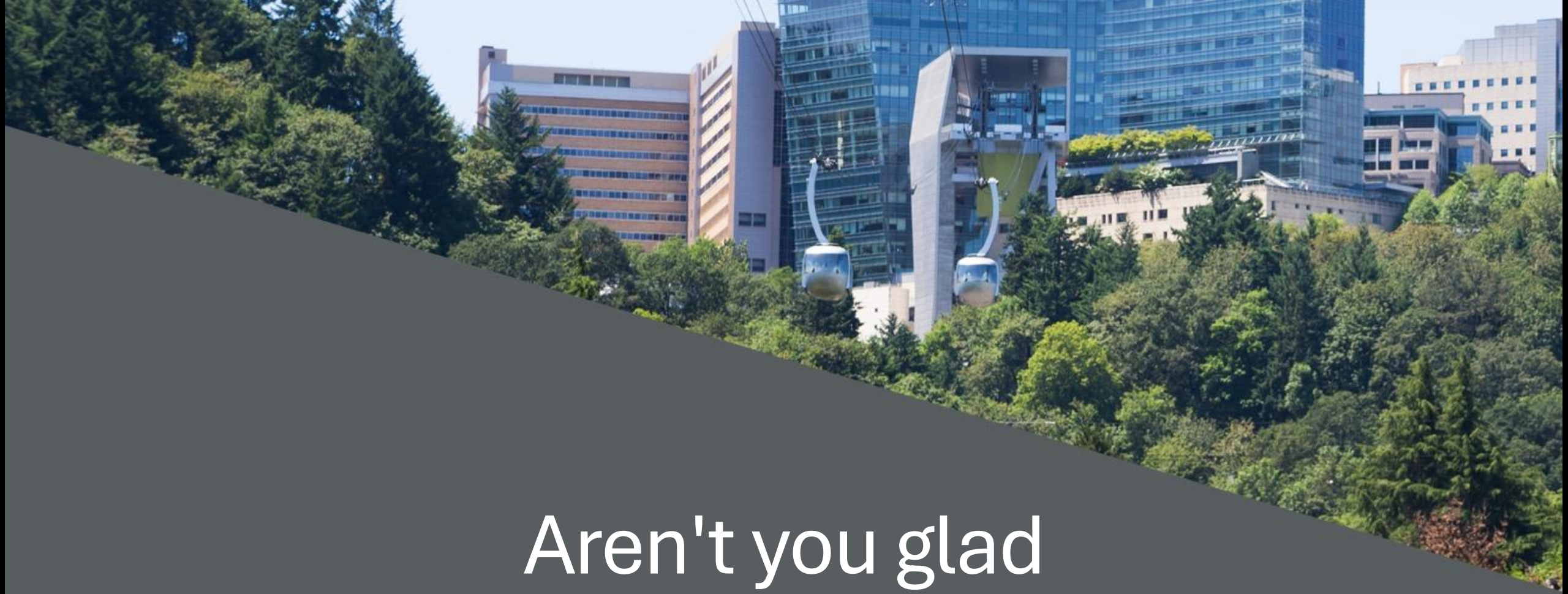
Cartilage

Fibrous

Other (mostly unknown)



Hematopoetic



Aren't you glad you called radiology?

Outline

- Putting the Peds in Pediatric MSK

Take-Home Messages

- Kids are not just little adults.
- View(s) and field-of-view matter.
- When in doubt about whether imaging will be helpful/what imaging to order…
  - Let's call radiology!
  - Give MORE history, not less.


Thank you!
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