

# Imaging of Child Abuse

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**Cleveland Clinic Children's**



# PRESENTER FINANCIAL DISCLOSURE

I have no financial relationships relevant to this presentation



# Objectives

- Describe mechanism of injury and imaging findings of child physical abuse
- Identify mimics of abusive injury
- Understand misconceptions regarding fractures of abuse and abusive head trauma
- Be familiar with ACR-SPR Appropriateness criteria for suspected child physical abuse



# Pediatric Non-Accidental Trauma Prevalence

- 676,000 estimated victims of child abuse and neglect nationally
- >120,000 victims of physical abuse
- >600 deaths from physical abuse

U.S. Department of Health & Human Services, Administration for Children and Families, Administration on Children, Youth and Families, Children's Bureau. (2018). *Child maltreatment 2016*.



# Pediatric Non-Accidental Trauma Prevalence

- <5% of hospitals in the U.S. are children's hospitals
- Most suspected victims of child maltreatment do not enter the health care system through a children's hospital

National Association of Children's Hospitals and Related Institutions. (2011). *Defining the Children's Hospitals Role in Child Maltreatment, Second Edition.*



# Role of the Radiologist

- Clinical diagnosis can be challenging
  - Patients commonly present to the emergency department at least once prior to the visit in which abuse is recognized
  - Choo EK, 2008: 30% with prior visit, 56% of these with injuries to head, neck, face, or extremities
  - Thorpe EL, 2014:
    - 33% with prior visit and retrospective evidence of abuse
- Detection and documentation of physical injury suggestive of abuse

## **Teaching Points**

Imaging is only one part of the work-up. Child abuse cannot be excluded by imaging. Communication with referring physician is critical.

# Imaging Work-Up for Suspected Child Abuse



Wootton-Gorges SL, Soares BP, Alazraki AL, Anupindi SA, Blount JP, Booth TN, Dempsey ME, Falcone Jr RA, Hayes LL, Kulkarni AV, Partap S. ACR appropriateness criteria® suspected physical abuse—child. *Journal of the American College of Radiology*. 2017 May 1;14(5):S338-49.



# Skeletal Survey

## Appendix 1. Complete skeletal survey table [16]

### Appendicular Skeleton

- Humeri (AP)
- Forearms (AP)
- Hands (PA)
- Femurs (AP)
- Lower legs (AP)
- Feet (PA or AP)

### Axial Skeleton

- Thorax (AP and lateral), to include ribs\* and thoracic and upper lumbar spine
- Pelvis (AP), to include the mid lumbar spine
- Lumbosacral spine (lateral)
- Cervical spine (AP and lateral)
- Skull (frontal and lateral)

AP = anteroposterior; PA = posteroanterior.

\*The addition of both oblique projections to the AP view of the rib cage may increase the yield of rib fractures.

- Skeletal survey is composed of separate individual coned images of each of the anatomical areas listed in the table

## Teaching Points

“Babygrams” in which the entire infant is included in a single radiograph have no role in the evaluation for child physical abuse.





# Skeletal Survey

- Indications
  - Suspected physical abuse in patient  $\leq$  24 months old
  - Suspected physical abuse in patient  $>$ 24 months old if
    - Unable to verbalize
    - Neurologic signs or symptoms, apnea, complex skull fracture, other fractures, suspected thoracic or abdominopelvic injuries, or injuries highly suspicious for child abuse
  - Follow-up 2 weeks after initial examination
    - Re-evaluate equivocal findings
    - Assess for healing, information regarding fracture age
    - Detect new fractures



# Radiographic Findings with Greater Specificity for Child Physical Abuse

High Specificity	Moderate Specificity	Low Specificity
Classic metaphyseal lesion Rib fractures Scapular fractures Spinous process fractures Sternal fractures	Multiple fractures Fractures of different ages Epiphyseal separations Vertebral body fractures, subluxations Digital fractures Complex skull fractures Pelvic fractures	Subperiosteal new bone formation Clavicular fractures Long bone shaft fractures Linear skull fractures

Kleinman, Paul K., ed. *Diagnostic imaging of child abuse*. Cambridge University Press, 2015.

Identification of any injury incompatible with history, mechanism, patient age, stage of development should prompt discussion with the referring physician



# Fracture Mechanisms in Child Abuse



- Shaking
- Torsion
- Direct impact



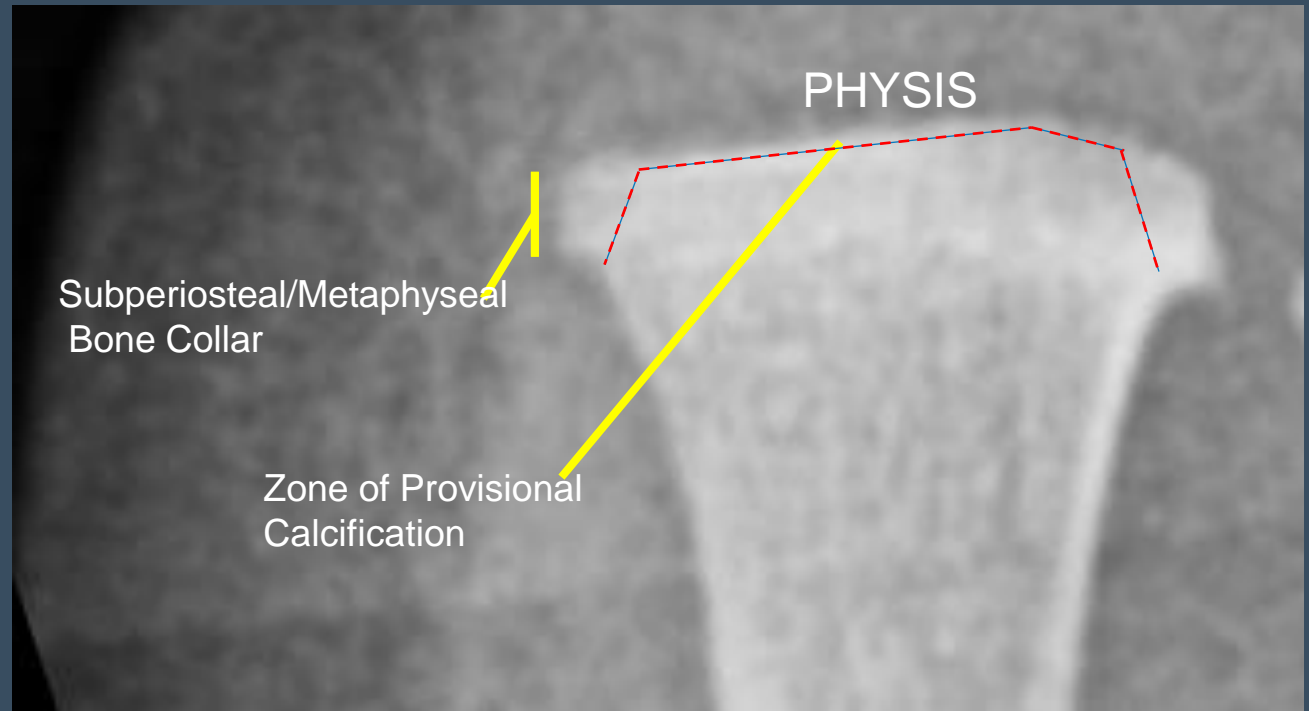
# Classic Metaphyseal Lesions (CML)

- 10-year retrospective case-control study (Kleinman, 2011)
  - Common in infants at high-risk of abuse, no cases in infants at low-risk
- Radiologic-histologic postmortem study of 31 infants that died with inflicted skeletal injury (Kleinman, 1995)
  - Second most common fracture (rib fractures first)
  - Most common fracture of long-bones
- Review of skeletal surveys for abuse (Barber, 2015)
  - Lower extremities most common site
  - 87% of cases had additional skeletal injuries

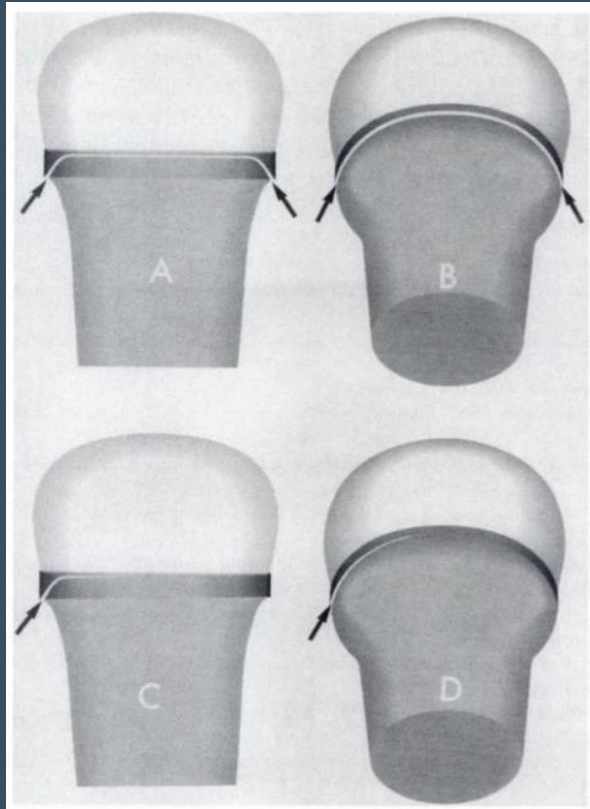


# CML: Mechanism and Pathology

- Torsion, traction, acceleration-deceleration shearing forces
- Planar fracture along trabecula of primary spongiosa deep to ZPC
- Fracture undercuts the subperiosteal bone collar
- Appearance depends on projection and fracture extent



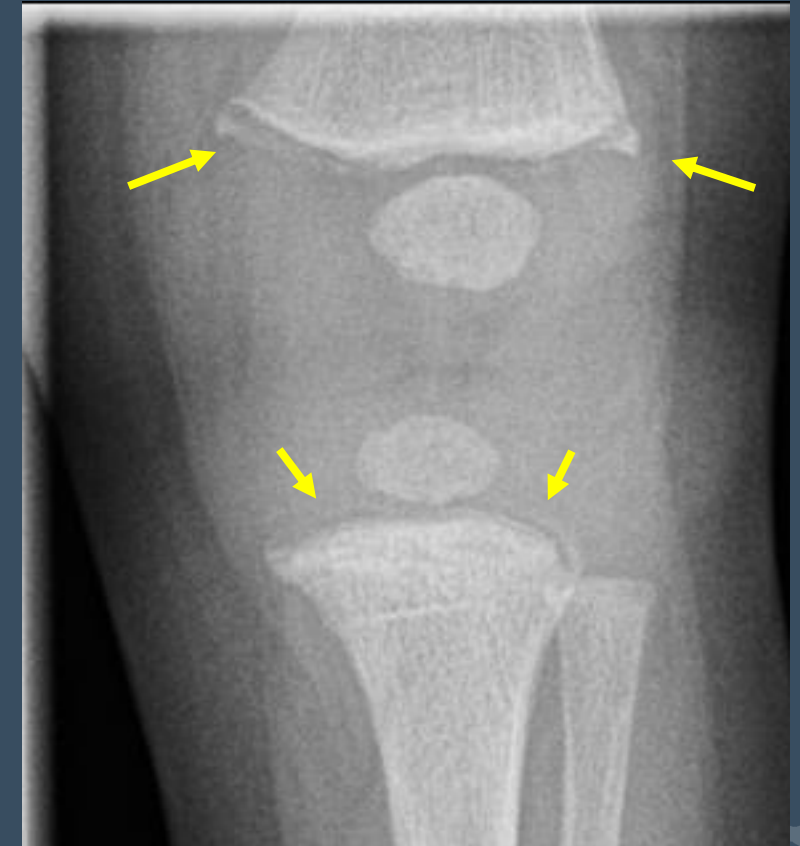
# CML



Kleinman PK, Marks JS.  
Relationship of the subperiosteal  
bone collar to metaphyseal  
lesions in abused infants. JBJS.  
1995 Oct 1;77(10):1471-6.



