REVIEW OF MUSCULOSKELETAL INJURIES IN PEDIATRIC NON- ACCIDENTAL TRAUMA

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BACKGROUND AND STATISTICS

- The intentional infliction of pain and suffering, both physical and emotional, on children is a distressingly common occurrence.

- Categorized as neglect (63%), physical abuse (19%), sexual abuse (10%), and psychologic abuse (8%).

- In the United States, approximately

  - 702,000 cases reported in 2014
  - 1,200 children fatalities
  - 1825 cases of abuse / day

- Children less than 1 year of age account for 44% of all abuse-related fatalities.

HISTORY

First description of child physical abuse was by the French forensic physician Ambrose Tardieu in 1860.

Battered Child Syndrome (Tardieu Syndrome)

Nurse Admits Shaking Three Babies to Death

They Refused to Take Formulas and Got on Her Nerves, She Explains to Police

August 28, 1956

New Haven, Conn.

Miss Virginia B. Jaspers

John Caffey

On the Theory and Practice of Shaking Infants

Its Potential Residual Effects of Permanent Brain Damage and Mental Retardation

John Caffey, MD, Pittsburgh

In the first modern discussion in 1946 of the parent-infant stress syndrome (PITS), or battered baby syndrome, I described six infants, 13 months or younger, who suffered from the combination of subdural hematomas and characteristic bone lesions.[1] During the last 25 years[2-5] substantial evidence, both manifest and circumstantial, has gradually accumulated which suggests that the whiplash-shaking and jerking of abused infants are common causes of the skeletal as well as the cerebrovascular lesions; the latter is the most serious acute complication and by far the most common cause of early death.[6]

Today we invite your attention to

John Caffey, MD

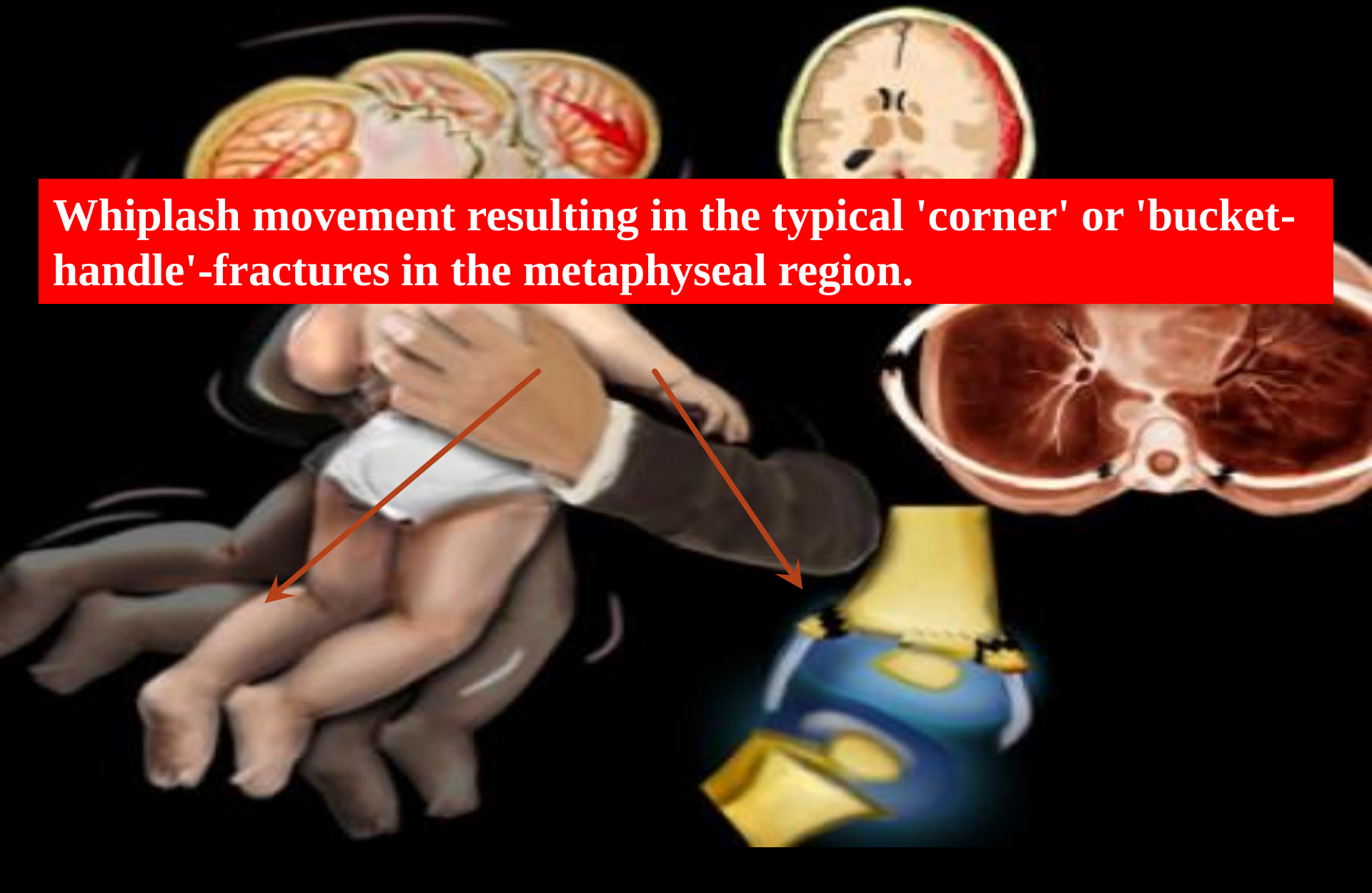
line of demarcation between pathogenic and nonpathogenic shaking is often vague.

The nature and distribution of the bone lesions in the PITS must be interpreted from the radiographic changes exclusively because they have not been studied systematically at either surgical exploration or necropsy. The metaphyseal avulsions are the most common of these lesions. Some are small fragments of cortical bone torn off the external edge of the cortical wall at the metaphyseal levels where the periosteum is most tightly bound down to the cortex. In most cases, however, they appear to be small chunks of calcified cartilage which have been broken off the edges

SHAKEN BABY SYNDROME

Chest is compressed resulting in rib fractures

SHAKEN BABY SYNDROME



Whiplash movement resulting in the typical 'corner' or 'bucket-handle'-fractures in the metaphyseal region.

SHAKEN BABY SYNDROME

BEHAVIORAL CLUES

- Excessive crying or developmental delay
- Fear, anxiety, clinging
- Phobias
- Nightmares, sleeping problems
- Social withdrawal
- Hyperactivity
- Poor concentration/distractibility

PHYSICAL SIGNS

- Fractures / Dislocations
- Bruising , Bites
- Cigarette burns
- Ear trauma / Lacerations
- Traumatic hair loss
- Retinal hemorrhage
- Head Injury, Subdural hematoma

ROLE OF THE RADIOLOGIST

- Physicians and other allied health professionals are mandated by law in all 50 states and the District of Columbia to report suspected abuse within 48 hours to Children's Protective Services

- 31% of confirmed abusive cases were missed on initial presentation and many infants sustained additional injury because of the delay in diagnosis

- Wide range of findings, which mimic other disease processes

- First to suggest the diagnosis :

  - High level of suspicion and awareness of the existence of child abuse

  - Discrepancy between history and severity of fractures

RADIOGRAPHIC APPROACH

Mental or physical trauma is central to all cases of child abuse

Osseous injuries are a major facet of child abuse & radiographic imaging plays a vital role in diagnosis.

Injuries are typically produced as a result of excessive and inappropriate force

RADIOGRAPHIC APPROACH

- Typical injuries- Metaphyseal lesion, rib fractures

- Every type and location of fracture has been documented in abused children

- Fracture is documented in 11%–55% of physically abused children

  76% long bones

  8% skull

  8% the ribs

- Atypical/Non specific injuries - but suspicious when the history is inconsistent with the type of injury.

