Fractures – When to Suspect Abuse

WI CAN
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Objectives
- Be able to describe the biomechanics of common abusive fractures
- Understand the importance of medical mimics of child abuse fractures
- Be familiar with typical histories (stories) in abuse and unintentional injury (accident) scenarios
- Understand the role of medical screening for occult injury in infants and young children suspected of being abused

Key Points
- Cause of fractures by type
  - Some fractures because of their very nature are highly correlated with abuse – ANY fracture can be from abuse
  - The only fracture expected in a short fall such as from a bed or sofa is a skull fracture, but skull fractures can be from abuse, as well
- Symptoms - Not all fractures are severely symptomatic
- Evaluation
  - Protocol-based screening is essential in suspected abuse cases
  - Only about 25% of all fractures are associated with bruises even if the injuries are from abuse
  - Siblings and household contacts of a child suspected to be abused should also be evaluated
- It is not possible to date fractures accurately by radiographs alone
Abusive Fractures (broken bones)

- Incidence
  - Frequency of fractures associated with abuse – 12% of all <36 mo hospitalized children with fractures (Leventhal 2008 Pediatrics)

- Age:
  - Most important risk factor
  - 55% to 70% of abusive fractures occur in children under 1 year of age
  - Incidence of abusive fractures is 1/2000; Medicaid is a major risk factor (Leventhal 2010 Pediatrics)

Presentation-Variable

- Swelling to extremity
- Pain to extremity
- Usually no bruising
- Decreased movement
- General fussiness
- No symptoms

Symptoms

- 2011 Farrell et. al- Interviews of parents of 206 children < 6 y/o with accidental extremity fractures. Mean age 3.7 years
  - No child with accidental fracture was asymptomatic
  - Parent noticed external sign of injury in 85%
  - 21% seen >8 hours after injury (median time was 1 hour)

Flawed by

- Recall/reporting bias- those who delayed in seeking care had a vested interest in underreporting/minimizing symptoms
- Did not survey both parents
- Few infants and toddlers- only 20% were <2 y/o.
What about bruises?
- Bruising does not differentiate between inflicted and unintentional
- About 25% of all fractures have associated bruises
- How can this be?
  - Skin compliance of young children
  - Bruises can be difficult to see in darkly pigmented children
  - Bruises can evolve over time, be covered by cast/splint, and heal quickly

Abusive Fractures
- Age of the child:
  - Most important risk factor
  - 55% to 70% of abusive fractures occur in children under 1 year of age
- Fractures are classified by
  - location (which bone and what part of the bone),
  - type (what is the direction of the break),
  - whether it is healing or not (healing vs. acute) and
  - angulation/displacement

Location
- What bone?
  - Long bones of the arm- humerus, radius, ulna
  - Bones of the hands- metacarpals and phalanges (finger bones)
  - Bones of the leg- femur, tibia, fibula
  - Bones of the foot- metatarsals and phalanges (toe bones)
- Where on the bone?
  - Long bones:
    - Closer to the trunk=proximal
    - Farther from the trunk=distal
  - Rib, skull
    - Anterior- toward the front of the body
    - Posterior- toward the back of the body
- What part of the bone?
  - Shaft- diaphysis
  - Growing part of the end- metaphysis
  - Growing cartilage- physes
  - Growth plate- epiphysis
Types - Diaphyseal Fractures

A. Transverse
B. Oblique
C. Spiral
D. Comminuted
E. Buckle

Biomechanics

- Transverse:
  - Fracture line perpendicular to long axis
  - Tensile or bending load
  - Direct or indirect force

- Spiral/Oblique:
  - Torsional force
  - Twisting about the longitudinal axis
  - Accidental or abusive
  - Toddler’s fracture
  - Exersaucer injury (see 2001 Grant in Pediatrics)
Biomechanics

- Buckle/Torus:
  - Compression (axial loading) or bending force
  - FOOSH fractures