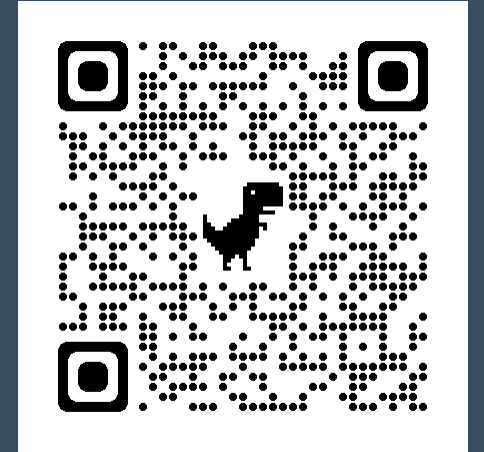
5-week-old female with bruising



12-week-old female with fall  
from height

# CML vs Rickets

- Myth propagated in the literature:
  - Rickets, hypocalcemia, and low vitamin D levels predispose children to fractures known to be highly specific for child abuse (CML)

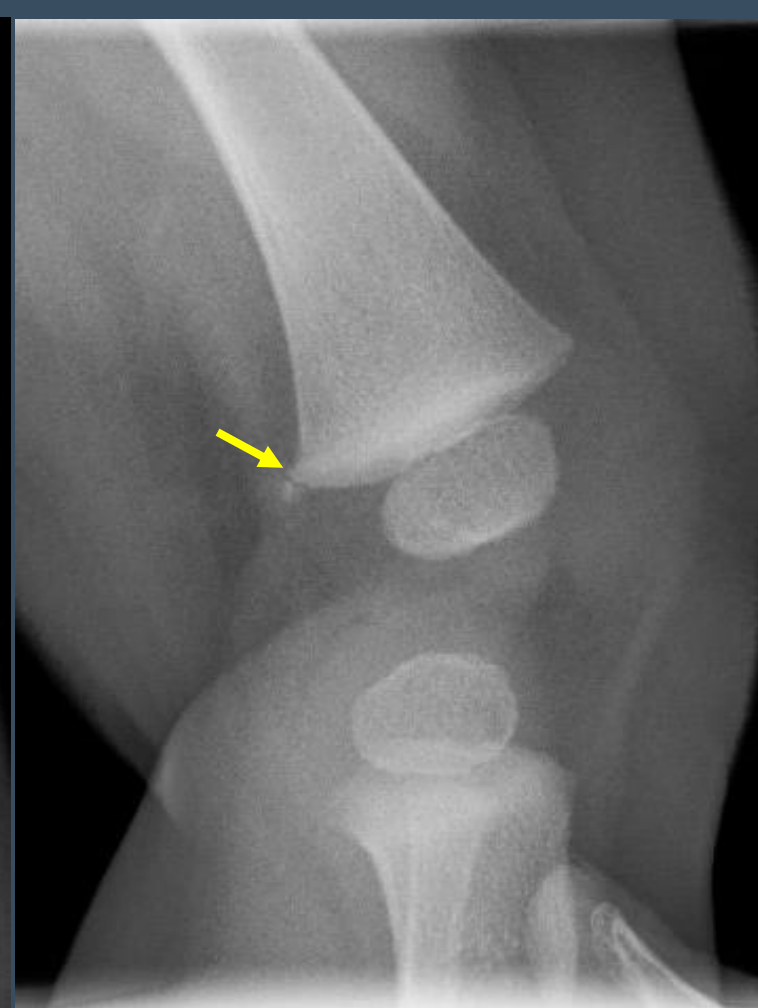
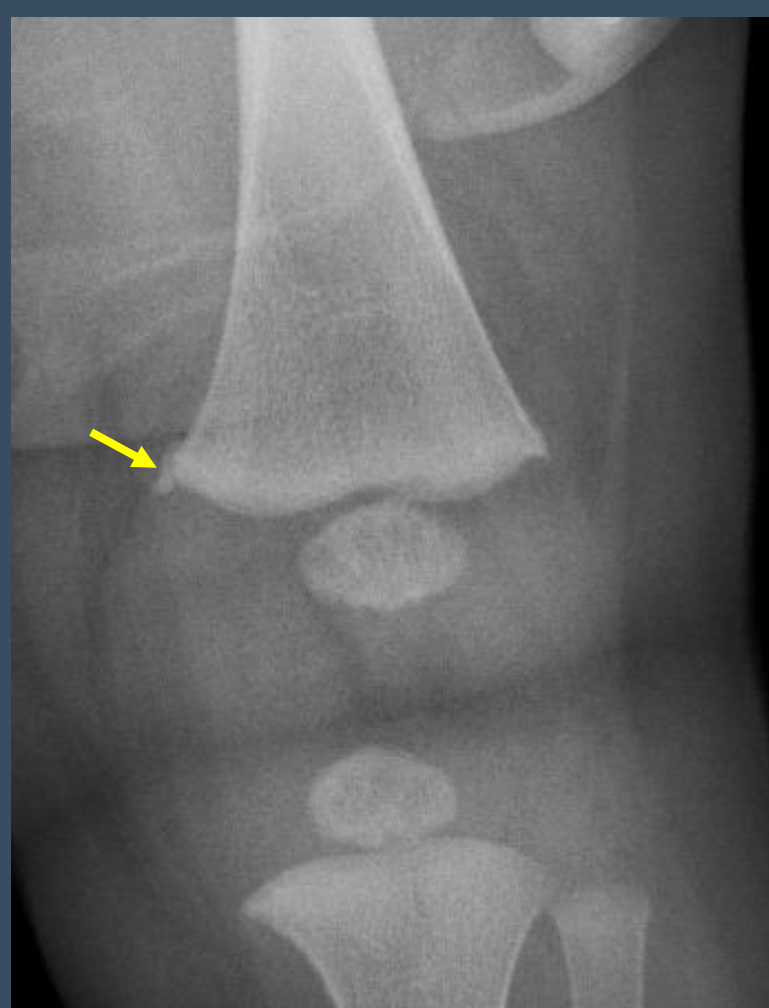
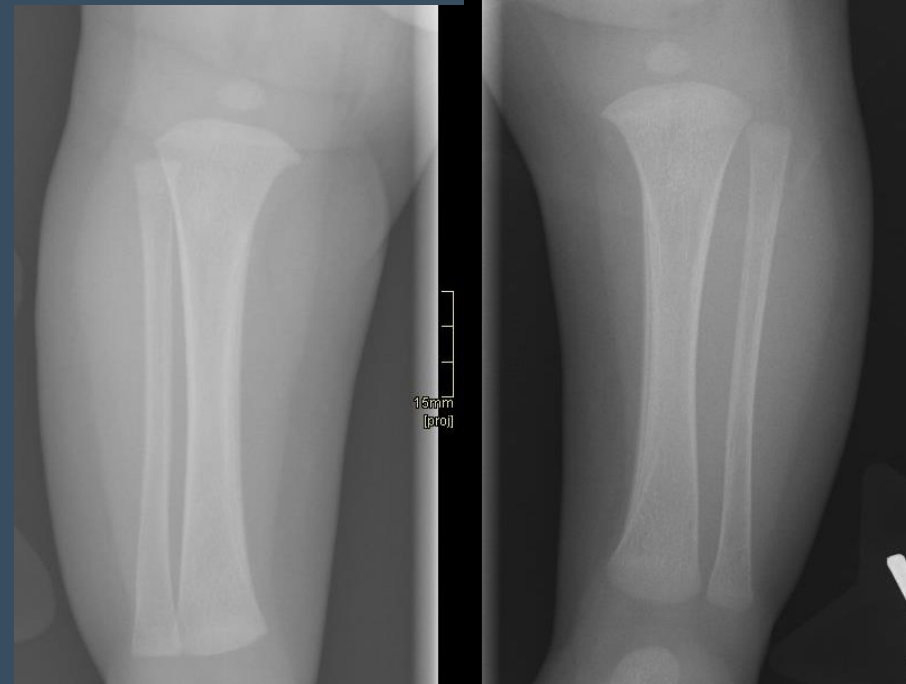
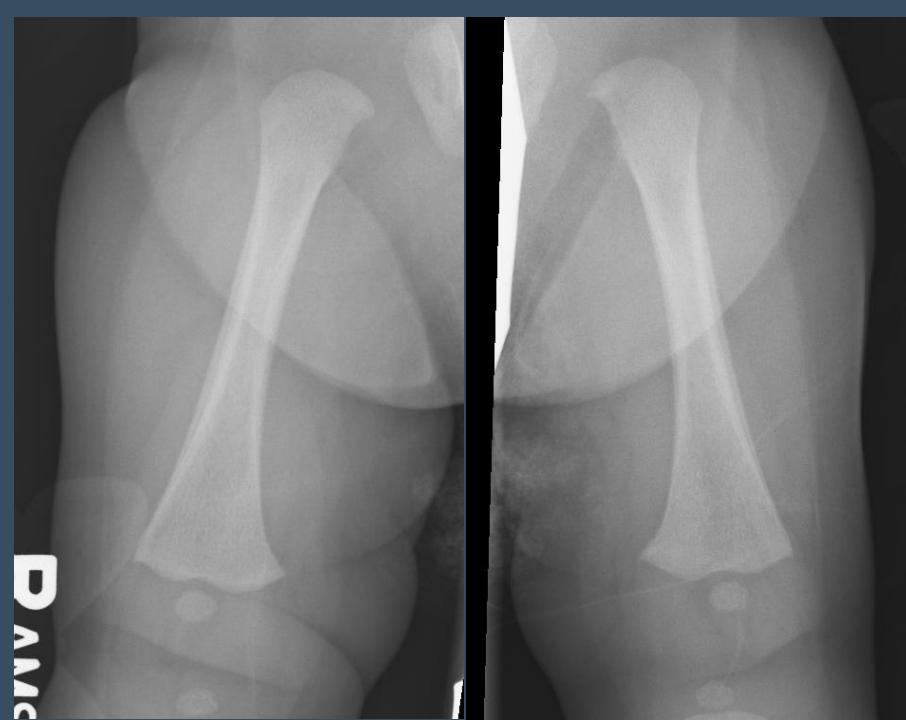


Servaes S, Brown SD, Choudhary AK, Christian CW, Done SL, Hayes LL, Levine MA, Moreno JA, Palusci VJ, Shore RM, Slovis TL. The etiology and significance of fractures in infants and young children: a critical multidisciplinary review. *Pediatric radiology*. 2016 May;46:591-600.

## Teaching Points

### CML vs Rickets

- When hypocalcemia is present but there are no radiographic findings of rickets, there is **NO** evidence of bone fragility and increased susceptibility to fractures.
- Vitamin D levels do not denote bone disease. The category of “insufficient” (greater than 20 ng/ml to less than 30 ng/ml) is not a valid threshold for bone health
- The fractures with high specificity for child abuse — classic metaphyseal lesions and posterior rib fractures — are **NOT** sequelae of rickets.



Normal Variants



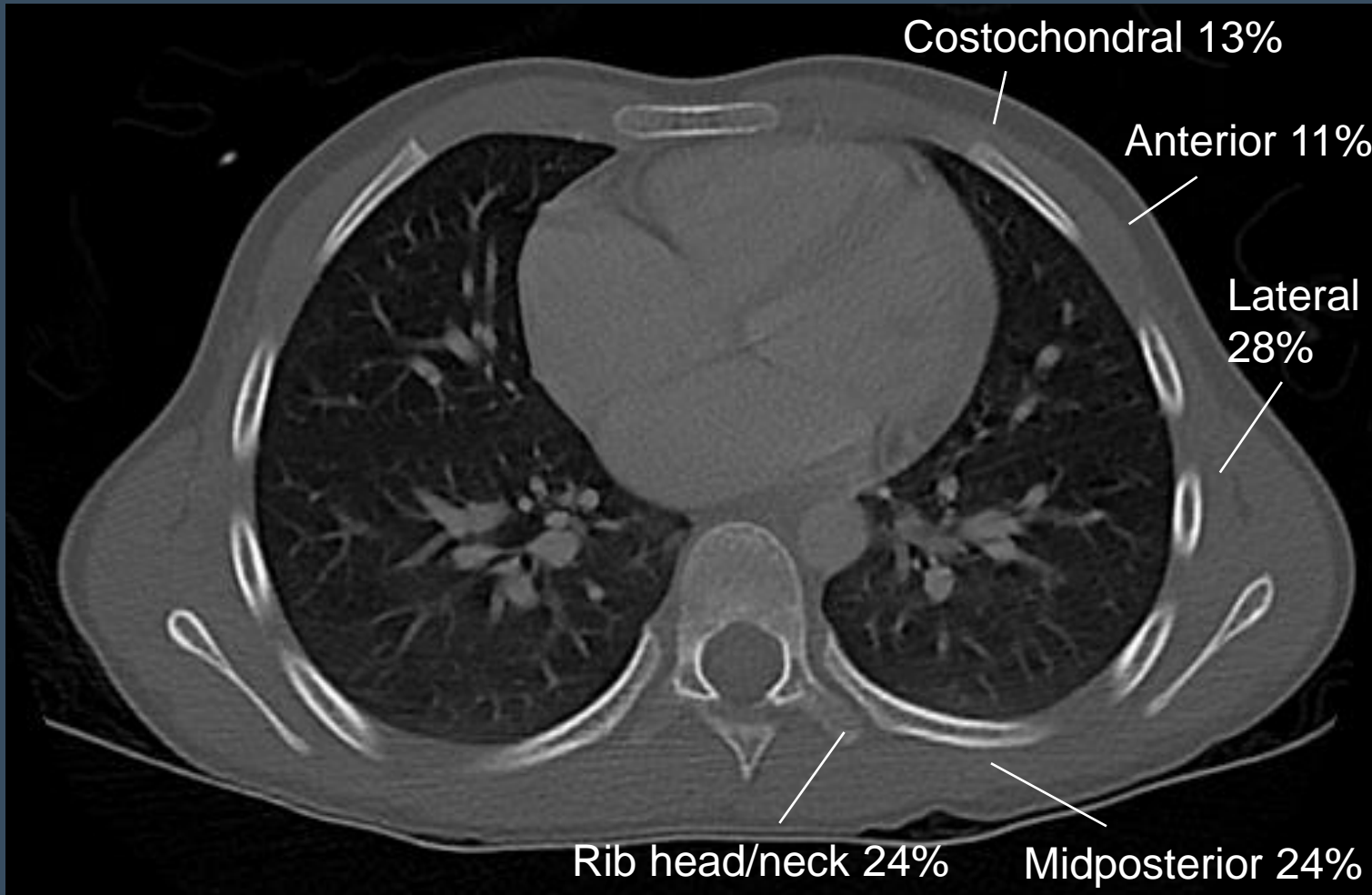


# Rib Fractures

- Highly associated with child abuse
  - 82% of rib fractures in infants <12-months-old caused by child abuse over 3-year period in multicenter study (Bulloch B, 2000)
  - 69% of rib fractures in hospitalized infants <12-months-old caused by child abuse, data from national inpatient database (Leventhal JM, 2008)
- Most common fractures of child abuse
- Majority are clinically occult
  - 9% with overlying bruising (Peters ML, 2008)