DISCORDANT HISTORIES

A toddler's fracture of the tibia in an infant who is not yet ambulatory and therefore not "toddling"

Complex skull fracture in an infant who "fell from a bed "

IMAGING

BABYGRAM

Babygram examinations are **NOT** considered sufficient for diagnosis

- Babygram examinations include the entire body imaged together on one film

- Loss of detail at the periphery of the field of view as the beam becomes angulated to the anatomic part in question

- Radiographic technique varies depending on the density of the body part

IMAGING

Radiographic skeletal survey includes

AP views of all the bones of the appendicular skeleton

AP and lateral views of the skull

ALL ON SEPARATE FILMS !!!!!!!

AP view of the chest

AP view of the abdomen

AP view of the pelvis all on separate films

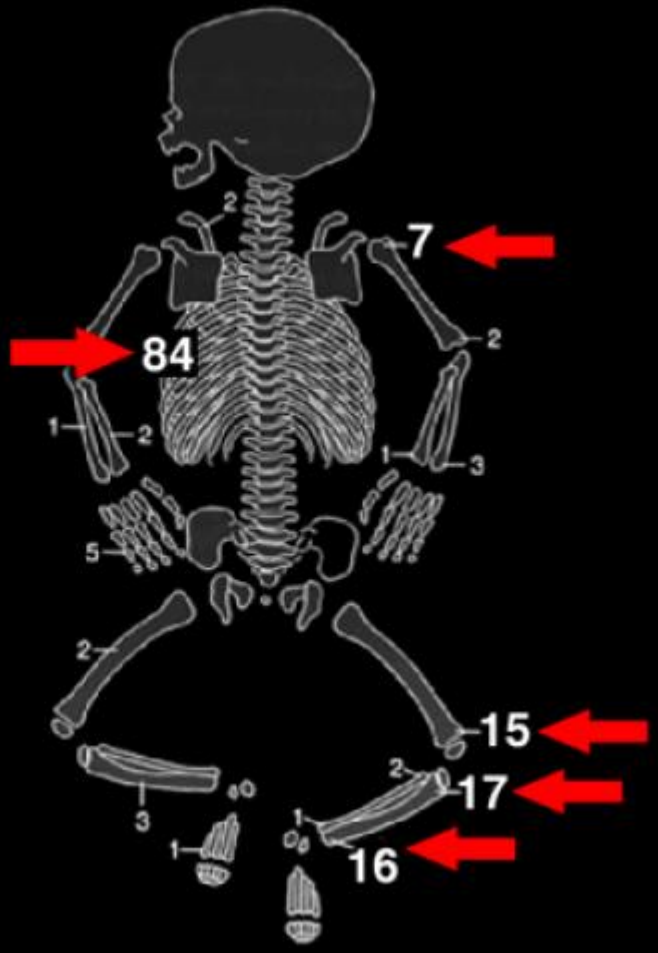
ADDITIONAL IMAGING MODALITIES

- CT scan may be necessary to evaluate for intracranial and solid organ injury, confirmation of radiographically subtle fractures

- Bone scintigraphy is highly sensitive but expectedly non specific;

  - Normal high uptake in the region of the growth plate obscures physeal injury

FRACTURE INCIDENCE



Kleinman P, ed. *Diagnostic Imaging of Child Abuse.* St Louis, MO: Mosby Inc; 1998

SPECIFICITY	INJURY
High	Classic metaphyseal lesions
	Multiple rib fractures especially posterior
	Scapular fractures
	Sternal fractures
	Clavicular fractures
	Spinous process fractures
Moderate	Multiple fractures
	Fractures in various stages of healing
	Epiphyseal separations
	Vertebral body fractures and separations
	Digital fractures
	Complex skull fractures
Low	Sub periosteal new bone formation
	Clavicular fractures
	Long-bone shaft fractures
	Linear skull fractures

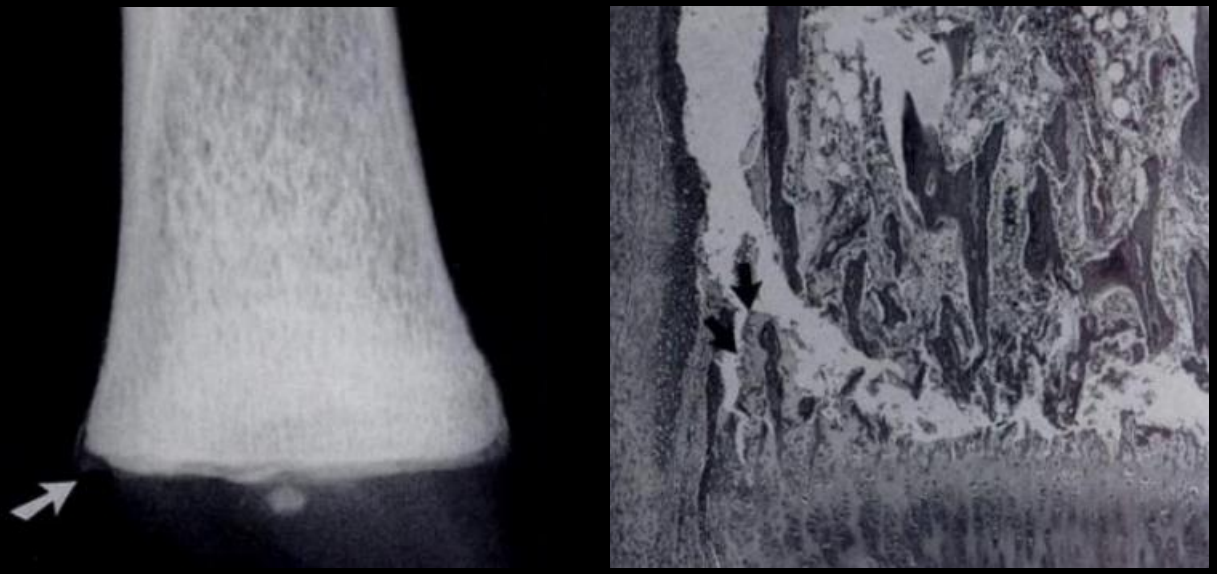
Kleinman P, ed. *Diagnostic Imaging of Child Abuse*. St Louis, MO: Mosby Inc; 1998

METAPHYSEAL FRACTURES

METAPHYSEAL FRACTURES

- One of the most salient radiographic features of NAT
- Most common tibia, distal femora and proximal humeri
- Indirectly applied forces
- Likelihood of detection directly related to technique
- Specificity decreases beyond infancy
- Avulsed fragments of bone at sites of periosteal attachment or zone of provisional calcification

METAPHYSEAL FRACTURES

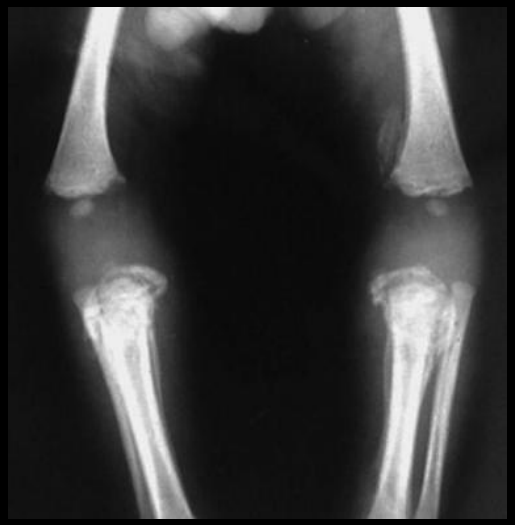


Fracture occurs through primary medullary spongiosa

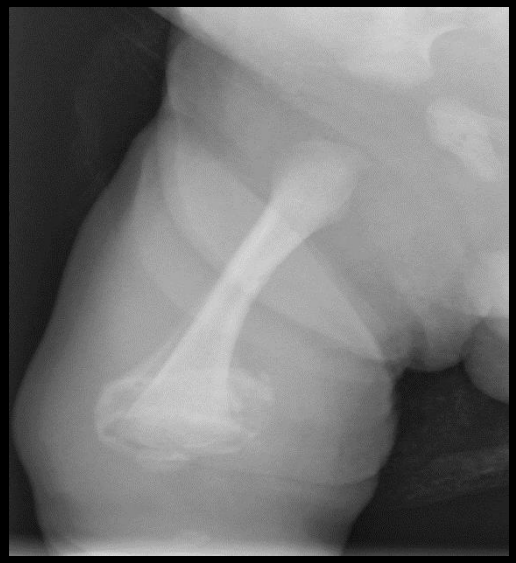
Kleinman P, ed. *Diagnostic Imaging of Child Abuse*. St Louis, MO: Mosby Inc; 1998