Fracture Patterns

- High Specificity:
  - Classic Metaphyseal Lesion (CML) - commonly called bucket handle or corner fractures
  - Rib - especially posterior
  - Scapula
  - Spinous process
  - Sternum

- Moderate Specificity:
  - Multiple, bilateral
  - Different ages
  - Vertebrae body
  - Digits
  - Complex skull fx

- Low Specificity:
  - Clavicle
  - Long bone shaft
  - Linear skull fx
  - Supracondylar fx humerus

Rib Fractures

- Most common fracture in child abuse (5-30%)
- Often diagnosed during healing phase (occult)
**Rib Fracture--Mechanism**

![Diagram of rib fracture mechanism]

**Classic Metaphyseal Lesions (CML)**
- Also called “bucket handle”, “corner”, or Classic Metaphyseal Lesions (CML)
- Highly correlated with abusive injury
- Mechanisms
  - Twisting or pulling of affected limb
  - Shearing of metaphysis from shaking
- Difficult to date
- Usually clinically silent (or quiet once the immediate pain has subsided)
- Most commonly in tibia, femur

**Skull Fractures**
- Simple:
  - Linear
  - Parietal
  - Accidental or abusive
  - Most are due to short falls (Leventhal 2008 and 2010)
Skull Fractures

- Complex:
  - Depressed
  - Diastatic
  - Comminuted
  - Stellate or branching
  - Multiple
- Occipital and frontal fx require more force than parietal fxs. Unusual in short falls

Jaw fractures

- Sublingual hematoma should raise this concern
- Often multiple fractures
- Mechanism – direct impact, often in the context of AHT

Medical Evaluation of Fractures

- History- Particularly developmental age/stage and details of the injury event and subsequent symptoms
- Physical Exam- Only about 25% of abusive or accidental fractures have associated bruises. Bruising is not helpful in assessment. (Valvano 2009, Peters & Starling 2008)
- Laboratory Analysis- Bone labs (Ca, PO4, Mg, Alkaline Phosphatase, intact PTH, Vit D-25). Only <25% of kids with overt rickets have fractures. Better to evaluate bone health and address issues related to possible metabolic bone disease in court.
- Imaging
Red Flags

- No history
- History inconsistent with developmental abilities
- Mechanism inconsistent with injury
- Other signs of abuse/neglect:
  - Bruises, scars, other fractures, old fractures
- Prior injuries
- Delay in seeking care
- Social risk factors:
  - DV, poverty (Medicaid), drug use

Imaging

- Skeletal survey in children under 2 y/o and repeat in 2 weeks. Second SS should omit skull, coned down views and oblique ribs unless specific interest
- Value of repeat SS—approximately 46% when selective; likely lower in universal screening
- Consider bone scan when safety is at risk. Even when bone scan is performed, repeat SS should be performed.

Skeletal surveys

- What are they?
  - Series of plain films (X-rays) of all of the major bones of the body:
- Why are there 2 parts?
  - To detect subtle fractures
  - To show healing of known fractures

2011 ACR Practice Guidelines:
Plain films vs. Bone Scan

- X-Ray may miss new fractures
- Bone Scan can identify “missed” fractures
  - Sty and Starshak—Radiology 1983; 146:369-375
    - 261 suspected abuse cases
    - 12 patients with 1 or more rib fractures identified by bone scan but not by X-ray
- Limited sensitivity for metaphyseal fractures due to normal uptake of tracer in growth plate
- Lacks sensitivity for skull fractures

Protocol for when to image

- All children less than 2 y/o if concerned about abuse
- Ages 2 y/o – 5 y/o abused children, consider a skeletal survey in some circumstances
  - History of musculoskeletal symptom
  - Siblings of severe physical abuse
  - Other
- Developmentally delayed children – consider regardless of age in some cases

Dating of fractures – inexact*

- Not possible in skull fractures or CMLs
- Skull fractures usually heal by 6 months but without callus
- CMLs usually heal by 4-6 weeks
- Long bone and rib fracture dating assumes there is no re-injury
- Little research basis- can sometimes put a minimum age but an outside range is very difficult.