# Rib Fractures



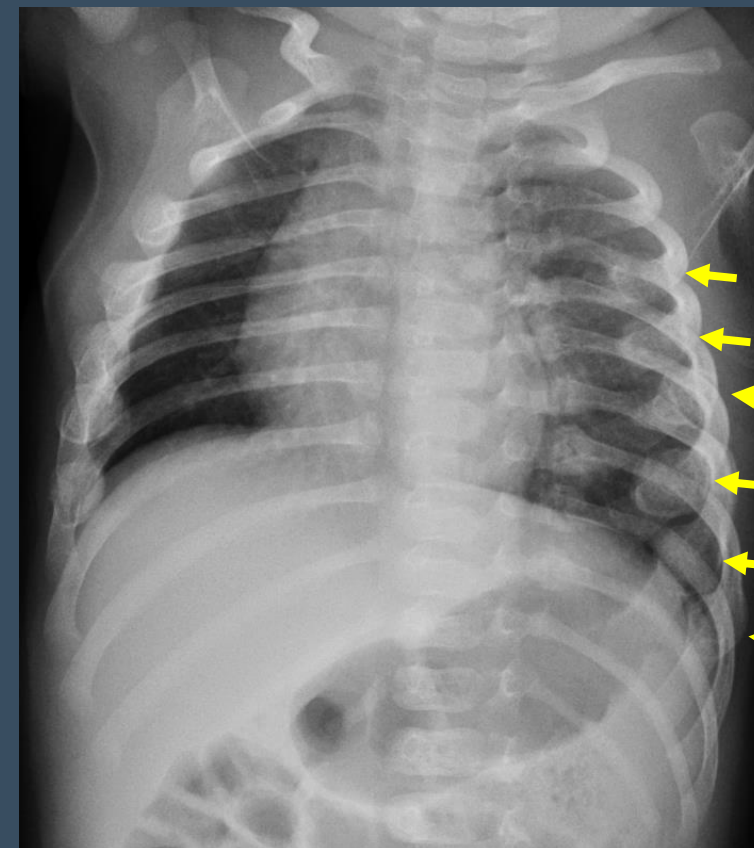
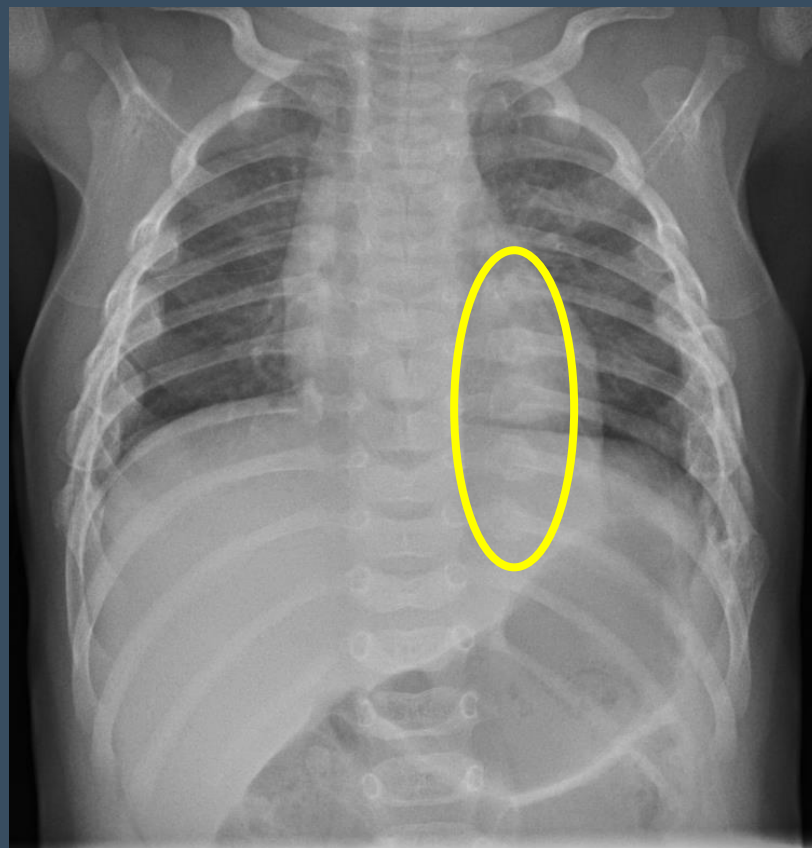
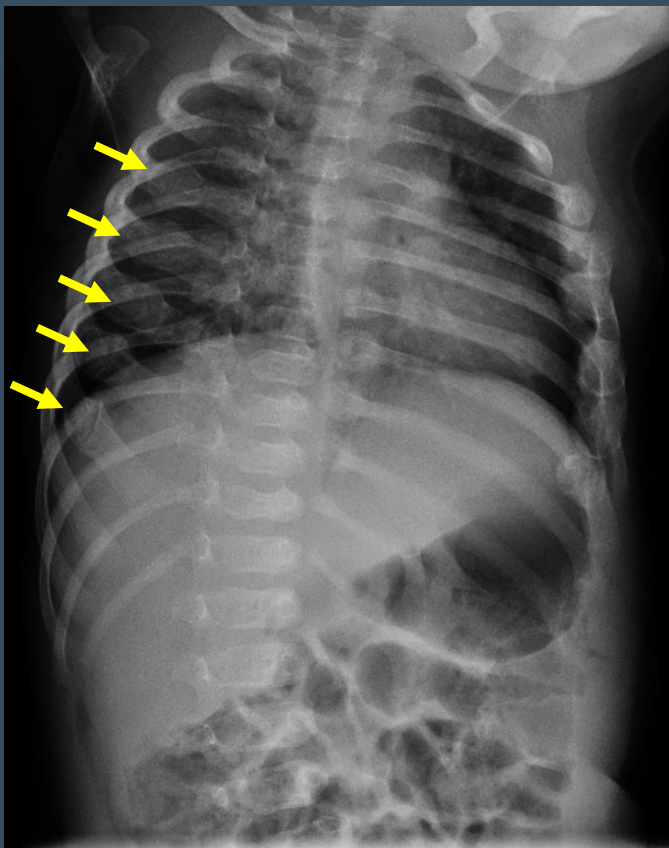
## Child abuse rib fractures

- More common posteriorly
- 65% involve ribs 5-8

## CPR fractures

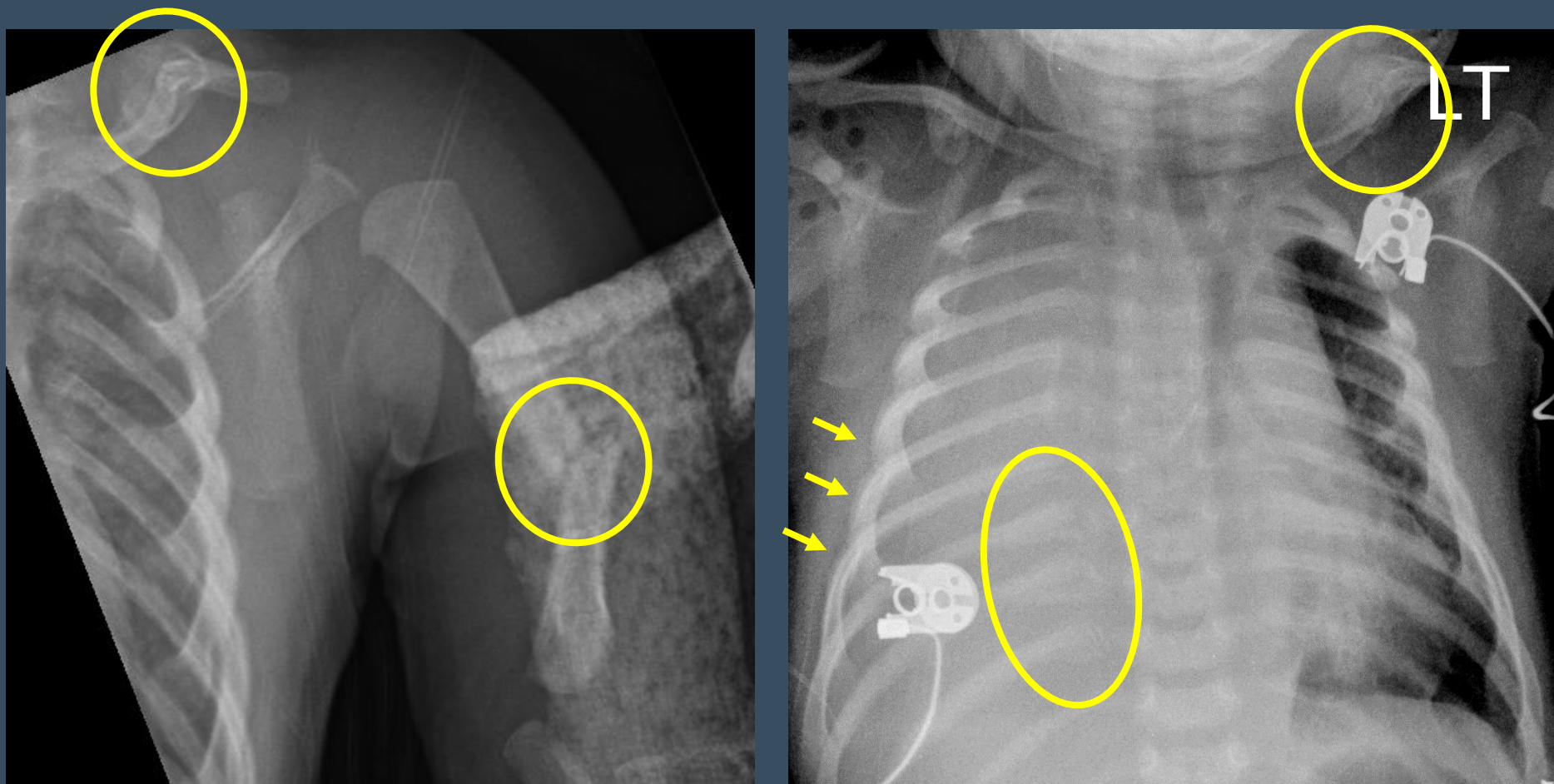
- Multiple studies show CPR-related rib fractures very rare in infants
- Typically anterior

