High Specificity Features on Plain Film of Non-Accidental Injury

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Objectives

- To provide an overview of non-accidental injury with respect to skeletal imaging findings
- To recognize metaphyseal lesions and posterior-medial rib fractures as high specificity findings for non-accidental injury
- To understand the common pitfalls of interpreting imaging findings for non-accidental injury
Statistics

- 3 million reports of child abuse each year in USA
- >5 children die every day due to child abuse in USA
- 50,000 deaths worldwide every year as a result of non-accidental injury
- True incidence of non-accidental injury likely higher due to underreporting
Mechanism

- Child held around chest and shaken violently back and forth
- Compression of chest → Rib fractures
- Whiplash movement of extremities → Classic Metaphyseal Lesion (CML)
- Severe angular acceleration/deceleration of head with/without direct impact → Intracranial injury
Risk Factors

- History of abuse of parent
- Substance abuse by parent
- Domestic Violence
- Lack of social supports
- Low socio-economic status
- Non-ambulatory status
- Special needs child
- Multiple gestation/Preterm/Unplanned pregnancy
- Sibling with history of abuse
Early Literature

- Caffey, 1946: association between healing long-bone fractures and chronic subdural hematomas in infancy; physical abuse as cause of injuries
- Caffey and Kempe, 1962: manhandling and violent shaking as mechanisms of injury with short and long term sequelae
- Kleinman, 1989: utility of high-detail postmortem radiography in identifying skeletal injuries
Non-accidental injury

- Rate of fractures caused by abuse: estimated 11-55%
- Majority of non-accidental injury in young children, <18 months old (80%)
- Evidence of prior injuries from abuse in 50-80% of fatal or near-fatal abuse cases
- If child with non-accidental injury returns to unsafe environment, 30-50% risk of further injury and 10% risk of death
Skeletal Survey

- American Academy of Pediatrics Committee on Child Abuse and Neglect recommends a skeletal survey for a child < 24 months old with suspicion of physical abuse.
- American College of Radiology also supports recommendation of skeletal survey for initial evaluation of non-accidental injury.
Skeletal Survey

ACR Guidelines:
- AP / lateral skull (+ Townes if suspicious of occipital fracture)
- Lateral cervical spine
- Lateral thoraco-lumbar spine
- Chest x-ray (AP) (left / right oblique ribs)
- Abdominal x-ray (AP)
- Left / right AP humeri
- Left / right AP forearm (Lat)
- Left / right PA hand
- Left / right AP femora
- Left / right AP tibia / fibula (Lat)
- Left / right AP feet
Technique

High Quality Skeletal Survey:

- Adequate spatial resolution
- High Signal to Noise
- Sufficient mAs
- Low kVp (50-70) for high contrast
- Cone to region of interest
- Monitored by RAD
- Follow up skeletal survey in 2 weeks
Bone Scintigraphy

- When skeletal survey is negative, but clinical suspicion remains high
- Requires sedation and radiation
- Diagnosis of more subtle fractures that may not be radiologically evident
- Detecting periosteal trauma and rib, spine, pelvic, and acromion fractures
- High uptake may obscure level of physis and skull fractures
Computed Tomography (CT)

- Assessment of intracranial injuries, skull fractures, solid organ, hollow viscera injury
- Requires sedation and high dose radiation
- Greater sensitivity to acute intra-cerebral and extra-axial hemorrhages than MRI
Magnetic Resonance Imaging (MRI)

- Adjunct for evaluating axonal shear injuries and dating intracranial hemorrhage
- Requires sedation, longer times, magnet availability
- Evaluating joint effusions, muscle hematomas, soft tissue edema, epiphyseal separation injuries
### Fractures

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<tr>
<th>High Specificity Lesions</th>
<th>Classic Metaphyseal Lesions</th>
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<tr>
<td></td>
<td>Rib Fractures (Post)</td>
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<tr>
<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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<tr>
<th>Moderate Specificity Lesions</th>
<th>Multiple Fractures</th>
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<td>Fractures at different ages</td>
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<td>Epiphyseal Separation</td>
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<td>Vertebral body fractures and subluxations</td>
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<td>Skull Fractures</td>
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<td>Digital Fractures</td>
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<tr>
<th>Low Specificity lesions</th>
<th>Subperiostal New bone formation</th>
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<td>Clavicular fractures</td>
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<td></td>
<td>Long bone fractures</td>
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<td>Linear skull fractures</td>
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Metaphyseal Corner fracture

- Whiplash-type injury at level of zone of provisional calcification
- High Specificity:
  - Children who are not yet walking cannot exert such force on their own
Pitfalls: Metaphyseal Beak/Spur

- **Beak**: medial projection of metaphysis, commonly seen in proximal humerus and tibia

- **Spur**: longitudinal projection of bone continuous with cortex and extends beyond metaphyseal margin
Rib Fractures

- High specificity for abuse:
- PPI of Posteromedial rib # in <3yo: 95%
Skull Fractures

- Moderately Specific for Non-accidental Injury
- Patterns: multiple “egg-shell” fractures, occipital impression fractures, fractures crossing sutures
- Most common: parietal bone & linear pattern
Long Bone Fractures

- Low specificity for Non-accidental injury
- Femur fracture in <1yo due to abuse: estimated 39-93%
## Healing & Dating of Fractures

<table>
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<th>Time course</th>
<th>Finding</th>
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<tr>
<td>4-10 days</td>
<td>Resolution of soft tissue swelling</td>
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<td>10-14 days</td>
<td>Subperiosteal new bone formation</td>
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<tr>
<td>14-21 days</td>
<td>Immature or soft callus, loss of fracture line definition</td>
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<tr>
<td>&gt;21 days</td>
<td>Mature or hard callus</td>
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Differential Diagnosis

- Accidental Injury: MVA, falls, birth trauma, CPR
- Bone Disease: Osteogenesis imperfecta (Type 1, 4), Osteopenia of prematurity, Rickett’s, Copper deficiency (Menke’s Kinky), Metaphyseal dysplasia, Syphilis, Rickets, Scurvy, Vitamin A intoxication, Prostaglandin treatments
- Medical condition: coagulation disorder, leukemia, connective tissue disorder
Role of Radiologist

- Be familiar with characteristic imaging findings in order to raise suspicion of non-accidental injury
- Consequences of inappropriately calling:
  - Under diagnosing: Delayed or no conviction, Re-injury, Death, Risk to others.
  - Over diagnosing: Wrongful conviction, Harm ing relationships: Parent-doctor, Family, Community
Teaching Points

- Skeletal surveys in the evaluation of children <2 yo with suspicion of abuse
- High specificity of metaphyseal lesions and posterior-medial rib fractures for non-accidental injury
- Repeat skeletal survey may be necessary
- Multidisciplinary team approach and communication with referring physician
References