BUCKET HANDLE FRACTURES

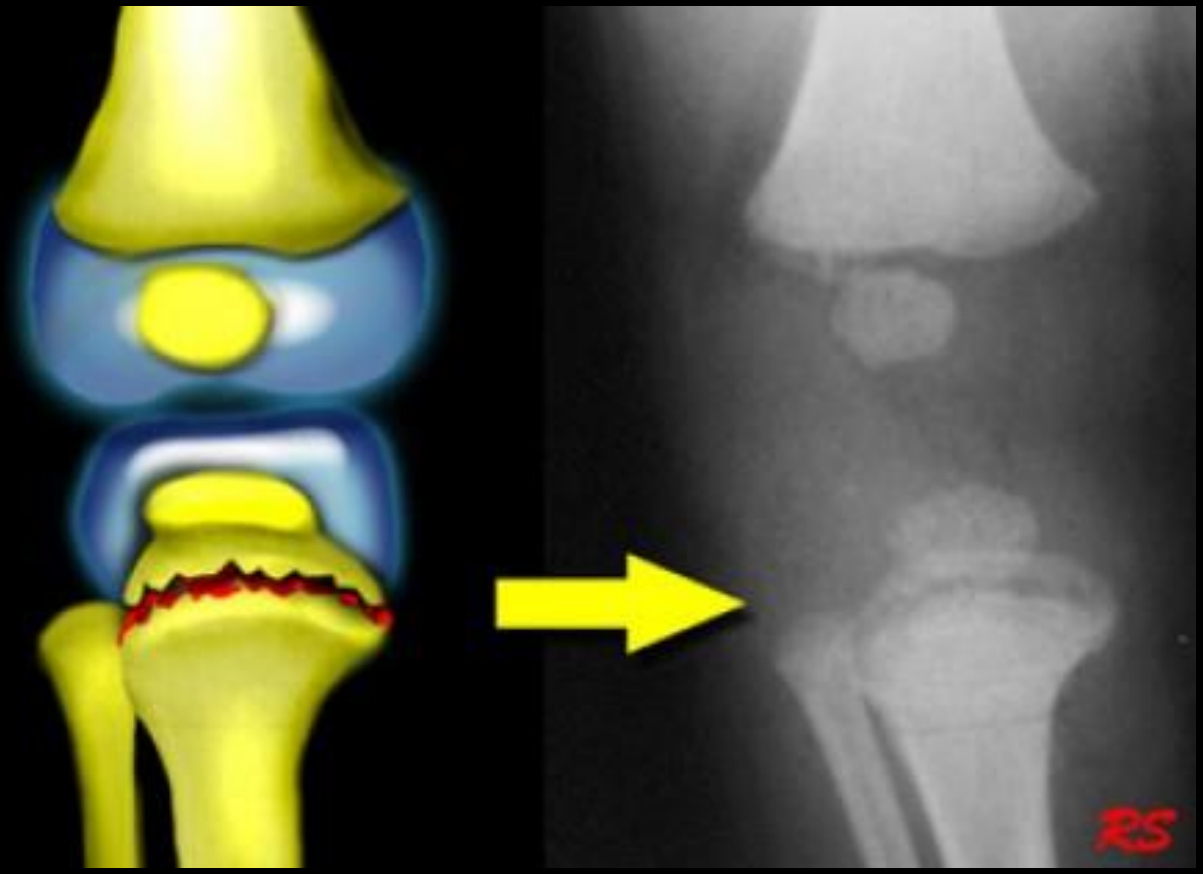
- Essentially the same as metaphyseal corner fracture



- Larger avulsed bone fragment seen 'en face' as a disc or “bucket handle”



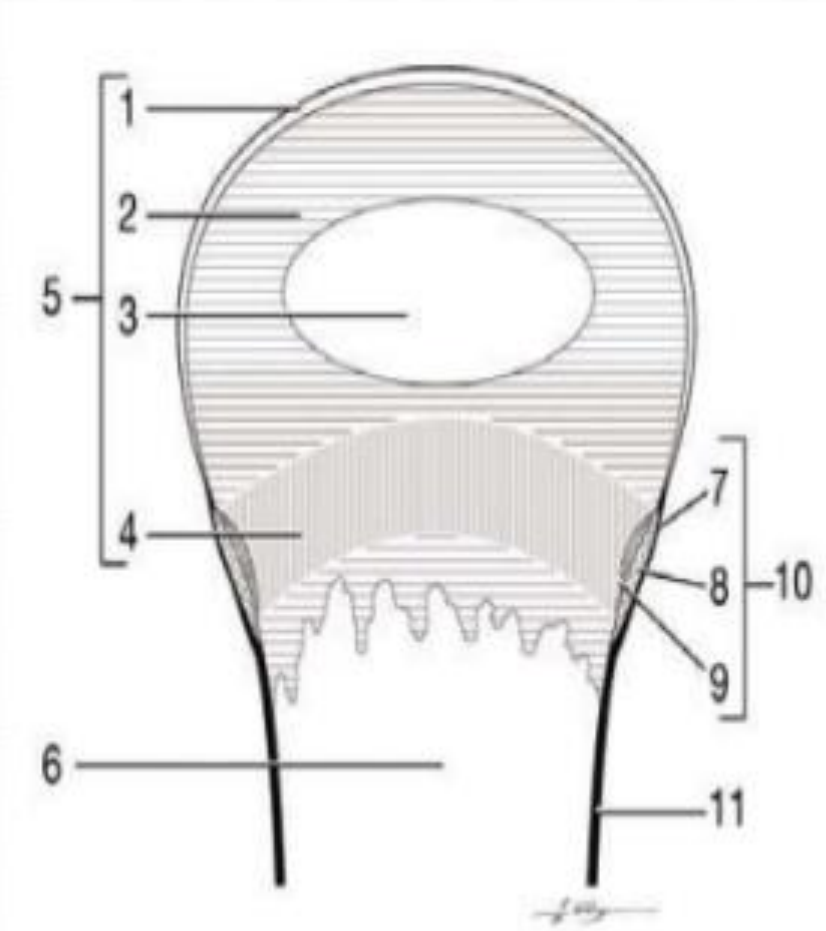
BUCKET HANDLE FRACTURES



www.radiologyassistant.nl/en/diagnostic-imaging-in-child-abuse.html

Components of the Epiphysis and Metaphysis

- (1) Articular cartilage
- (2) Epiphyseal cartilage
- (3) Secondary center of ossification;
- (4) Epiphyseal plate;
- (5) Epiphysis;
- (6) Metaphysis;
- (7) Fibrous layer of the periosteum;
- (8) Ringof LaCroix;
- (9) Groove of Ranvier;
- (10) Fibrous components of the epiphyseal plate;
- (11) Cortical bone.