# Rib Fractures



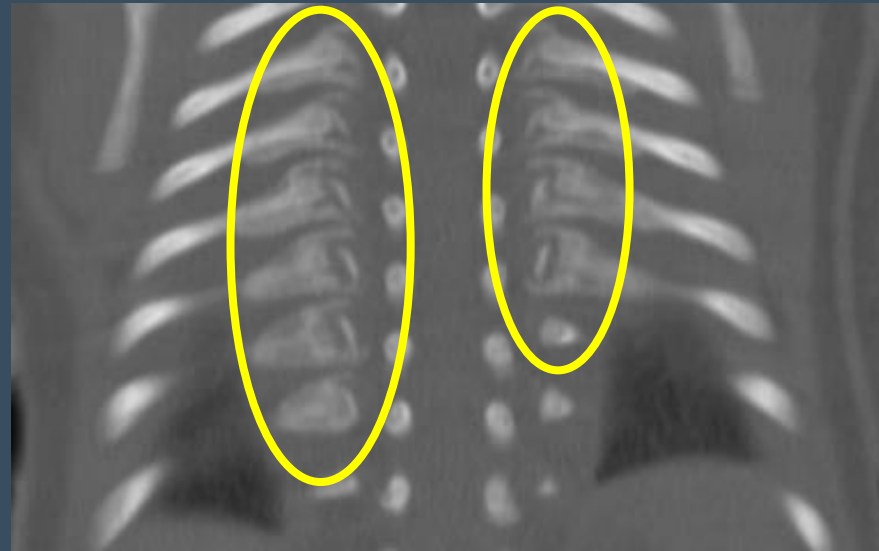
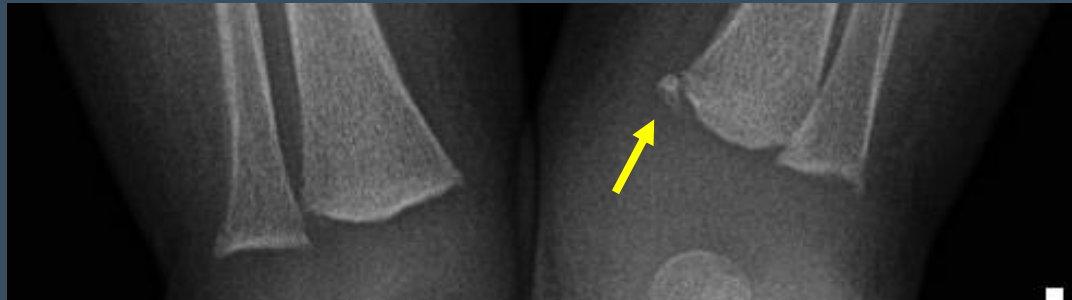
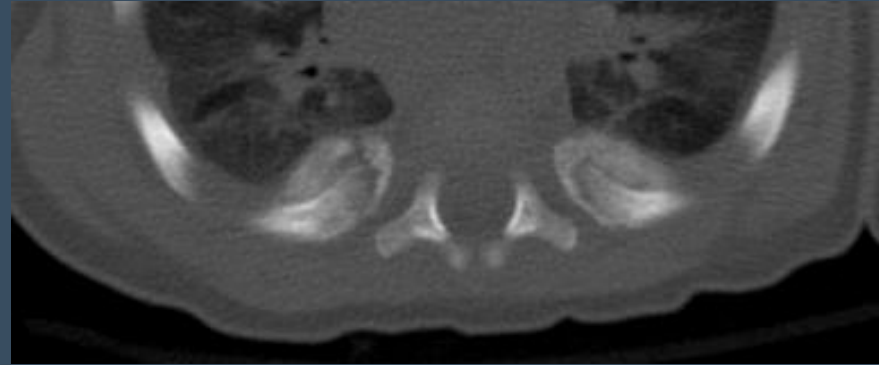
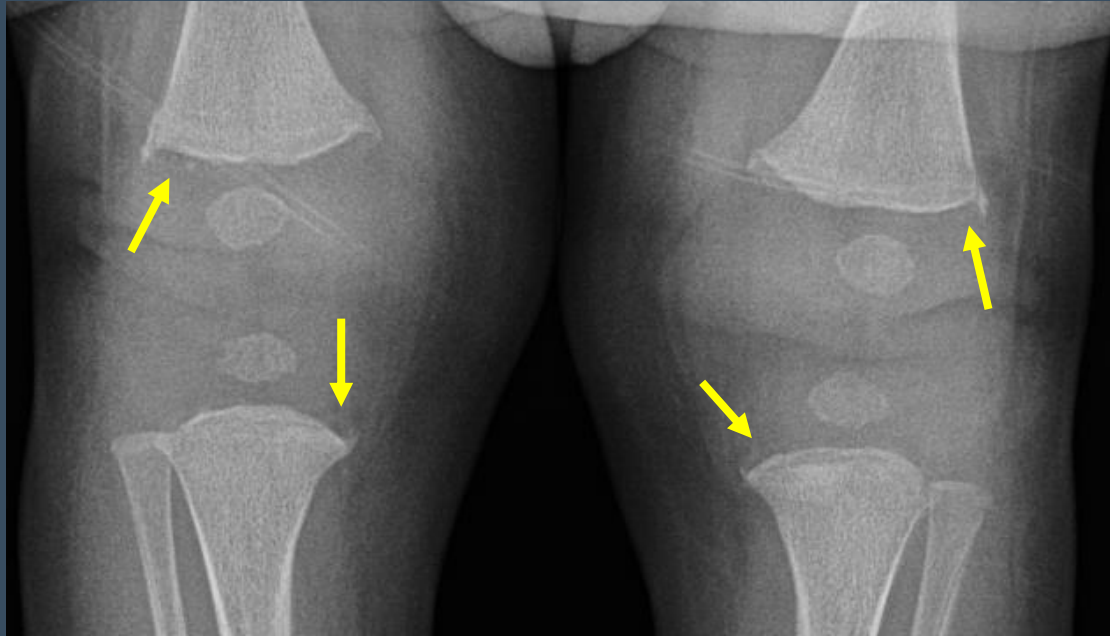
12-week-old female status-post fall

# Rib Fractures



28-day-old with fracture and no history of trauma

# Rib Fractures



28-day-old with fracture and no history of trauma



# Rib Fractures: Pitfall/Mimic



Sternal ossification centers may overlap ribs on oblique projections and mimic healing fractures

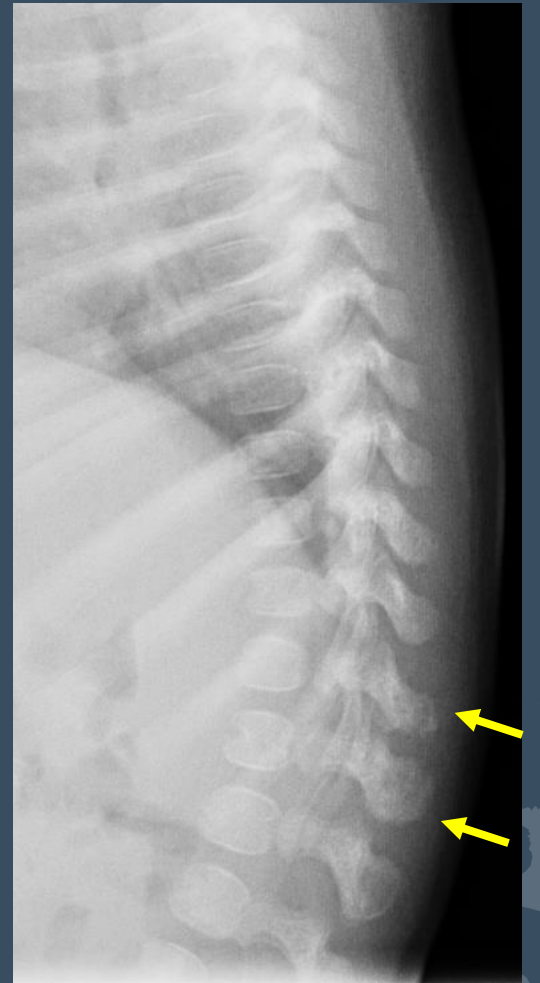
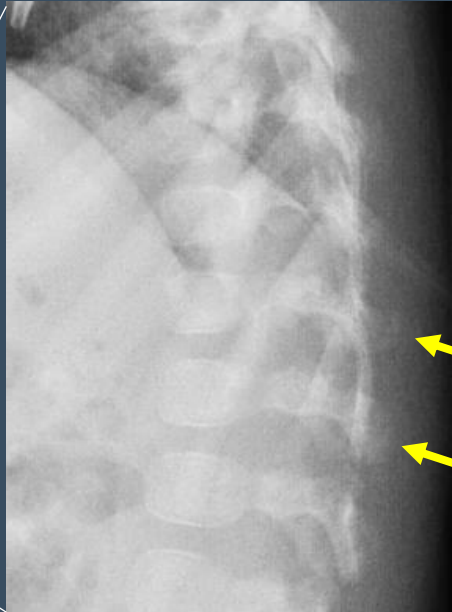
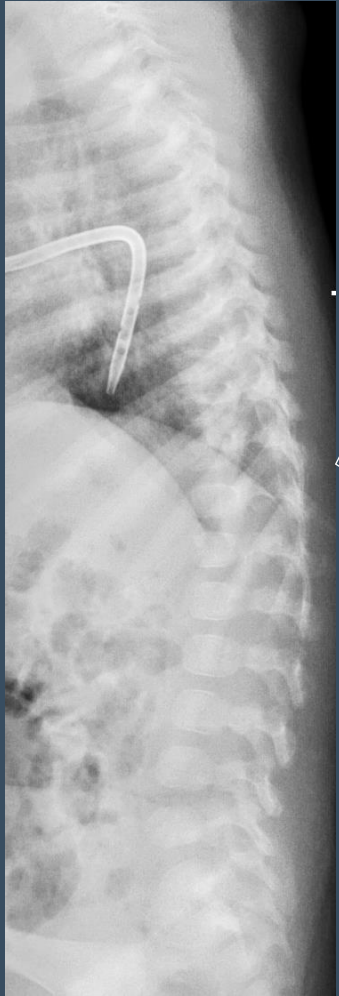


# Spinous Process Fractures

- Specific, but less common
- Hyperflexion injury from shaking
- Avulsion of cartilage/bone at attachment of interspinous ligament
- May not have radiographic findings acutely in young infants in whom spinous process is predominantly cartilaginous
- Associated vertebral body fractures common