Can We Date Fractures? (Kleinman)

- Induction
  - Inflammation, removal of damaged tissue
  - 3-7 days
- Soft Callus
  - New bone formation
  - 5-14 days in children, earlier in infants
- Hard Callus
  - Union of fracture
  - 14-21 days (loss of fracture line definition)
- Remodeling
  - Smoothing of callus to original configuration
  - 3 months-1 year (longer in older children)

Radiation Exposure in Diagnostic Imaging

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Estimated Medical Radiation Doses for a 3-Year-Old Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging Area</td>
<td>Effective Dose</td>
</tr>
<tr>
<td>X-ray of head</td>
<td>0.0015</td>
</tr>
<tr>
<td>Anterior view of spine</td>
<td>0.01</td>
</tr>
<tr>
<td>Total head and body</td>
<td>0.05</td>
</tr>
<tr>
<td>Total body, arms, and legs</td>
<td>0.19</td>
</tr>
<tr>
<td>Total body, arms, and legs</td>
<td>0.33</td>
</tr>
<tr>
<td>Total body, arms, and legs</td>
<td>3</td>
</tr>
<tr>
<td>CR: indicates chest radiography; Ti: spine, technetium-99m; TD: total dose; mSv: millisieverts</td>
<td></td>
</tr>
</tbody>
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Skeletal Survey - 0.716 per survey = 1.4 mSv when study is repeated
(Ahmed BA Pediatrics 2010;126;e851-e858)

Background exposure from natural sources is 3.0 mSv per year.
(Frush DP Pediatrics 2003;112;951-957)

1 mSv = 1000 microSv

Lifetime cancer risk with diagnostic imaging

- Cancer risk may increase with early exposure to as little as 10-50 mSv and is widely thought to increase a small, but significant amount with 50-100 mSv
- "Background" radiation is the largest exposure and CTs account for the second largest exposure
- Sea level background radiation is about 1.8 – 3 mSv/year
- 8 hours of flying at 36,000 feet is the same as 9 days of ground exposure
For more information:
- Generally, pediatric health care institutions are going to use Image Gently principles
- Image Gently: What Parents Should Know about Medical Radiation Safety
  - [http://pedrad.org/Portals/6/Procedure/Image_Gently_8.5x11_Brochure.pdf](http://pedrad.org/Portals/6/Procedure/Image_Gently_8.5x11_Brochure.pdf)

Who Did It?
- Who first noticed any symptoms?
- Would symptoms be expected? Corner fractures, skull fractures and rib fractures often have minimal symptoms after the initial trauma event
- Who last saw the child well?
- Who has had access to the child?
- Who might be a witness, especially siblings?

What happened?
- Detailed description of events during the prior 48 hours
  - What were the symptoms?
  - In what order did the symptoms develop?
  - What was the child's position before and after?
  - If a fall occurred, what was the height of the fall and the surface?
  - What was the caretaker response?
- Was there a delay in seeking care? If so, why?
- Delay in seeking care is very common with skull fractures!
Where did it happen?
- Where did the child become symptomatic?
- Where was the child found?
- Did any emergency phone calls take place?
- Where did these calls take place?
- How did the child get to the hospital?

Precipitating events – “Why?”
- Crying
- Child ill
- Culmination of stress
- Single explosive episode
- Feeding problems
- Toilet training
- Domestic violence/Drug abuse
- Torture

Fractures
Differential Diagnosis or “What else could this be?”
### Differential Diagnosis

- **Accidental Injury**
  - Short Falls
    - 3 studies of falls from hospital beds
    - 367 subjects
    - 3 linear parietal skull fractures (1/100 short falls involving infants), 1 clavicle fracture, no neurological complications
  - Stair Falls
    - CHOP study of 363 patients ([Joffe Pediatrics 1988;82:457](#))
    - Initial mild to moderate impact followed by series of low-energy non-injurious falls
    - 6% fractures (humerus, tibia, radius/ulna), 1 concussion, no intracranial hemorrhage; no visceral injury
    - Vast majority sustained only minor soft tissue injuries
    - Multiple, truncal or proximal extremity injuries are suspicious