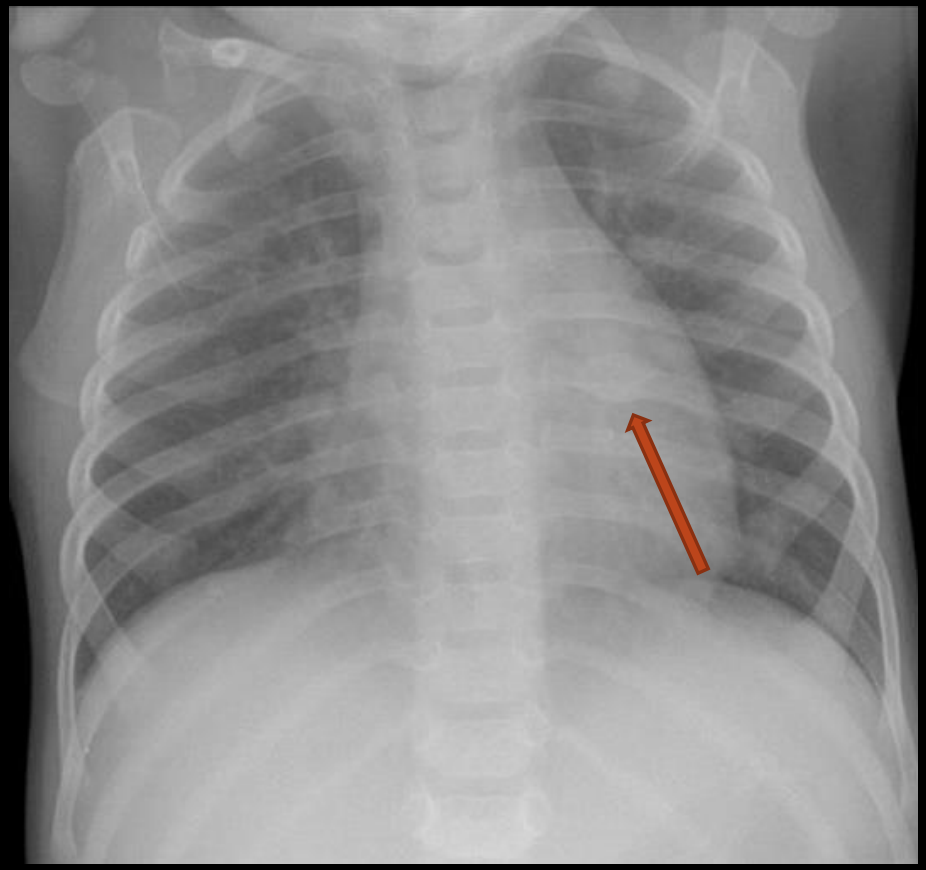


PITFALLS

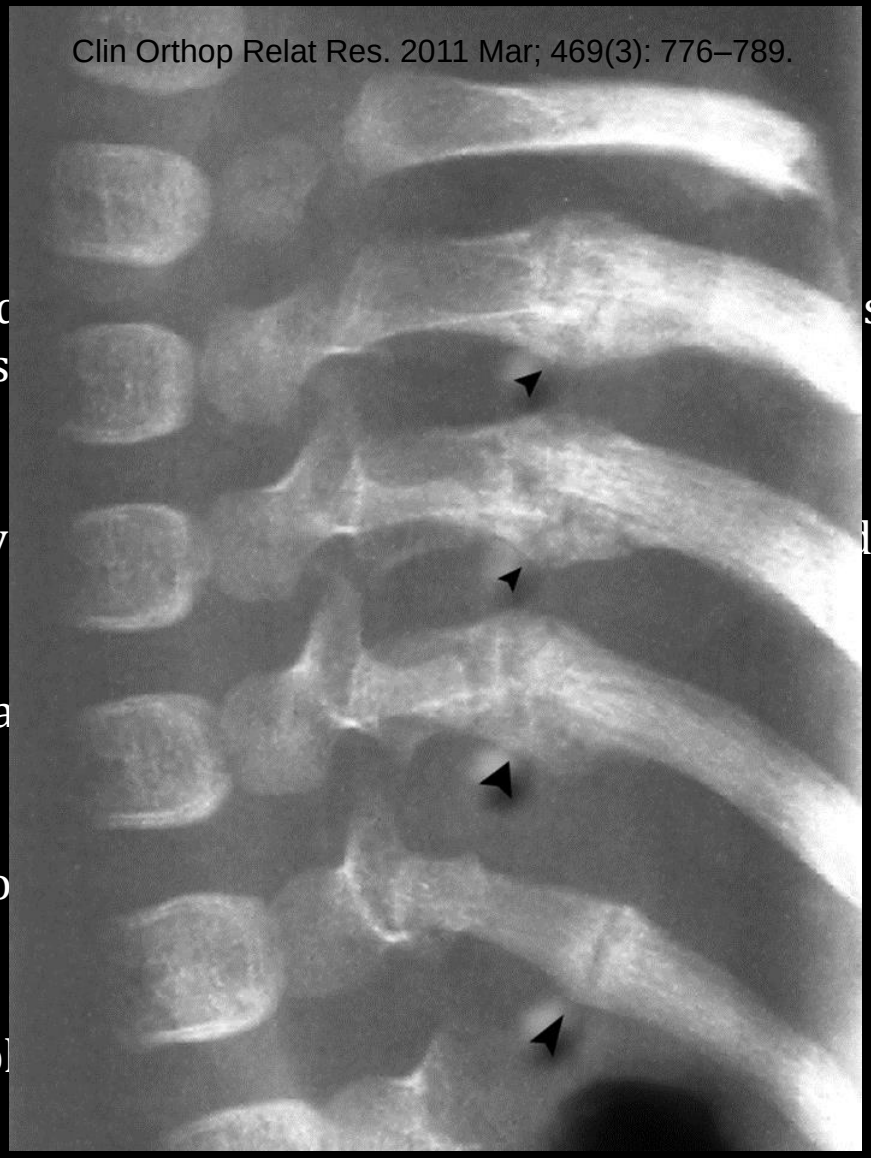
Ring of Lacroix / Groove of Ranvier

Clin Orthop Relat Res. 2011 Mar; 469(3): 776–789.