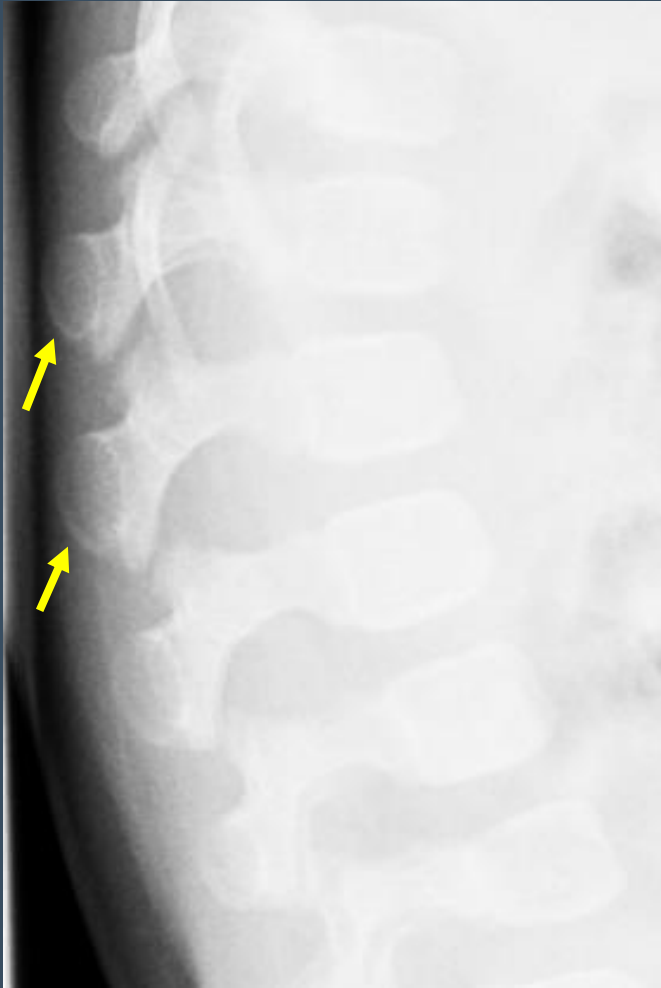
# Spinous Process Fractures



28-day-old with fracture and no history of trauma

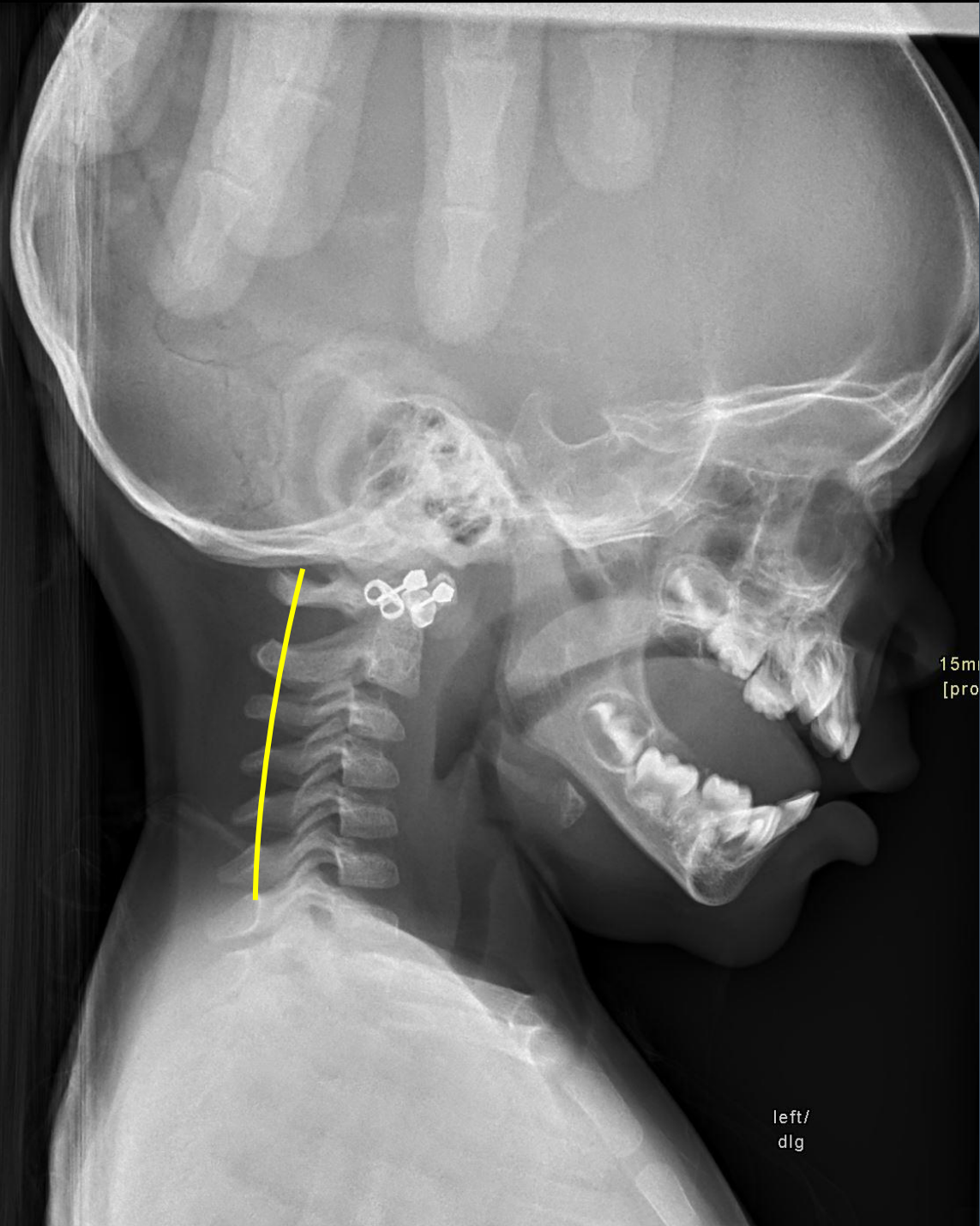


# Spinous Process Fractures: Pitfall/Mimic



- Spinous process metaphyseal equivalent
- Transverse metaphyseal lucency normally seen 10-days post-natal life and several weeks after
- Smooth, parallels margin
- Less conspicuous on follow-up
  - Fracture with periosteal reaction, irregularity
- Secondary ossification center at tip of spinous process in 2<sup>nd</sup> decade of life





# Pseudosubluxation

- Seen in first decade of life
- Anterior positioning of C2 in relation to C3, commonly seen normal finding in children
- Spinolaminar line intact
- Consider true subluxation if posterior arch of C2 > 2mm off from a line joining the posterior arch of C1 and C3

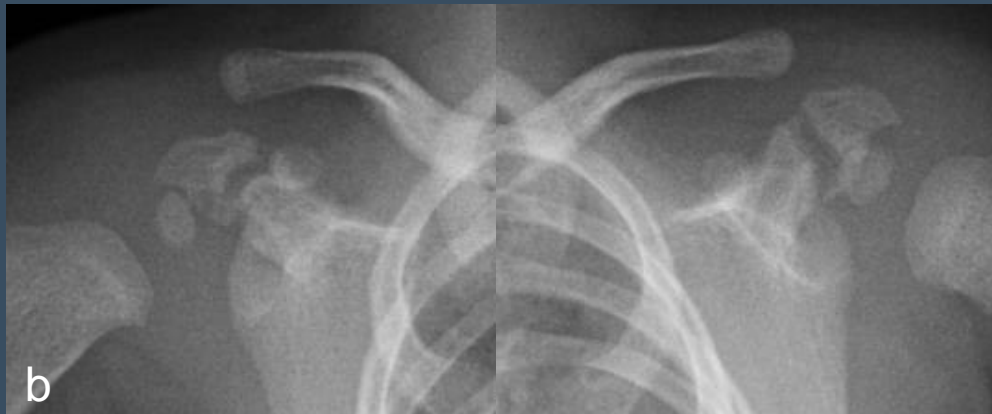
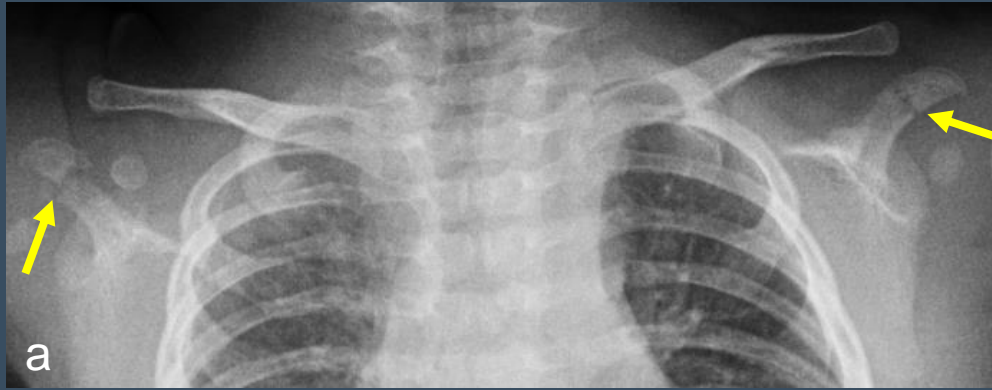


# Scapular Fractures

- Review of skeletal surveys for abuse (Barber, 2015)
  - Uncommon, 1% of cases of suspected abuse
  - Skeletal surveys considered positive in all cases with scapular fractures
  - Significantly associated with intracranial injury
  - Acromion most common site of fracture, 85%
    - Midportion most common



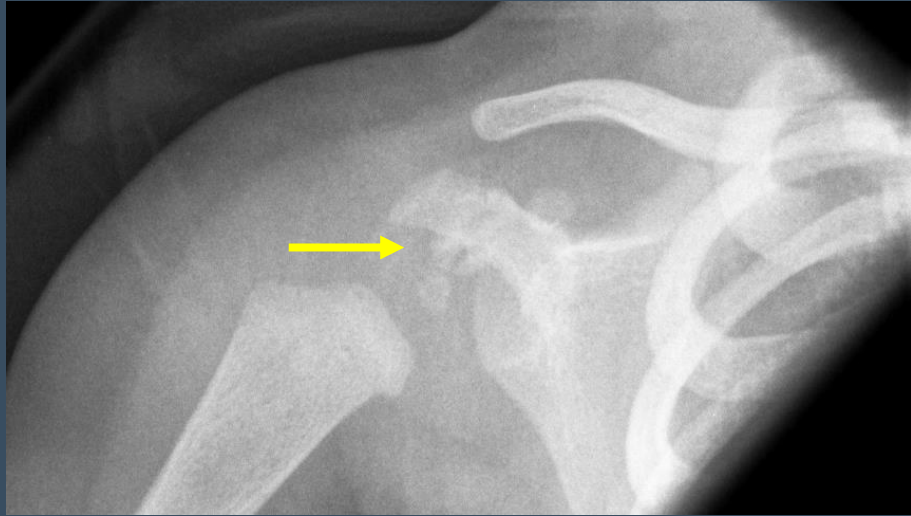
# Scapular Fractures



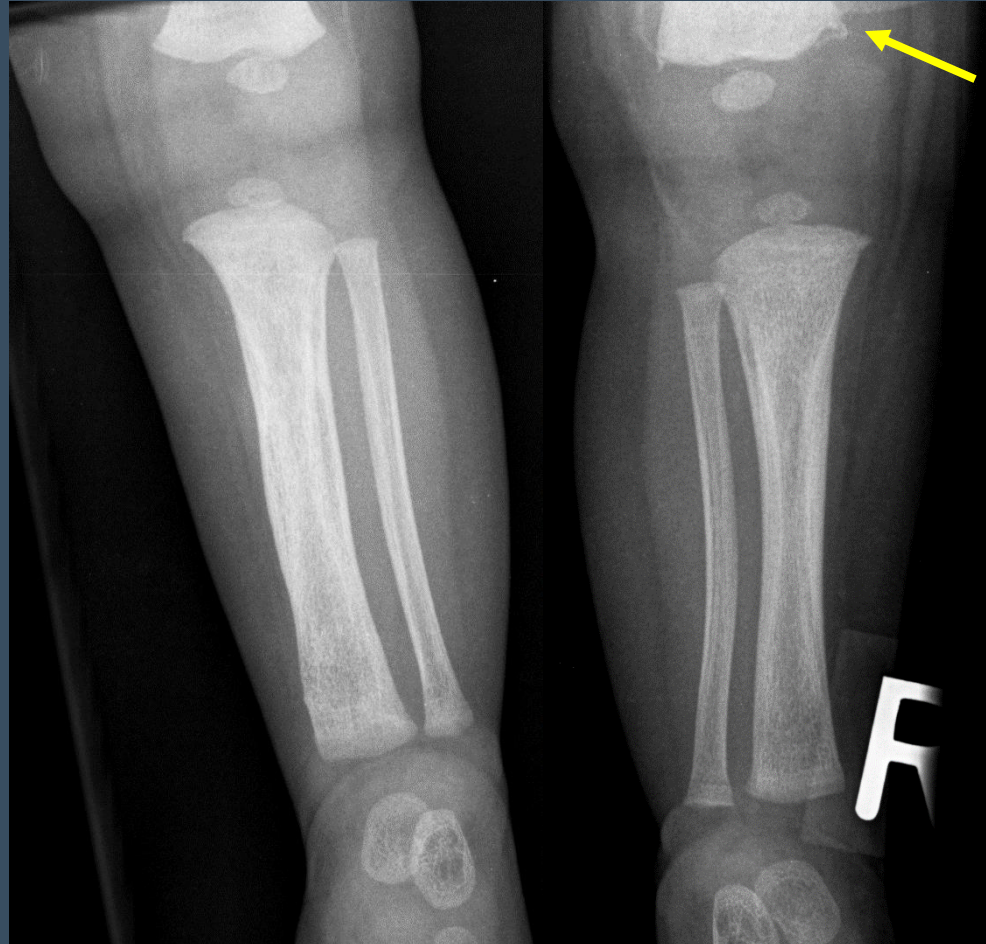
- 6-week-old not moving left leg with left tibia CML
- a. Initial skeletal survey
  - b. 3-week follow-up, progression of healing
  - c. 6-week follow-up, progression of healing



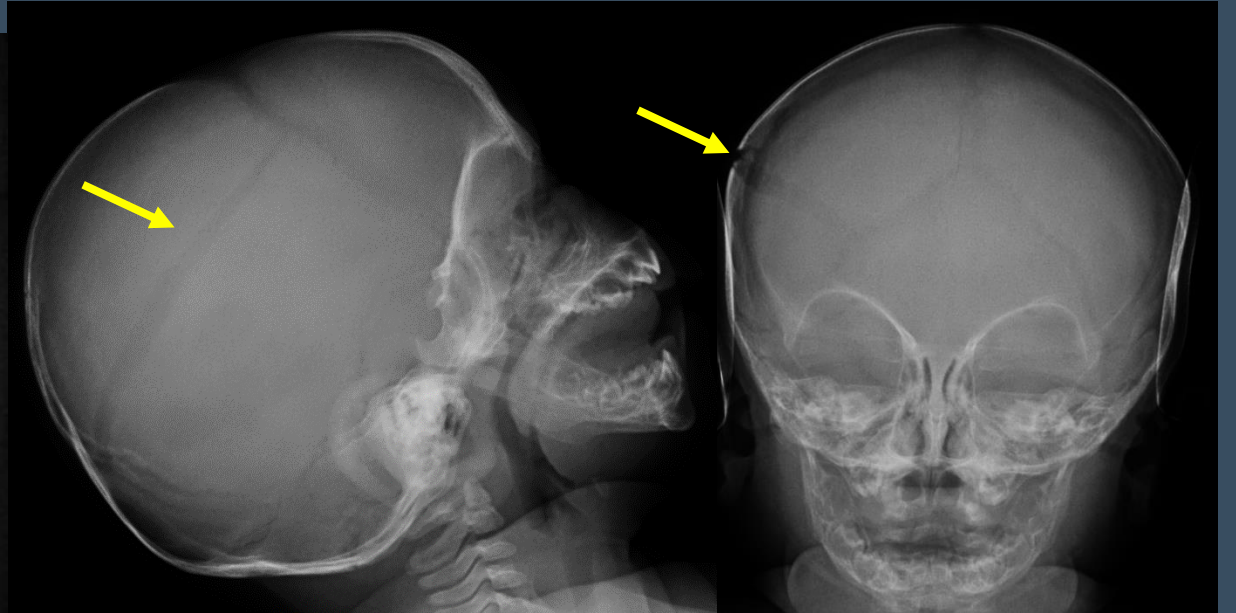
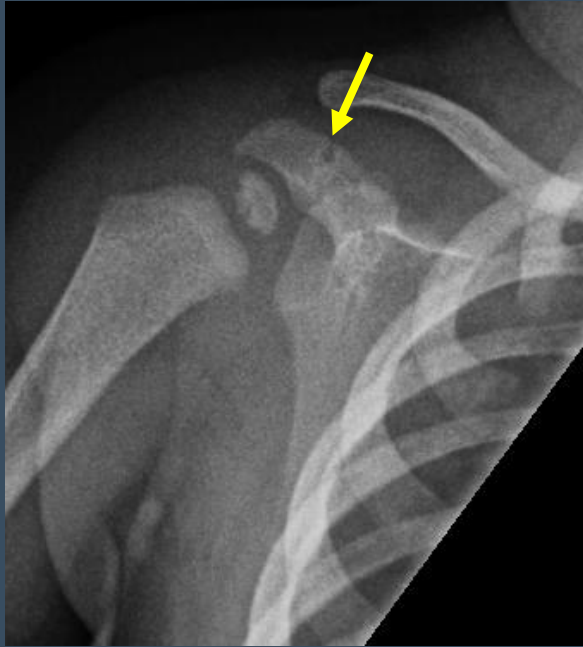
# Scapular Fractures



