Radiologic Assessment of Child Abuse in Infants: A Focus on Plain Film Analysis of Highly Specific Fractures

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General Overview

- Introduction
- Case Presentation
- Menu of tests
- Diagnostic Pediatric Fractures
- DDx of Suspected Child Abuse
- Summary
General Overview of Child Abuse

- About 2 million children in the US are harmed or maltreated by their caretakers every year.

- In 2002, roughly 1,400 children died at the hands of their caretakers.

- Of these fatalities, 30% were as a consequence of physical abuse.

- Infants and young children are at greatest risk: an estimated 76% of these fatalities occurred in children under the age of 3 years.

While staggering, officials believe these numbers to be underestimations; many more children slip under the radar of officials and are continuously placed at the mercy of perpetrators.

There are certain key radiological musculoskeletal findings that can clue the medical community in to suspected child abuse.

This presentation will highlight how radiologists can play a crucial role in diagnosing child abuse, with a focus on musculoskeletal imaging.

We will focus on an index patient whose findings will highlight fractures of the lower extremities and thoracic cavity in infancy.
Our Index Patient

- 5 week old male in previously good health.

- Transferred to Children’s Hospital Boston from an OSH after mother presented to outside ED noting baby’s altered mental status.

- At OSH, head CT revealed subarachnoid, subdural, and intraparenchymal hemorrhage.

- Boy was transferred to CHB for further evaluation and for work-up of “non-accidental trauma” a.k.a. child abuse.
## Menu of Tests to Use in Evaluating Child Abuse

<table>
<thead>
<tr>
<th>TEST</th>
<th>INDICATIONS</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain Films</td>
<td>• Search for occult trauma in suspected child abuse</td>
<td>• Complete survey of entire skeleton</td>
<td>• Subtle acute fractures may not be detected on plain film</td>
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<tr>
<td></td>
<td>• Rule out non-accidental trauma in siblings of abused children</td>
<td>• Low doses of radiation</td>
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<td></td>
<td></td>
<td>• No sedation necessary</td>
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<tr>
<td>Computed Tomography (CT)</td>
<td>• Assess for ICH or skull fractures in cases of suspected head trauma</td>
<td>• Visualization of cerebral anatomy allows for detection of even subtle hematomas, edema, or parenchymal contusions</td>
<td>• Requires sedation</td>
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<tr>
<td></td>
<td>• Assess for ICH or skull fractures in cases of altered mental status</td>
<td>• Bone windows can be used to assess for skull fractures/widened sutures</td>
<td>• High doses of radiation administered to young children</td>
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## Menu of Tests

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| Magnetic Resonance Imaging (MRI) | - Suspected head trauma  
- Altered mental status  | - More sensitive than CT at detecting hemorrhages of different ages  
- Allows for detection of white matter shearing injuries | - Requires sedation  
- Long time required for study  
- Motion artifact |
| Bone Scintigraphy     | - Evaluation for occult fractures not identified on plain film  | - Increased sensitivity over plain film for detecting rib fractures, subtle shaft fractures, and areas of periosteal disruption | - Limited data re: sensitivity for subtle metaphyseal and spinal fractures  
- Sedation required  
- Insensitive for cranial injuries |

Findings supported suspicions of non-accidental trauma, a.k.a. child abuse. Now crucial to look for any occult MSK trauma. Next imaging step?
Guidelines for Imaging of Skeletal Injury in Suspected Child Abuse

<table>
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<tr>
<th>Age</th>
<th>Recommended Imaging</th>
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<tbody>
<tr>
<td>0 to 12 months</td>
<td>- Skeletal Survey +/- Scintigraphy</td>
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<td>- F/u Survey in 2 weeks</td>
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<tr>
<td>12 mo to 2 years</td>
<td>- Skeletal survey or scintigraphy</td>
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<tr>
<td>2 to 5 years</td>
<td>- Skeletal survey or scintigraphy if abuse strongly suspected</td>
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<tr>
<td>5 years and older</td>
<td>- Radiographs of individual sites of injury suspected on clinical grounds</td>
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Guidelines for Skeletal Survey

- **Indication**
  - Mandatory in all cases of suspected physical abuse in children younger than 2 years

- **Imaging Protocol**
  - **Appendicular skeleton**
    - Humeri (AP)
    - Forearms (AP)
    - Hands (oblique, PA)
    - Femurs (AP)
    - Lower legs (AP)
    - Feet (AP)
  - **Axial Skeleton**
    - Thorax (AP and lateral)
    - Pelvis (AP; including mid and lower lumbar spine)
    - Lumbar spine (lateral)
    - Cervical spine (lateral)
    - Skull (frontal and lateral)

- Images must be high-contrast and high-resolution.

# Diagnostic Utility of Radiologic Findings

<table>
<thead>
<tr>
<th>High Specificity Lesions</th>
<th>Classic Metaphyseal Lesions</th>
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<tbody>
<tr>
<td></td>
<td>Rib fractures (posterior especially)</td>
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<td></td>
<td>Scapular fractures</td>
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<td>Spinous process fractures</td>
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<td>Sternal fractures</td>
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<table>
<thead>
<tr>
<th>Moderate Specificity Lesions</th>
<th>Multiple fractures</th>
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<tr>
<td></td>
<td>Fractures at different ages</td>
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<tr>
<td></td>
<td>Epiphyseal separations</td>
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<td></td>
<td>Vertebral body fractures and subluxations</td>
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<td></td>
<td>Digital fractures</td>
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<td>Skull fractures</td>
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<tr>
<th>Low Specificity Lesions</th>
<th>Subperiosteal new bone formation</th>
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<tr>
<td></td>
<td>Clavicular fractures</td>
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<tr>
<td></td>
<td>Long bone fractures</td>
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<tr>
<td></td>
<td>Linear skull fractures</td>
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</table>
Skeletal Survey of Our Patient Revealed...