MULTIPLE POSTEROMEDIAL RIB FRACTURES

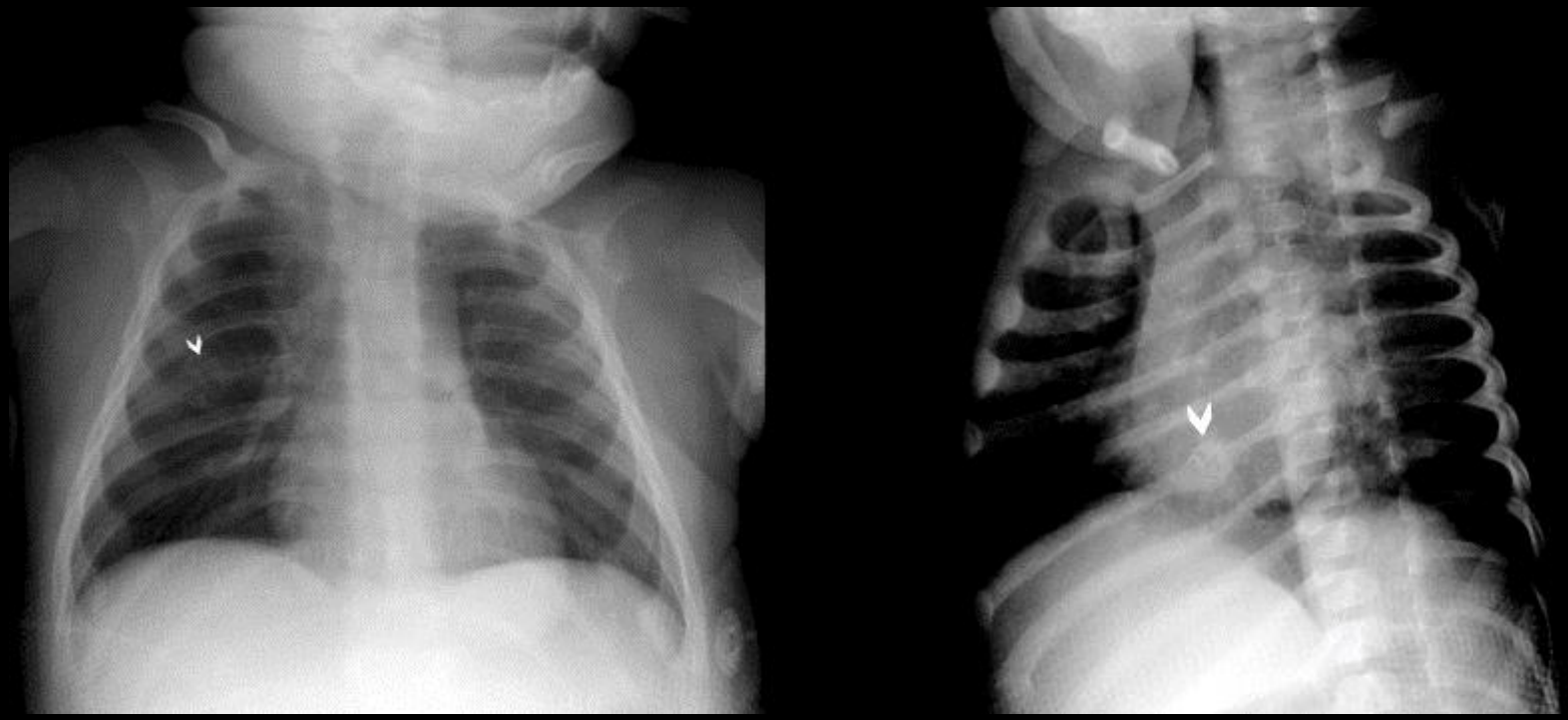


MULTIPLE POSTEROMEDIAL RIB FRACTURES



- Posteromedial rib
- Can only be caused steromedial ribs against transverse process
- Does NOT occur w – CPR
- Identification of ca
- Role of CT – ease o
- Oblique radiograp

MULTIPLE POSTEROMEDIAL RIB FRACTURES



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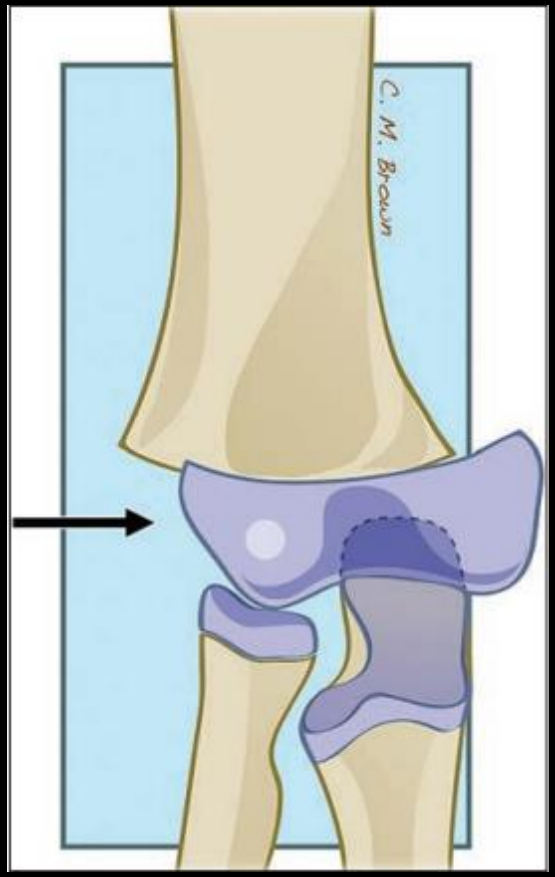
EPIPHYSEAL SEPARATION

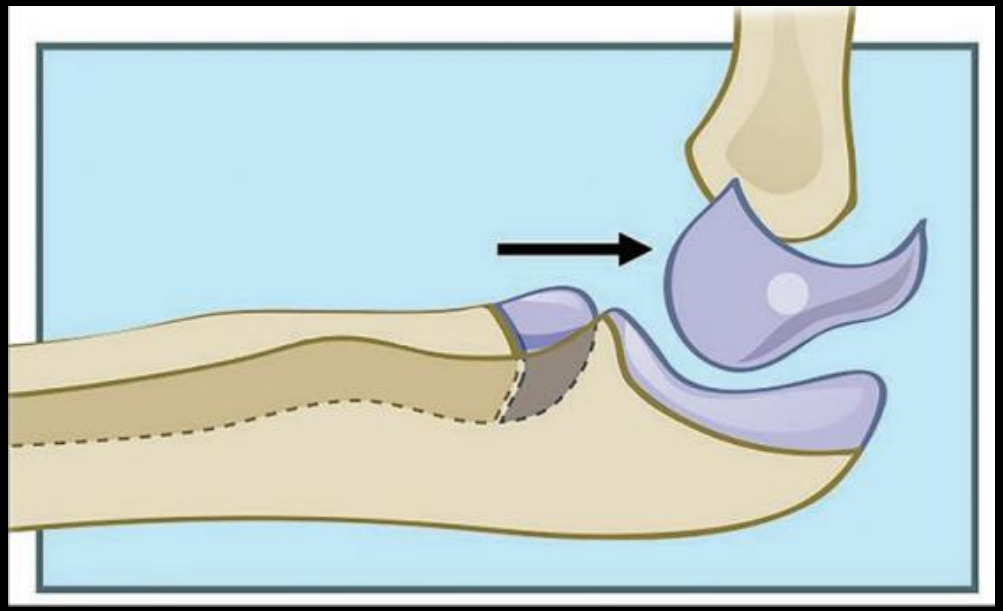
- Moderate specificity ; often over looked
- Fracture occurs through the cartilaginous physis – separation of epiphysis
- Epiphysis frequently non-ossified – missed by in experienced observer
- Most common – distal humeral epiphysis

EPIPHYSEAL SEPARATION

- Often misdiagnosed as dislocation
- Radius and ulna move medially and posteriorly with respect to the humeral metaphysis
- Fibrous joint capsule is less fragile than the physis; Elbow dislocations **DO NOT** usually occur in infants
- Ultrasound / MRI for confirmation
- Ultrasound is preferred - No sedation required