7-month-old male



# Scapular Fractures

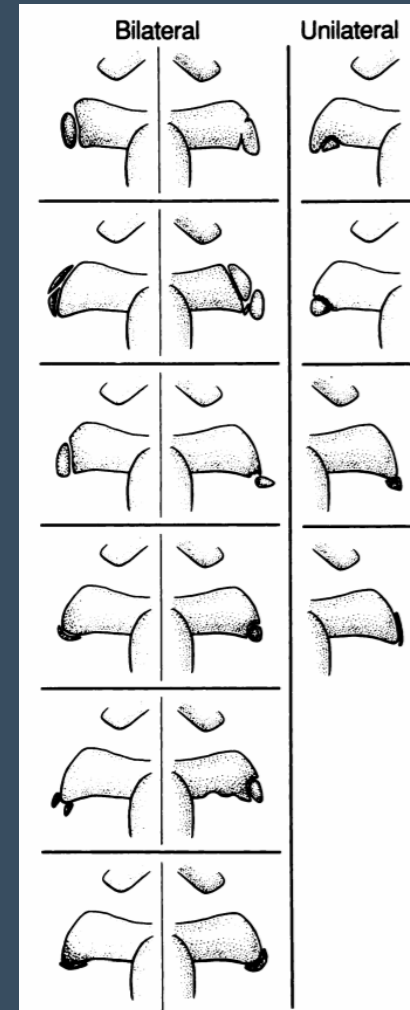
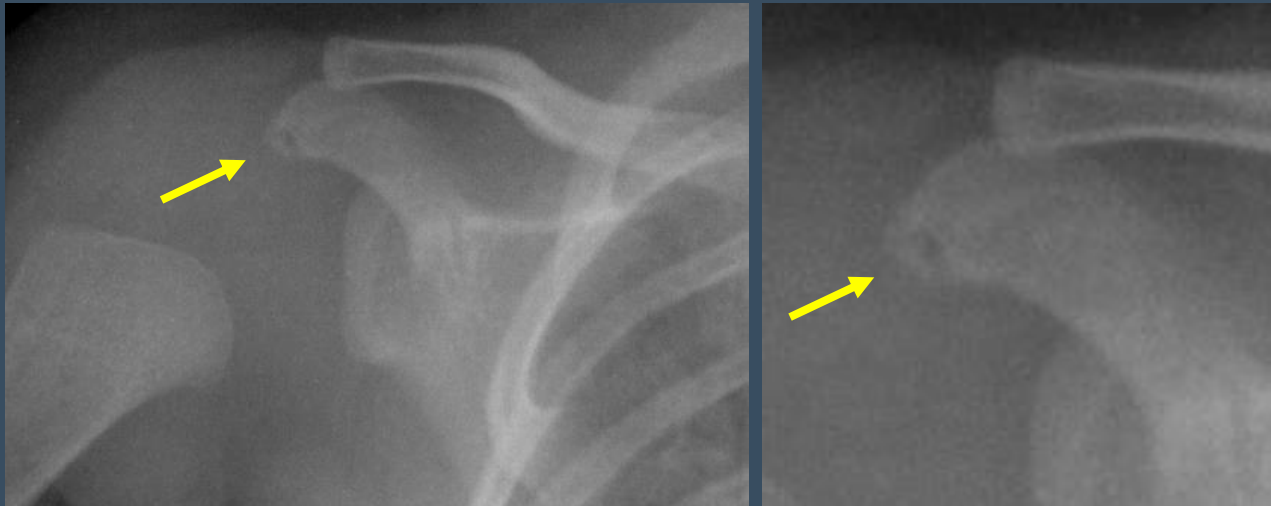


3-month-old female  
previously presented  
with blood in diaper  
and head bruises



# Scapular Fractures: Pitfall/Mimic

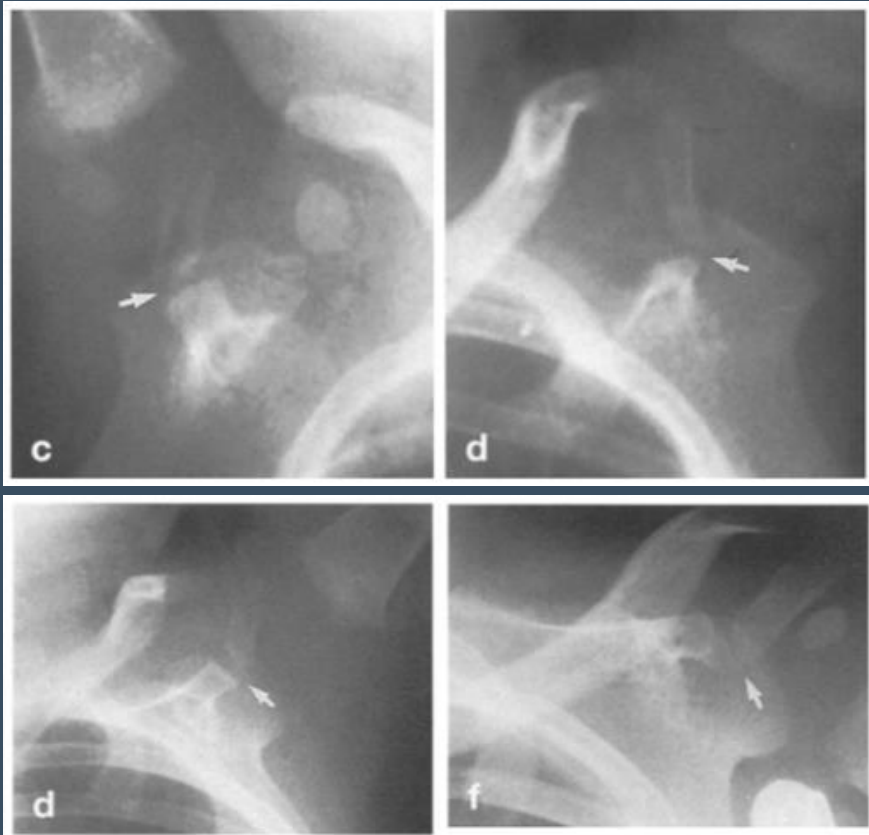
- Acromial accessory ossicles
  - Ossicles typically inferior and anterior
  - Well-defined margins
  - No callus formation
  - Secondary ossification centers appear 2<sup>nd</sup> decade of life



Kleinman PK, Spevak MR. Variations in acromial ossification simulating infant abuse in victims of sudden infant death syndrome. *Radiology*. 1991 Jul;180(1):185-7.



# Scapular Fractures: Pitfall/Mimic



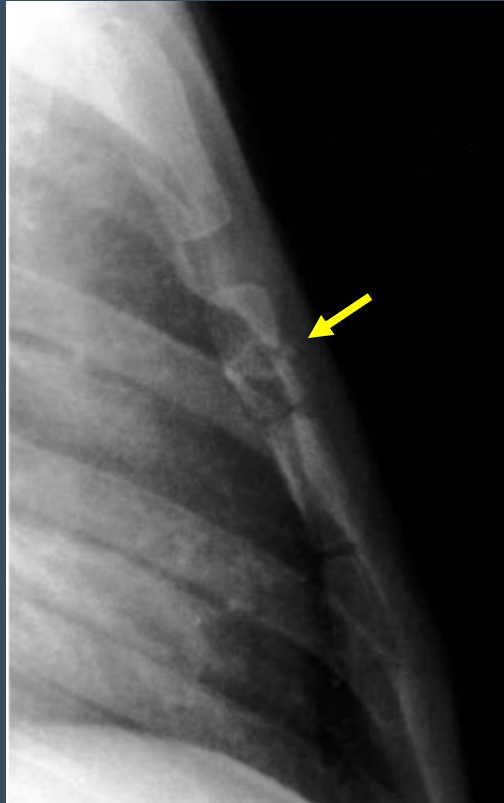
- Rarely, lateral basiacromion develops as separate center
  - Well-defined margins
  - Elongates over time
  - Remains separate for at least 1 year
  - May have other dysplastic features

Currarino G, Prescott P. Fractures of the acromion in young children and a description of a variant in acromial ossification which may mimic a fracture. *Pediatric radiology*. 1994 Aug 1;24(4):251-5.





# Sternal Fractures



2-year-old abused female

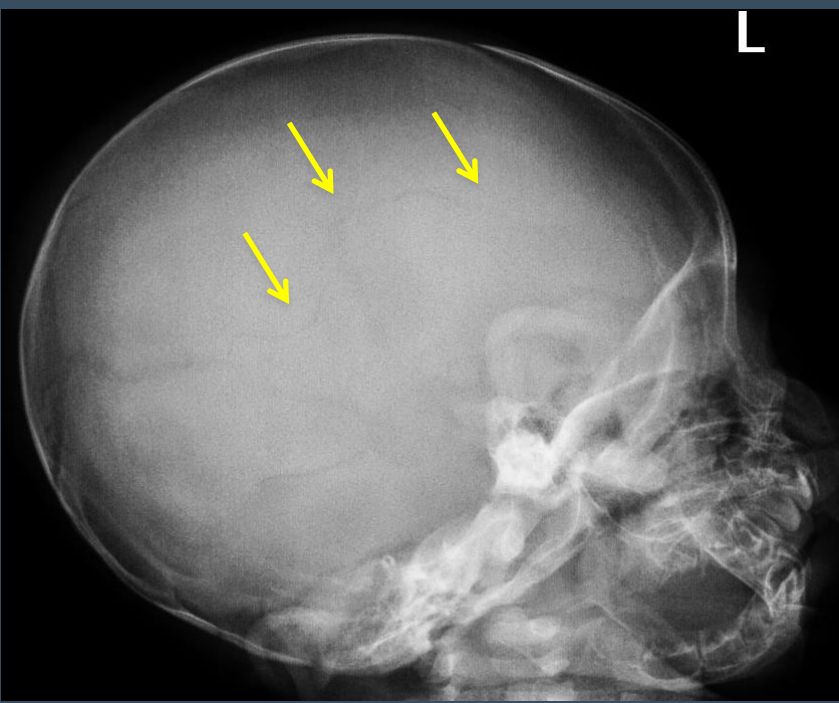
- Uncommon, small number of reports of fractures children <3-years-old
  - Hechter, 2002: 2/4 cases in children <3-years-old suspicious for abuse
- Direct impact or hyperflexion, associated with spine injury
- Buckling, linear lucency, or widened sternal synchondrosis



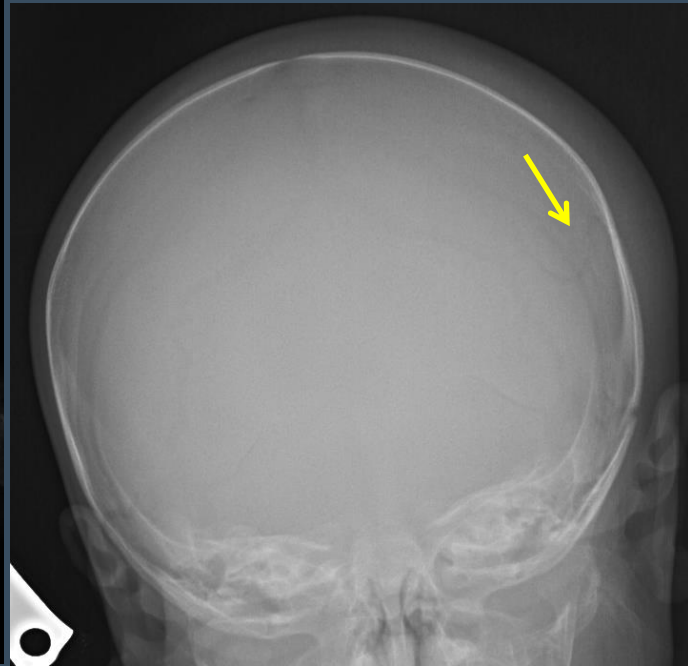
# Skull Fractures

- Simple or complex
- Overlying soft-tissue swelling suggests acute fracture
- Birth Injury
  - Typically simple fracture but indistinguishable from abusive
  - No longer visible in 1-2 months