- Classic metaphyseal lesion of the right distal femur
  - AND
- Multiple healed posterior rib fractures
- These two findings are highly specific for abuse and corroborated the medical team’s suspicions.
Discussion on Diagnostic Findings

- Before we take a closer look at metaphyseal lesions, let’s review the anatomy of long bones!
Anatomy of Long Bones at Birth

During fetal development:

- Proliferation and hypertrophy of chondrocytes
- Concurrent mineralization of the bony matrix
- Increased diaphyseal compact bone
- Increased vascularity
- Appearance of secondary ossification centers

At birth:

- Calcified cartilage
- Epiphyseal (secondary) ossification center for head
- Outer part of periosteal bone beginning to transform into compact bone
- Medullary (marrow) cavity
- Epiphyseal capillary

The Infantile Long Bone’s Achilles’ Heels

Chondro osseous Junction (COJ)
- Density of cartilage here < that of cartilage in adjacent epiphysis
- Susceptible to planar fractures

Subperiosteal bone collar
- Rendered susceptible to fractures by physiologic resorption which causes normal flaring of ends

The Classic Metaphyseal Lesion (CML)

- Most highly specific radiologic injury for child abuse
- Results from tractional and torsional forces applied to infant limb.
- Forces planarly disrupt the metaphysis at the COJ.
- Fracture courses peripherally and encompasses the subperiosteal bone collar.

Fracture Patterns Characteristic of the CML

- Tangential views of the CML produces the corner fracture pattern.
- Angulation of the X-ray beam when projecting the CML yields the bucket-handle pattern.

Our Patient: The Corner Fracture CML

Findings:
- Asymmetric, transverse radiolucency in subphyseal region = plane of disruption (white arrows)
- Extension of the fracture line into the subperiosteal bone collar, forming asymmetric fragmented edges, or corner fractures (red arrows above)
Companion Patient: 6 month old with head injury

AP Plain Film of Right Distal Femur

Fracture encompassing subperiosteal bone collar

Synapse, Children’s Hospital Boston.

AP Plain Film of Left Distal Femur

Metaphyseal corner fracture

Synapse, Children’s Hospital Boston.
Companion Image: The Bucket-Handle CML

Image from Stritch School of Medicine, Loyola University Chicago. Use and utility of radiology in the work-up of suspected child abuse.
http://www.meddean.luc.edu/lumen/meded/Radio/curriculum/Pediatrics
Posterior Rib Fractures

- Next let’s evaluate another highly specific fracture: the posterior rib fracture.
**Posterior Rib Fractures**

- Very unusual even in setting of severe accidental trauma in infants
- Clinically occult
- Result from excessive anteroposterior compression of chest during shaking or with impact

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*Fig. 5-7*  Mechanism of injury, diagram. With anteroposterior compression of the chest, there is excessive leverage of the posterior ribs over the fulcrum of the transverse processes. This places tension along the inner aspects of the rib head and neck regions, resulting in fractures at these sites (arrows). This mechanism is also consistent with the morphologic patterns of injury occurring at other sites along the rib arcs and at the costochondral junctions (arrows).

Our Patient

Healed fractures of left 4th, 5th, 6th and 7th posterior ribs

Faint radiolucency = possible lateral fracture of 6th rib
Skull Fractures

- Lastly, let’s briefly evaluate skull fractures in the setting of child abuse.
Skull Fractures

- The skull is one of the most common sites of injury in non-accidental trauma, ranging from 7 to 30% of all fractures.
- Most fractures of the skull are dynamic injuries, from either blunt trauma of a mobile object to a stationary infant head or collision of a mobile infant with a stationary object.
Companion Patient: 6 month old boy with head injury

Fracture of the Parietal Bone

Differential Diagnoses for Radiologic Findings of Child Abuse

- Osteogenesis Imperfecta
- Rickets
- Osteomyelitis
- Congenital syphilis
- Scurvy
- Leukemia
- Accidental Trauma
- Obstetric Trauma
Narrowing the DDx

- The above conditions can present with radiologic findings similar to those found in child abuse.

- Radiologists and clinicians can use the following to help narrow their differential and make a definitive diagnosis.
  - Clinical history (is stated mechanism of injury consistent with radiologic findings?)
  - Presence of multiple fractures and fractures at different stages of healing
  - Presence of fractures highly specific for child abuse, such as the CML and posterior rib fractures
  - Absence of signs/symptoms that may be expected with other conditions on our differential.

- In so doing, radiologists can play key roles in protecting children who are victims of abuse.
Summary

- Child abuse affects more than 2 million American children each year.

- Musculoskeletal fractures are an important diagnostic manifestation of child abuse, and can be assessed via a skeletal survey when child abuse is suspected.

- Although multiple organic diseases, accidental trauma, and obstetric trauma may all account for pediatric fractures, certain fractures are highly specific and diagnostic for child abuse.

- Metaphyseal fractures of long bones and posterior rib fractures remain the pediatric fractures most highly specific for child abuse.

- Radiologists play a key role in identifying and diagnosing suspected child abuse.
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References

- Stritch School of Medicine, Loyola University Chicago. Use and utility of radiology in the work-up of suspected child abuse. http://www.meddean.luc.edu/lumen/meded/Radio/curriculum/Pediatrics