EPIPHYSEAL SEPARATION





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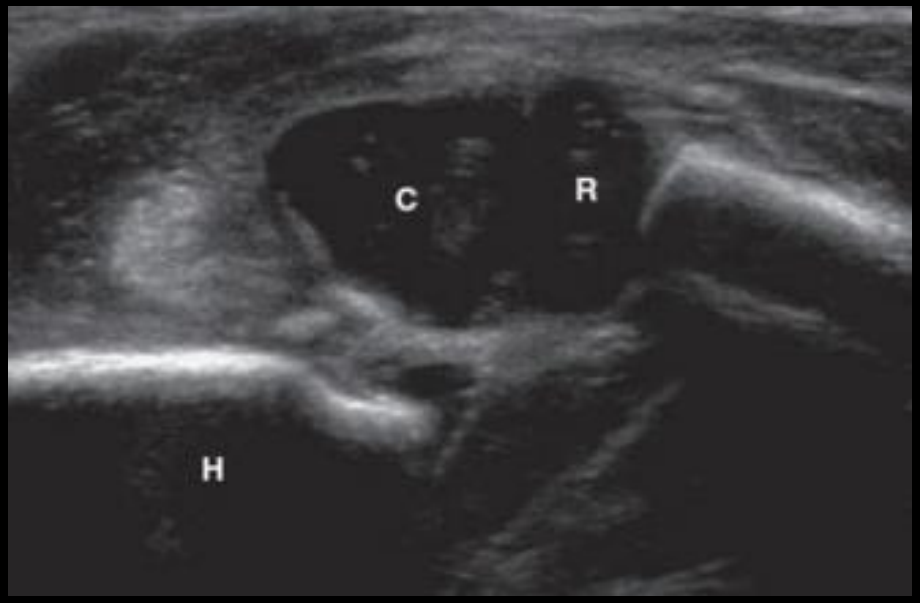
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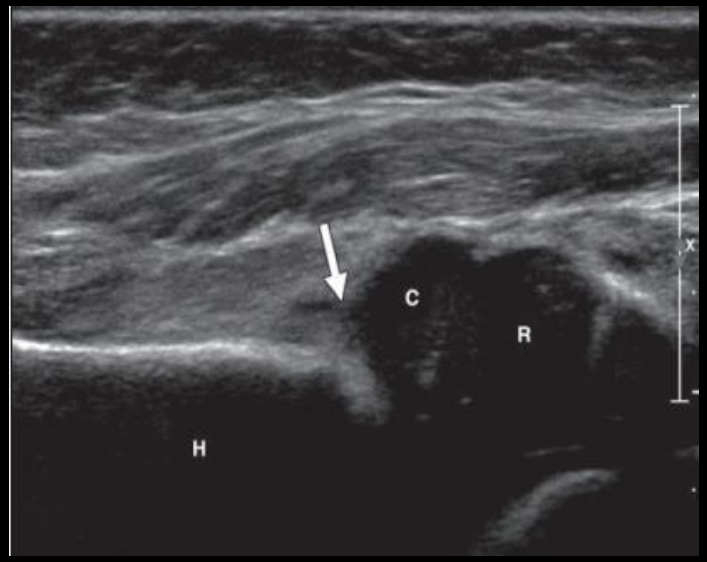
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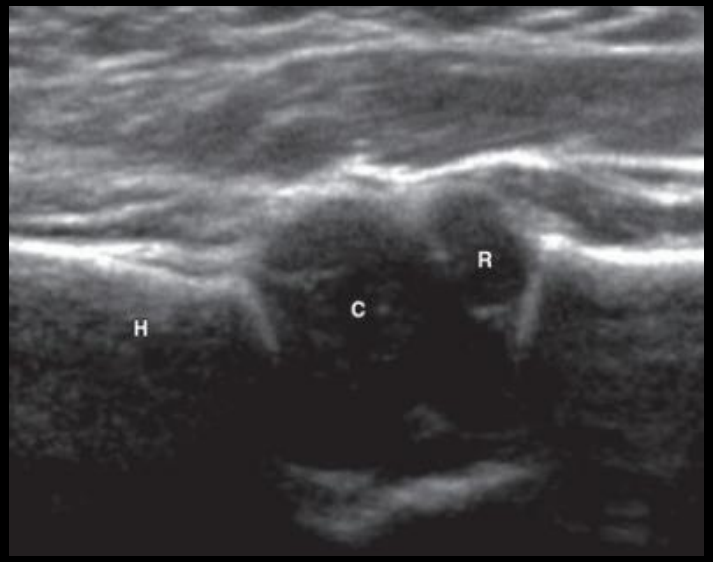
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Pediatric Radiology, 1995, Volume 25, Number 7, Page 562
K. Nimkin, P. K. Kleinman, S. Teeger

MULTIPLE FRACTURES OF VARYING AGE

- Moderately specific ; multiple fractures in varying stages of healing

- High index of suspicion – erroneous diagnosis is socially devastating for the family

- Stages of fracture healing : (accelerated in infants)

  Resolution of soft tissue swelling - 4 to 10 days
  Sub periosteal new bone formation - 10 to 14 days;
  Immature or soft callus - 14 to 21 days
  Loss of fracture line definition -14 to 21 days; and
  Mature or hard callus - > 21 days

- Callus may be markedly delayed in osteopenic patients

MULTIPLE FRACTURES OF VARYING AGE

- Intra- articular fractures : NO callus formation at fracture site (absence of periosteum)

- Periosteal elevation / reaction more proximally in the bone away from the joint

- Lateral condylar corner fracture; sub periosteal new bone formation in the diaphysis and metaphysis, ending at the capsular origin

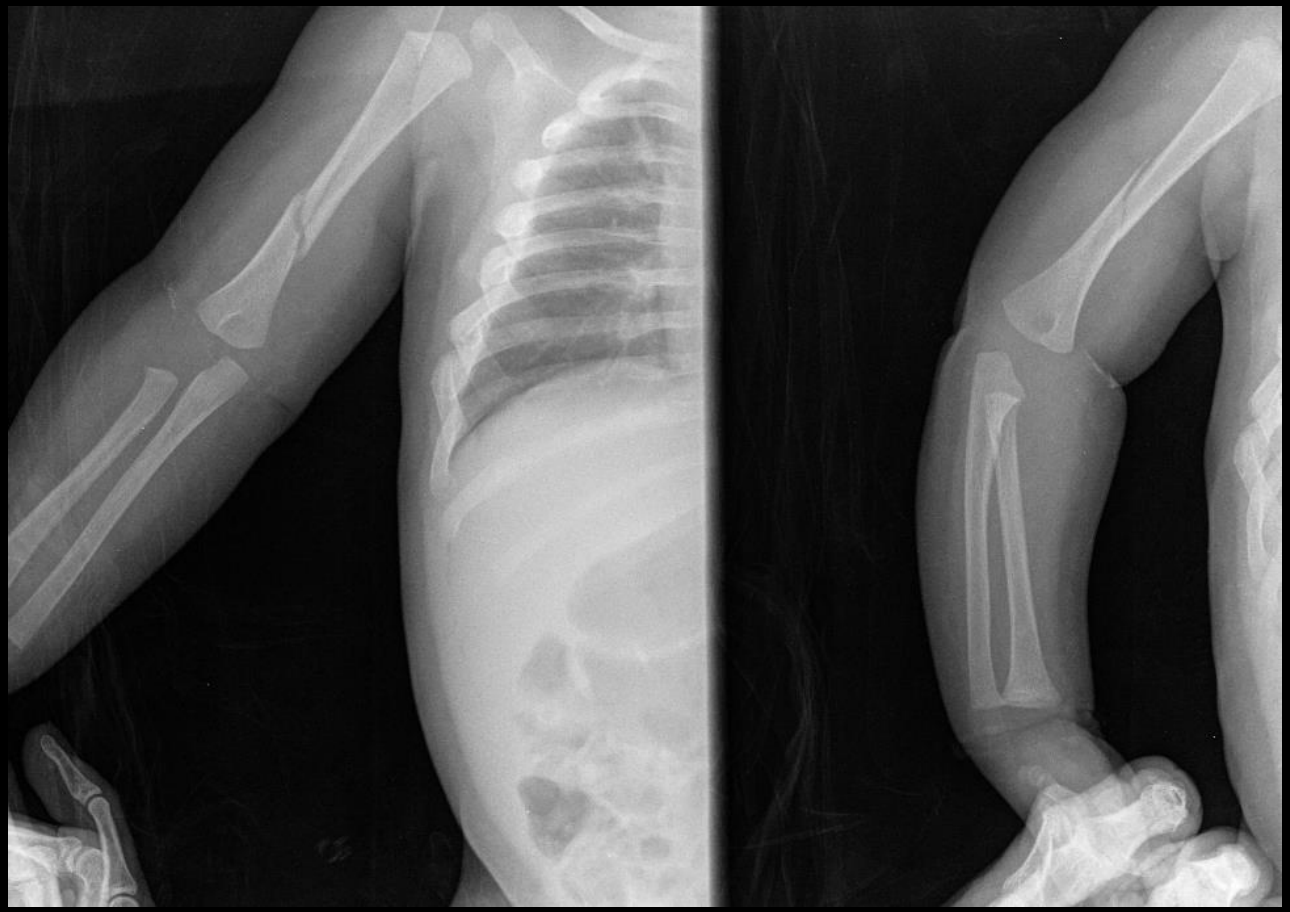
LONG BONE FRACTURES (TODDLER'S FRACTURE)