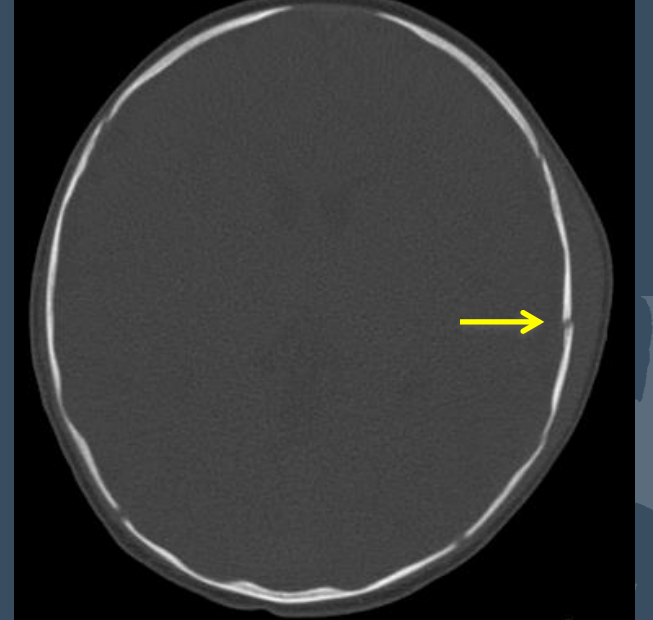
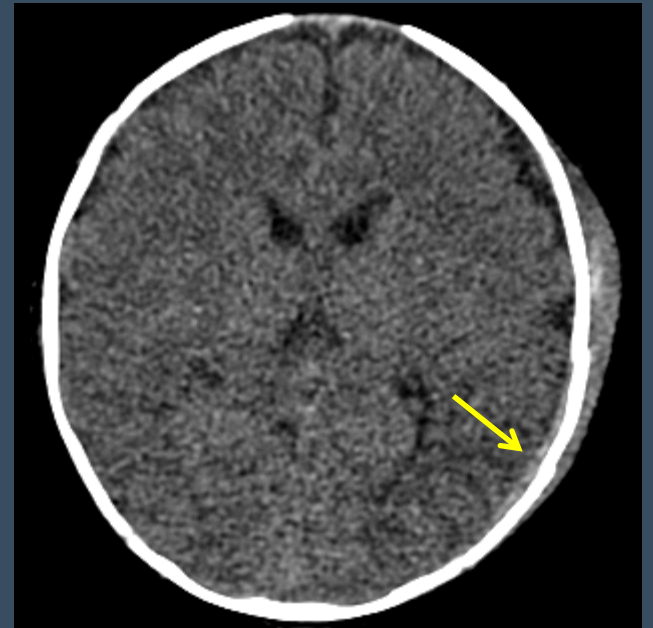




56-day-old with left head swelling



2-week follow-up

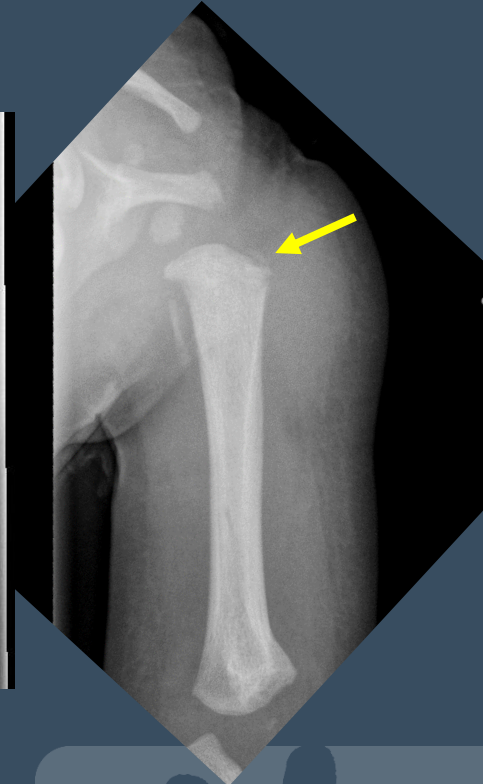
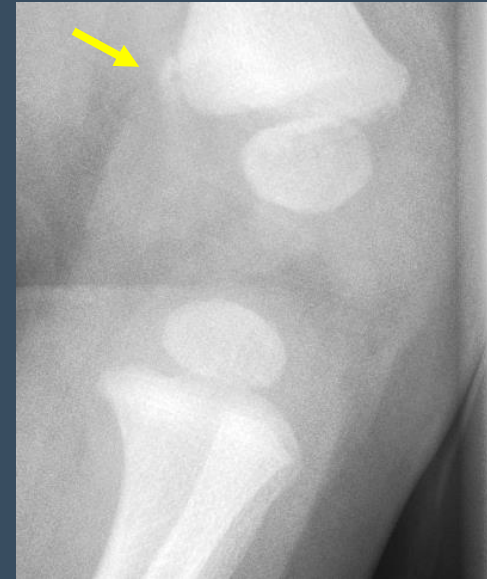
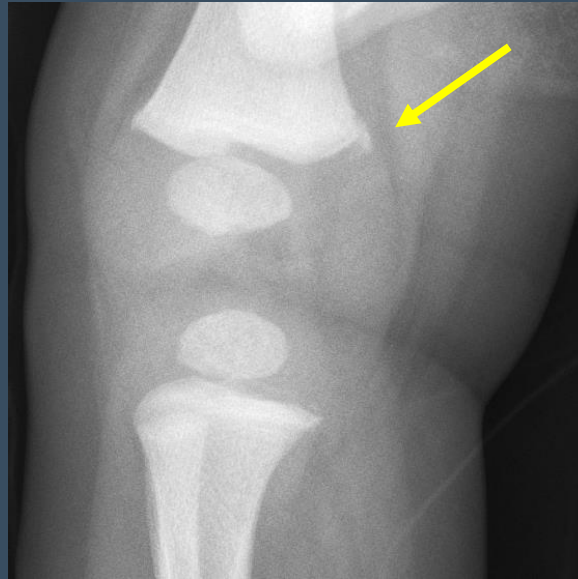


# Skull Fractures

# Skull Fractures



4-month-old with left arm swelling



# Abusive Head Trauma (AHT)

- Diagnostic term for inflicted intracranial injury
  - Compilation of SDH, retinal hemorrhage/retinoschisis, and rib, metaphyseal or other fractures, history inconsistent with injury
- AHT is leading cause of fatal head injuries and serious/fatal traumatic brain injury in children <2-years-old



# Imaging Work-Up of AHT

- CT in acute setting, MRI in non-acute setting
- Child with neurologic signs or symptoms, apnea, complex skull fracture, other fractures, or injuries highly suspicious for child abuse
  - CT head, MRI head, MRI spine “Usually appropriate”
- Child with suspected physical abuse, but no neurologic or visceral injury clinically suspected
  - CT head, MRI head “May be appropriate”
  - BUT strongly consider in infants <12 months old
- Child with suspected abusive thoracic or abdominopelvic injury, OR child  $\leq 24$  months old with high suspicion for abuse and negative initial skeletal survey
  - CT head, MRI head “May be appropriate”



# AHT Imaging Findings

- Intracranial hemorrhage
- Bridging vein injury
  - High specificity for AHT
  - Hyperdensities in paramedian high convexity
- Parenchymal ischemia, edema, and axonal injuries



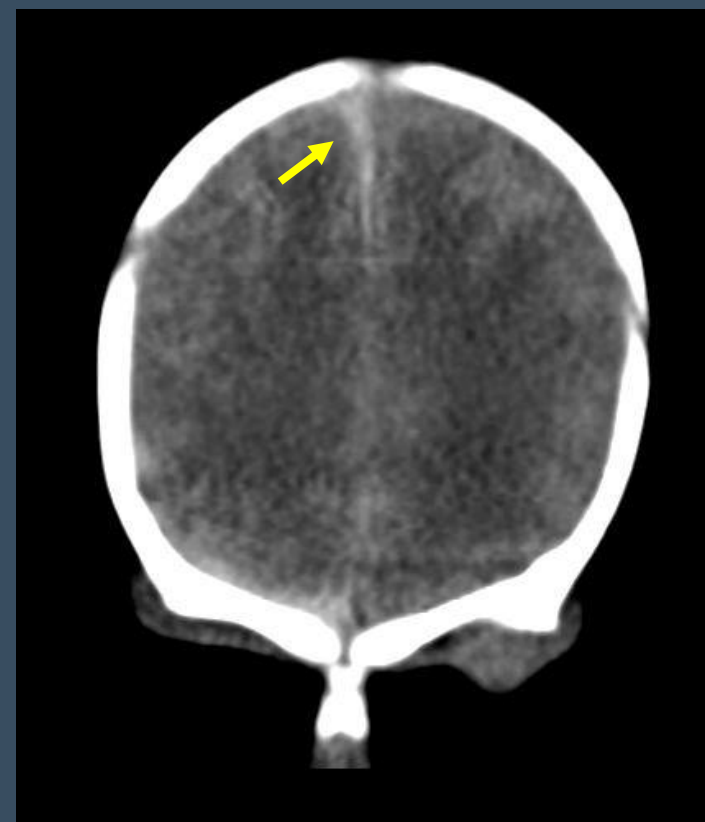
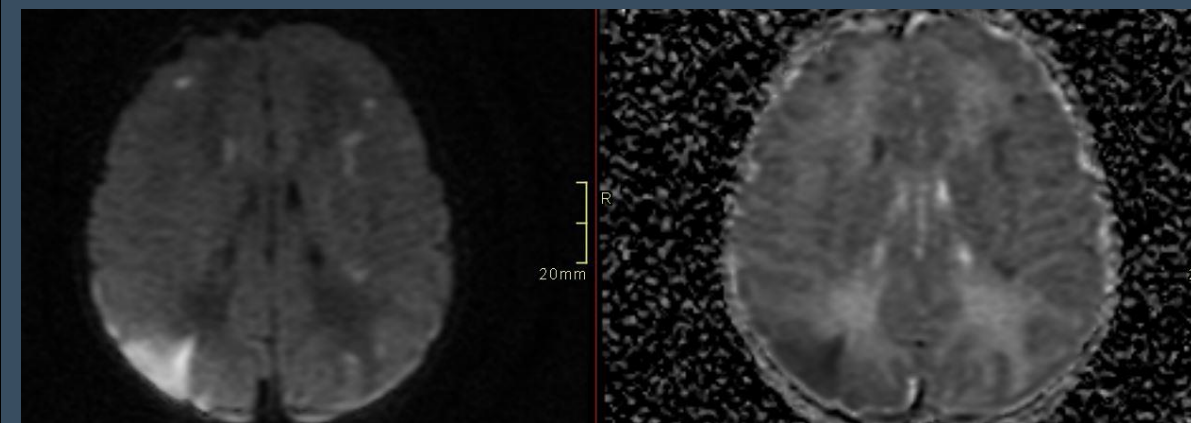
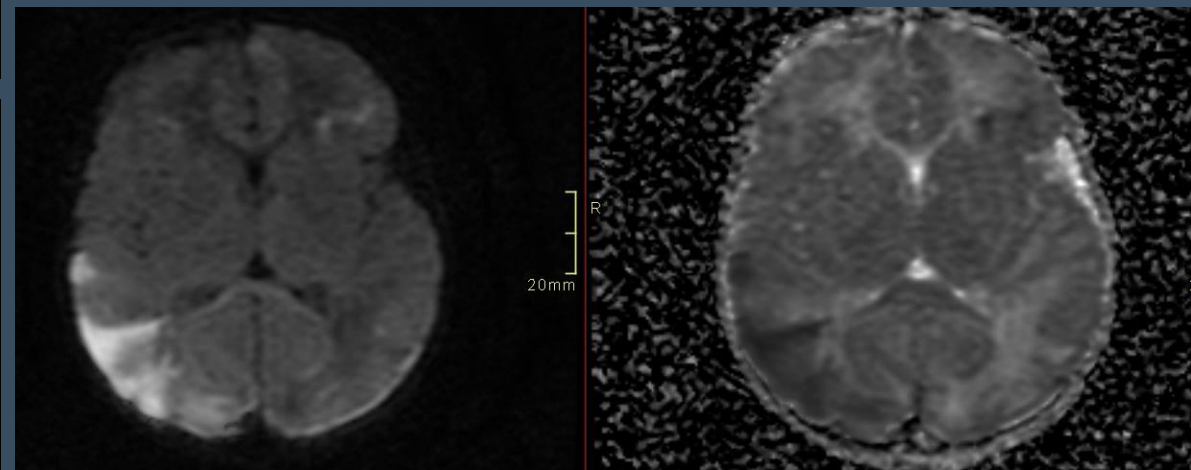
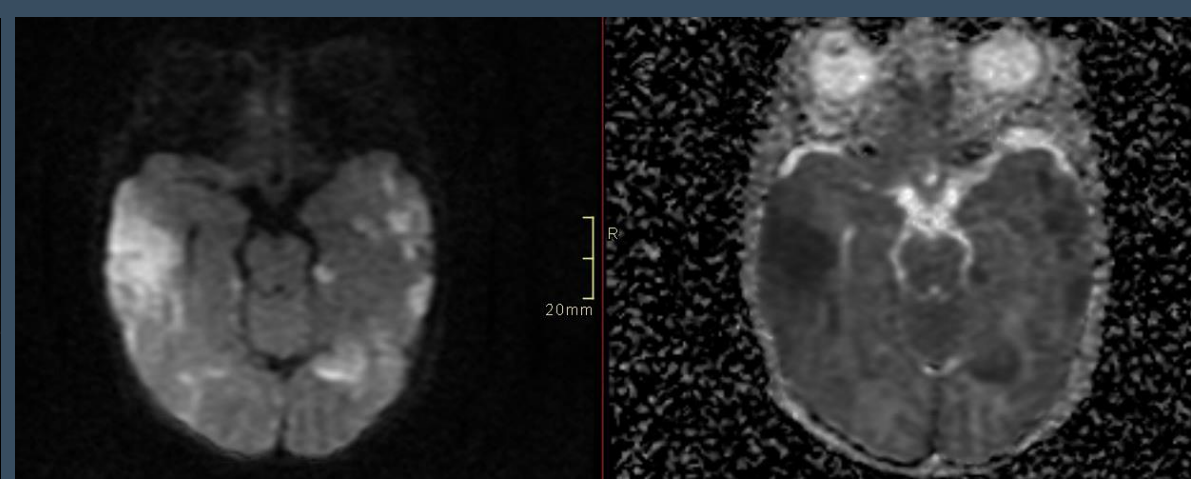
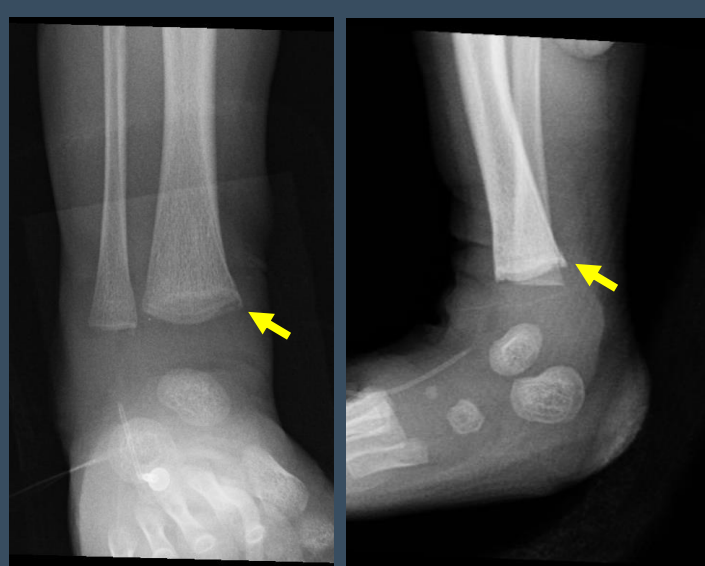
# AHT Subdural Hemorrhage