- **Obstetrical Injury**
  - Clavicle and humerus fractures most common
  - Rib fxs rare but can occur in LGA infants
  - LGA infants
    - shoulder dystocia
    - vacuum- or forceps-assisted delivery

- **Conditions/diseases that predispose to fracture:**
  - Osteopenia of prematurity (<1500 gm, cholestatic jaundice, TPN>3wks, Lasix>2wks, immobilization, Cu and Calcium deficiency)
  - Nutritional: scurvy, rickets
  - Infection: osteomyelitis, syphilis
  - Neuromuscular disorders
  - Kidney disease: calcium wasting
  - Drugs: Vitamin A, methotrexate, prolonged glucocorticoid use, anti-epileptic meds and others
  - Leukemia
  - Other- normal variants, hyper/hypothyroidism, Menke's, etc.
Normal Variants

- Many normal variants exist
- Mendosal suture with an Inca bone
- Many other examples!

Osteogenesis Imperfecta

- Heritable collagen disorder with variable phenotypic expression
  - Type I: Mild; decreased production of Type I collagen* 71% of OI
  - Type II: lethal in perinatal period; 9% of OI
  - Type III: severe, progressive, usually apparent at birth; 15% of OI
  - Type IV: Moderate; production of defective collagen* 5% of OI
  - Other
  - *Can be confused with NAT

Features of OI

- Type I
  - Blue sclera (60-70%)  
  - Hearing loss (50%); presents in 2nd decade  
  - Wormian bones  
  - Osteopenia  
  - Dentinogenesis Imperfecta
- Type IV
  - Normal sclerae  
  - Short stature  
  - Hearing loss  
  - Wormian bones  
  - Dentinogenesis Imperfecta
Diagnosis of OI

- **Family History**
  - Frequent fractures, hearing loss in teen or young adult, joint laxity, abnormal teeth
  - Spontaneous mutations are common so family history may be negative
- **Physical Exam**
  - Osteopenia on plain films; decreased lamina dura (surrounding tooth socket)
  - Skin biopsy to culture fibroblasts or blood for DNA sequencing
    - Each with 85% sensitivity
    - Several months for results
- **Genetics consult**

Does CPR Cause Rib Fractures?

- **Pre-2005:**
  - Feldman and Brewer (1984)
    - 113 children
    - Mostly civilian CPR
    - No fractures
  - Spevak and colleagues (1994)
    - 91 infants
    - Various CPR training
    - No fractures
  - Of over 900 children in the literature, only 3 had rib fractures; never posteriorly

2-handed CPR

- Since 2005, 2 handed CPR has become AHA standard- No published case of posterior rib fractures related to this
- *2010* Matshes and Lew (Am J Forensic Med Pathol 2010;31: 303-307) reported 5 cases of infant death with possible multiple acute anterolateral rib fx from 2 handed CPR.
- Literature analysis by Maguire et al, concluded that if they occur, they are anterior (see 2010 Matshes and 2009 Weber [Weber et al Forensic Science International 2009;180(3):75-81]) and not posterior.
2014 Franke,I et al

- 2-thumbs approach to CPR since 2000 in Germany
- German study of 3 children's hospitals
- All < 12 months with professional CPR over 10 yrs who had CXR
- Excluded infants with osteopenia, bone disease, abuse
- Independent review of CXRs – 80 infants; 39 had a f/u CXR after at least 10 days
- No rib fracture on any CXRs
- Conclusion – rib fractures should raise significant concerns about child abuse

Key references

- Jenny C. Evaluating Infants and Young Children With Multiple Fractures. Pediatrics 2006;118:1299-1303
- Books:
  - Kleinman’s Diagnostic Imaging of Abuse
  - 2011 Jenny’s Child Abuse and Neglect Diagnosis, Treatment, and Evidence

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