Low specificity but extremely common (39-93 %)

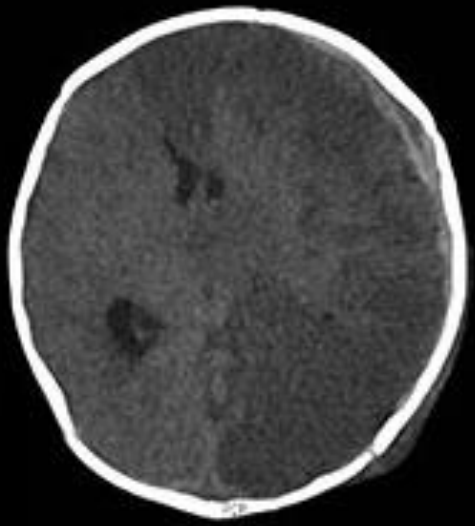
Spiral & Transverse fractures – most common

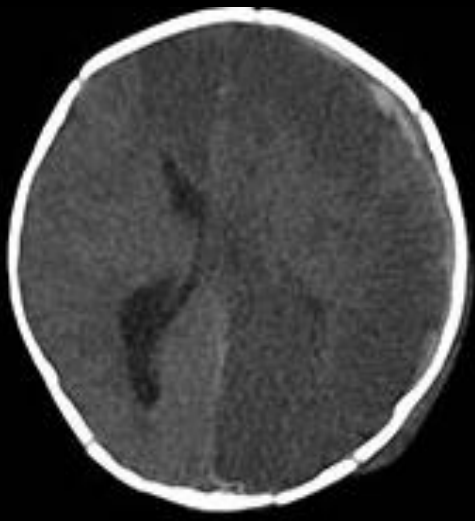
Femoral fractures in children < 3 years age highly suspicious

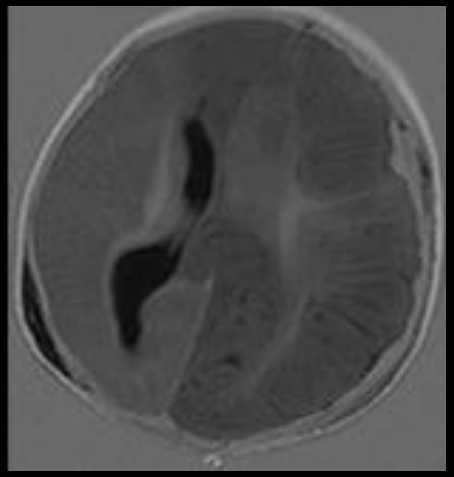
LONG BONE FRACTURES (TODDLER'S FRACTURE)