- SDH
  - Most common intracranial imaging finding, up to 90% (Bradford, 2013)
  - Hypodense and hyperdense components can be seen with acute and chronic ICH
- Challenges:
  - Birth-related SDH
    - Frequent but resolve within 4-6 post-natal weeks and do not appear to rebleed (Choudhary 2018)
  - Benign Enlargement of Subarachnoid Space (BESS)
    - Differentiate from SDH: no compression of gyri, veins
    - BESS with SDH in <6%, assessment for trauma still recommended



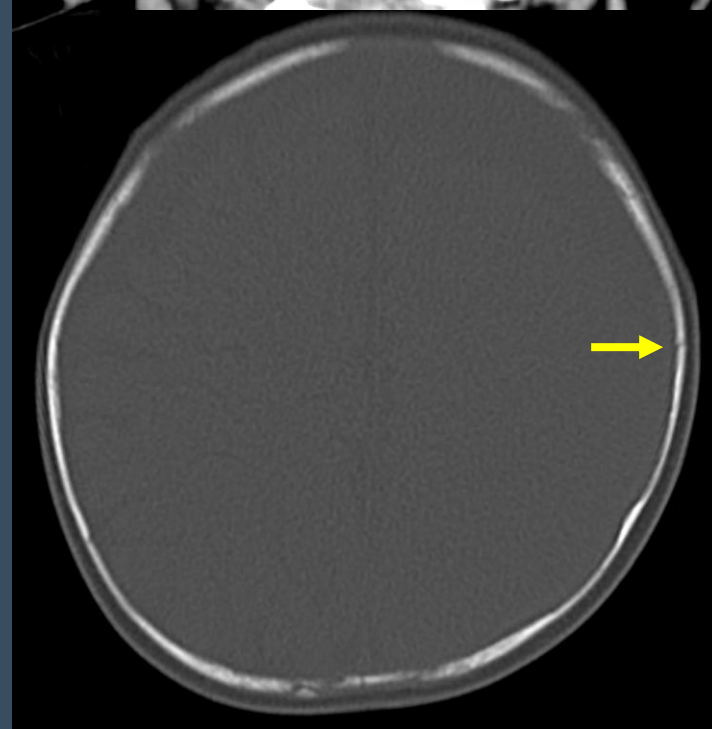
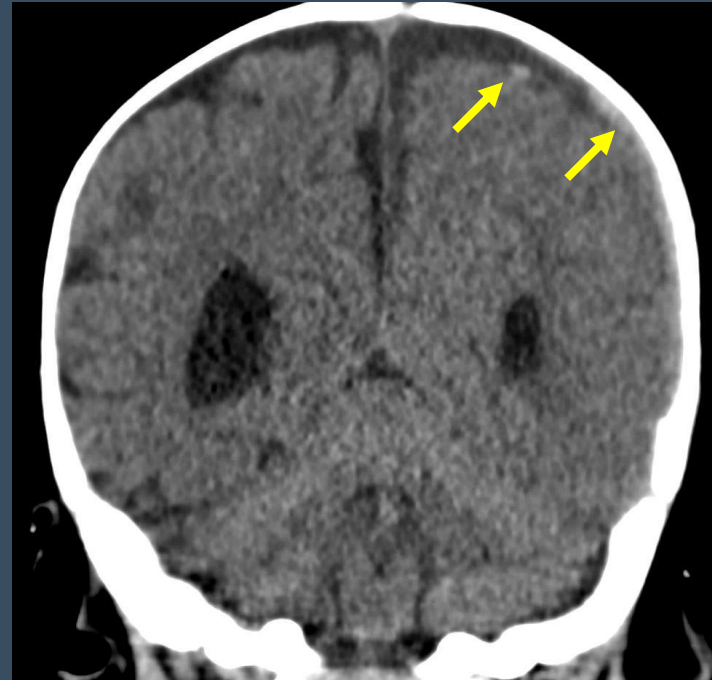
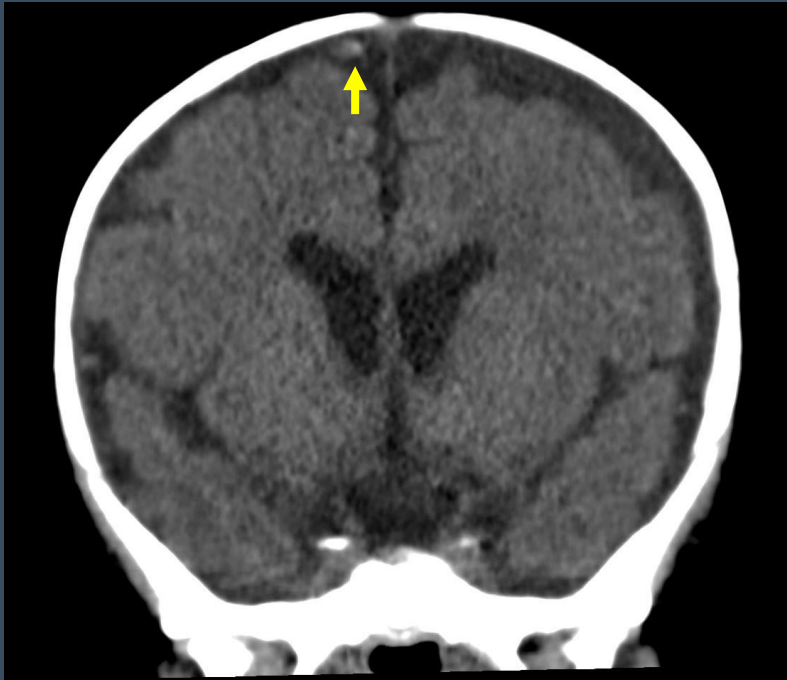
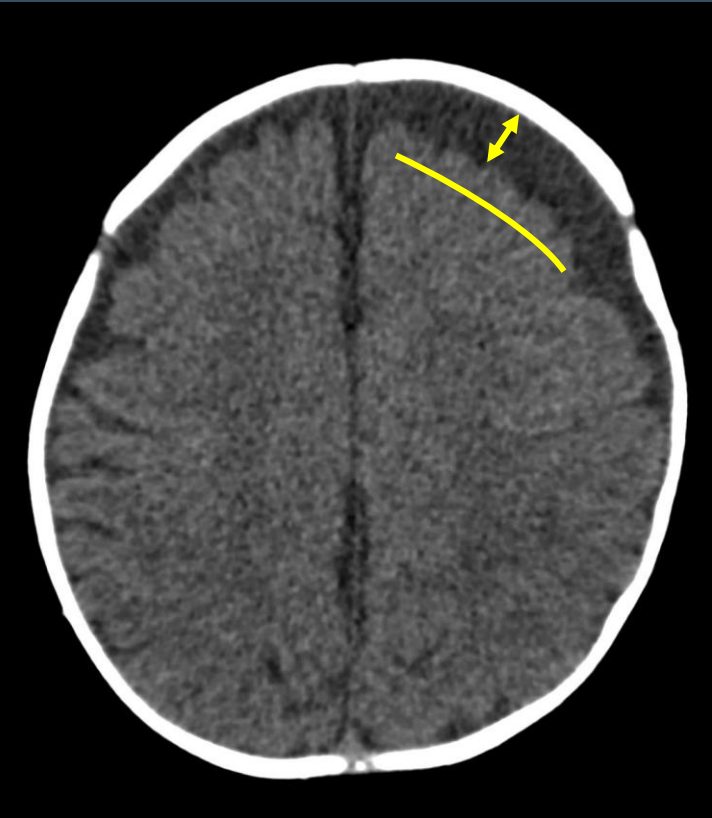


Modified babygram – ↓sensitivity for ↑specificity fractures of abuse



3-week-old with poor feeding and fatigue

- Healing CML
- SDH
- Temporal, parietal-occipital diffusion restriction
- DAI



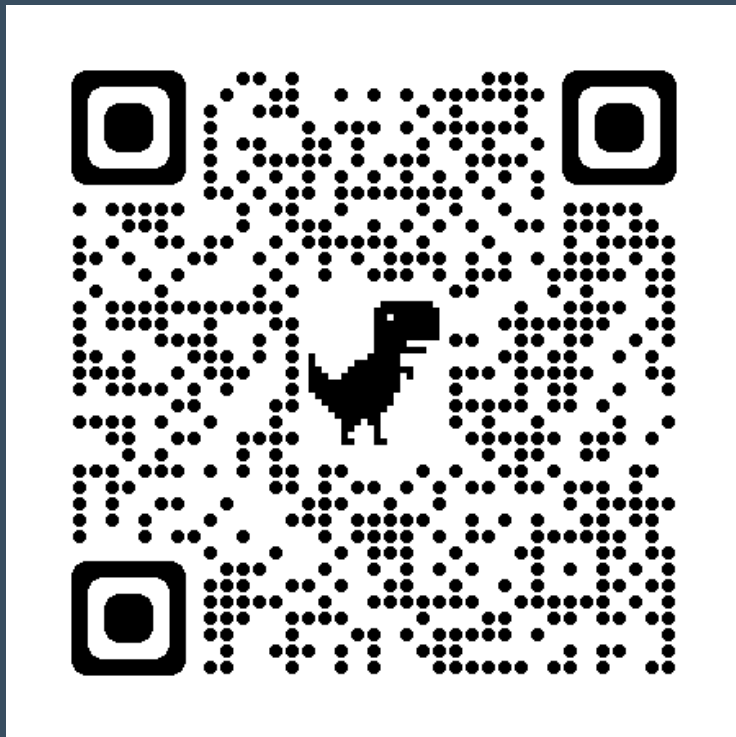
### 3-Month-Old with Emesis

- Initial head CT interpreted as BESS with recommendation for follow-up MRI if warranted
- Follow-up shows thrombosed bridging vein, acute on chronic subdural hemorrhage, chronic skull fracture
- Retinal hemorrhages on fundoscopic exam

# AHT

## Teaching Point

Cerebral sinovenous thrombosis, hypoxic-ischemic injury, lumbar puncture or dysphagia, choking/vomiting are NOT causative in the constellation of injuries in AHT.



Choudhary AK, Servaes S, Slovis TL, Palusci VJ, Hedlund GL, Narang SK, Moreno JA, Dias MS, Christian CW, Nelson MD, Silvera VM. Consensus statement on abusive head trauma in infants and young children. *Pediatric Radiology*. 2018 Aug;48:1048-65.



# Summary

- Be vigilant
- Communicate
- Babygrams are not skeletal surveys
- High-specificity fractures relate to mechanism of injury
- AHT vs birth injury + BESS





**Every life deserves world class care.**