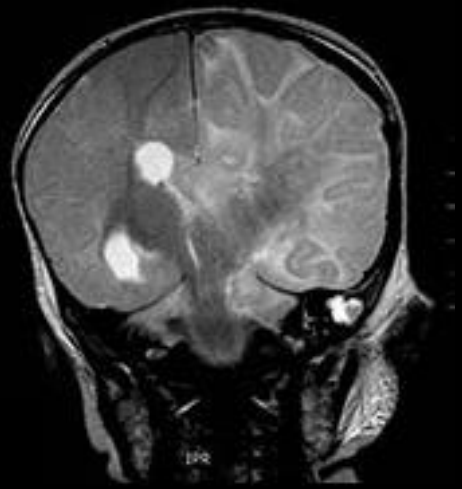


SKULL FRACTURES



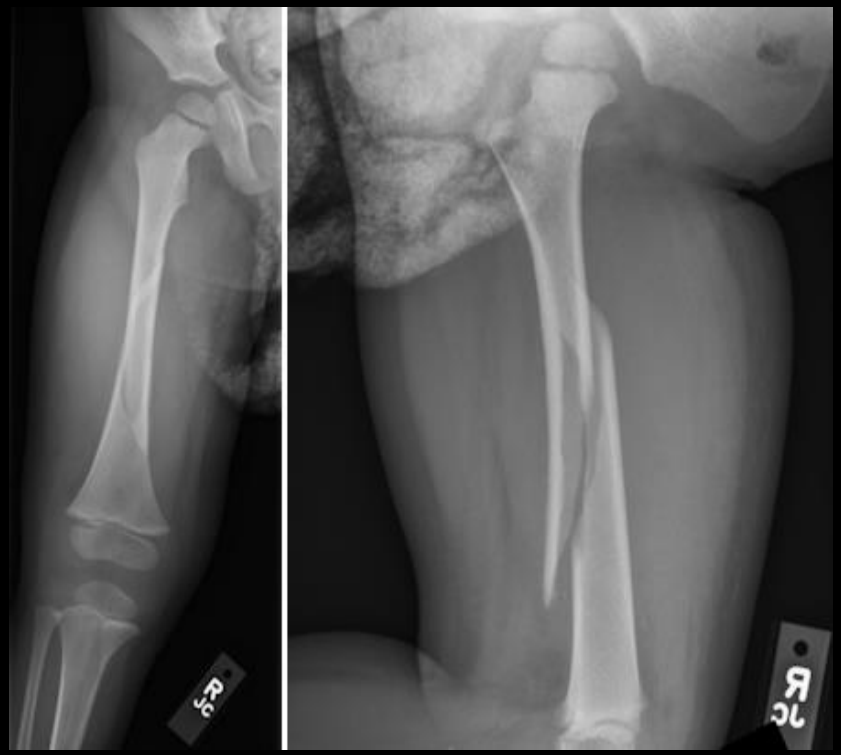






DIFFERENTIALS

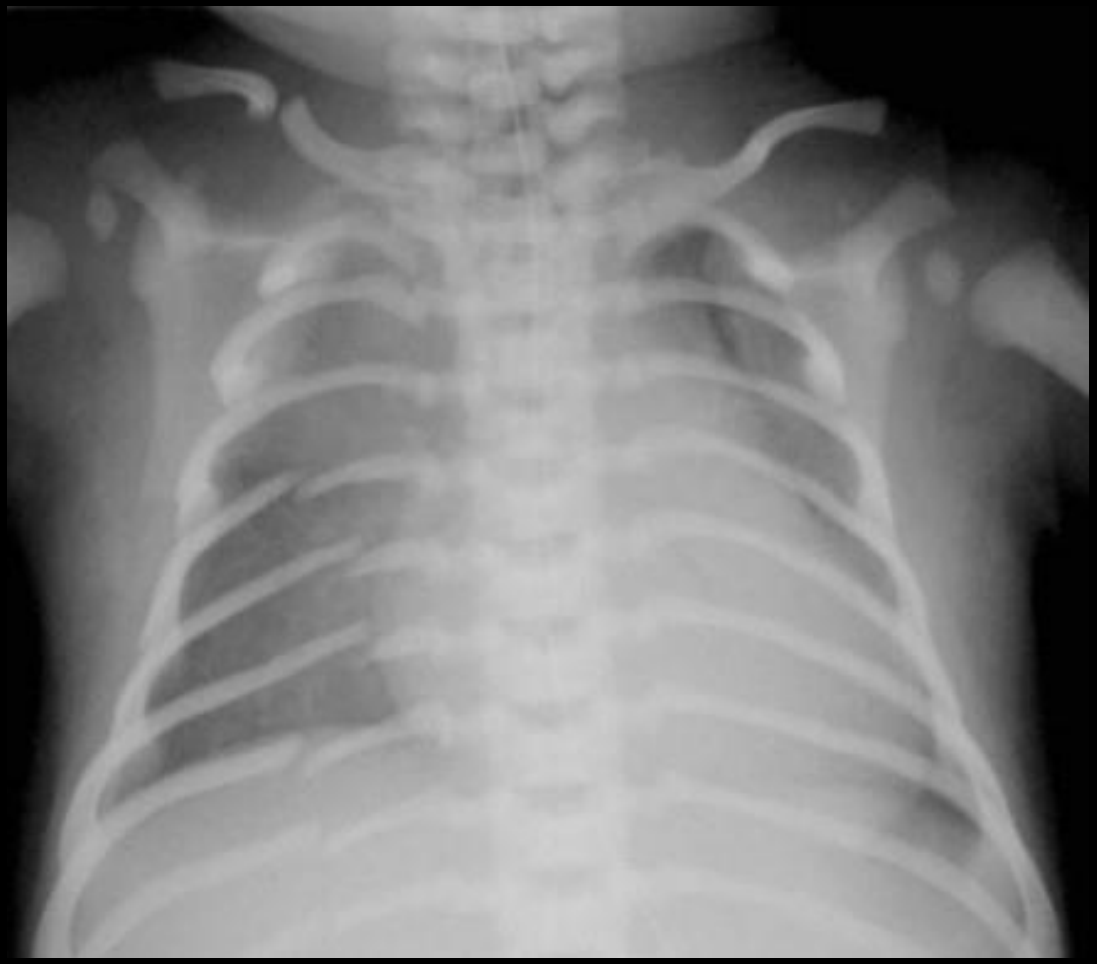
RICKETS



RICKETS

- Rickets is a very common cause of osteopenia
- Osteopenia is commonly present in premature children and other hospitalized children
- Premature children can sustain multiple fractures including classic CMLs
- Detailed clinical and social history
- Accurate dating of fractures
- Posteromedial rib fractures are ALWAYS suspicious !!

ACCIDENTAL INJURIES



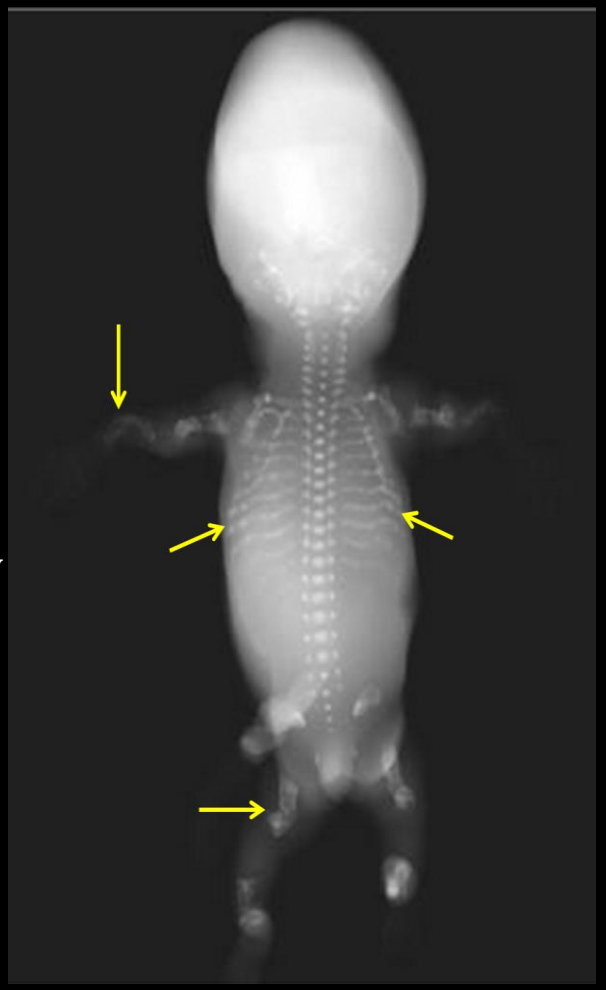
ACCIDENTAL INJURIES

- History is clear and consistent
- Findings reflect severity of forces
- No unexplained skeletal injuries are identified
- Birth trauma possible cause of rib fractures in infants, but is extremely rare
- Rib fractures require significant force ; chest wall is more elastic allowing for greater compression
- CPR does not cause posterior rib fractures

OSTEOGENESIS IMPERFECTA

OSTEOGENESIS IMPERFECTA

- Increased bone fragility; multiple fractures
- Complexity and variability make differentiation from abuse very challenging
- Mutation and biochemical collagen analysis are frequently performed
- Rib fractures usually lateral vs posteromedial in NAT
- CML exceedingly rare in OI



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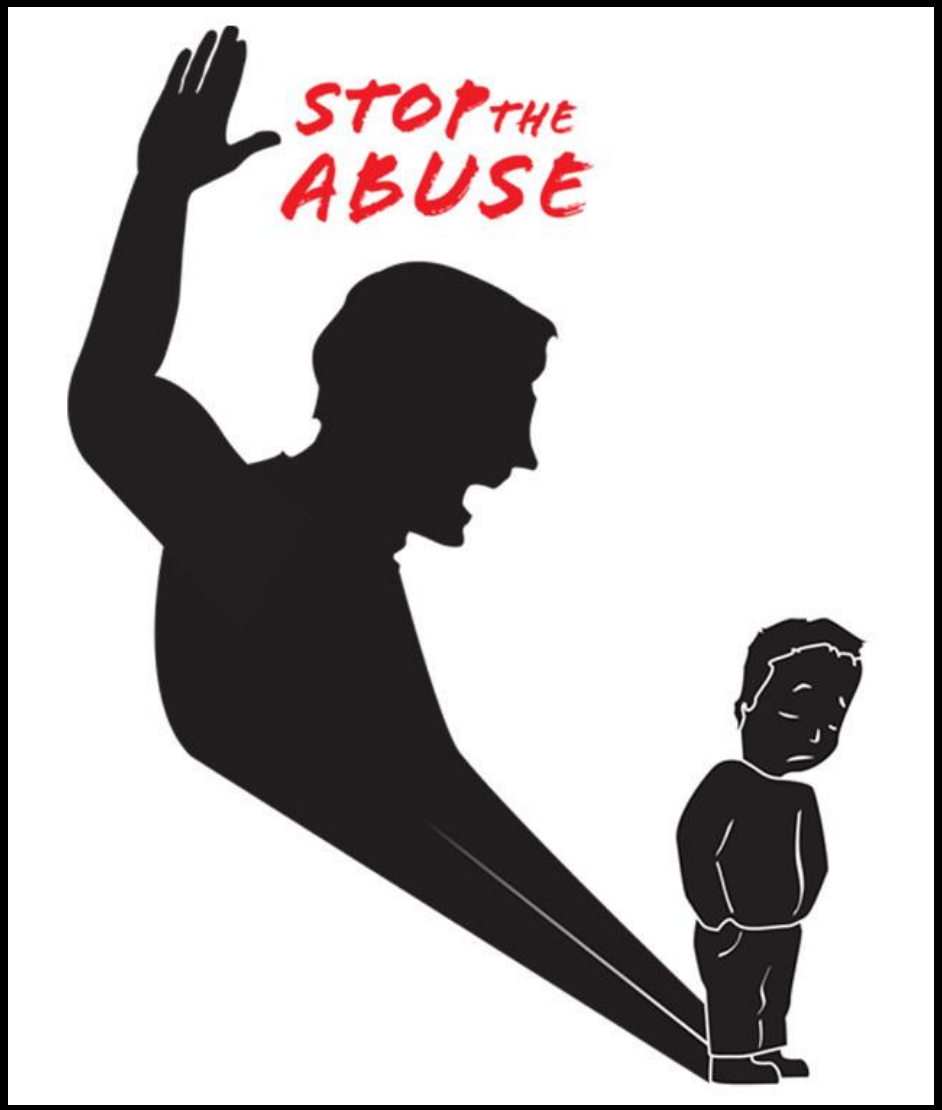
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ABUSE