Subtle Fractures of the Immature Skeleton

Susan D. John, MD, FACR
Immature Skeleton

• More porous, more elastic recoil
• Thinner cortex
• Open physes (cartilage)
• Developing epiphyses
• Strong ligaments
Pediatric Fractures

- Epiphyseal-metaphyseal separations (Salter-Harris fractures)
- Greenstick fractures
- Buckle (torus) fractures
- Plastic deformation injuries (bowing fractures)
Epiphyseal-Metaphyseal Fractures

- Separation at cartilaginous physis
- Salter-Harris classification
  - I  physis only
  - II  metaphyseal
  - III  epiphyseal
  - IV  epiphyseal and metaphyseal
Salter Harris I injury
Salter Harris II fracture
14 year old with pain after FOOSH
Where is the fracture?

A. Radius
B. Ulna
C. Scaphoid
D. Two of the above
E. No fracture seen
Ulnar Styloid Process Fracture

- Avulsion of attachment of TFCC or ulnocarpal ligament
- High association with radial fracture

SH II fracture
Oblique views important because of tendency for fractures to occur along dorsal aspect of metaphyses.
13 year old s/p auto-bike accident
Salter-Harris Fracture – Distal Femur
Transitional Fractures of Adolescence

- Occur when physis is partially fused
- Most common in distal tibia
Multiplanar CT shows fragment:
- displacement
- orientation
- number

2 mm
Complex Epiphyseal-Metaphyseal Fractures (Triplane Fractures)
2 Part Triplane Fracture
3 part Triplane Fracture
3 part Triplane Fracture
Metaphysis

Epiphysis
Buckle (Torus) Fracture

- Impaction
- Hyperextension
  - FOOSH
  - Jumping injuries
Buckle (Torus) Fracture – Distal Radius
Slight differences in position can make these fractures “invisible”.
Too young for developing tibial tuberosity
Plastic Deformation Injuries

- Bowing deformity without visible fracture line
- Multiple microscopic infractions along convex surface
3 year old with pain after a fall
Supracondylar fracture (buckle type)

- Joint effusion without visible fracture
  - Sign of significant traumatic force
  - Fractures common but may be subtle
Lateral Condyle Fractures
Lateral condyle fracture

- Potentially unstable
- Displacement hard to see
- MDCT for extent and displacement
Milch I

Milch II

Common

Unstable

Cubitus varus in 42\%
Lateral Condylar Fracture – Treated with Casting Only

- Can result in non-union or cubitus varus deformity
Longitudinal Olecranon Fractures

- Non-displaced
- Oblique or longitudinal
Transverse intra-articular olecranon fracture

- Fall on flexed elbow
Monteggia Lesion
Radial Neck Fractures

- Buckle and SH II fractures most common
Medial Epicondyle Avulsion Fractures

- Look for asymmetrical medial soft tissue swelling
- Compare with other side when in doubt
Non-Accidental Trauma

- Incidence of fractures and TBI caused by NAT in hospitalized children
  - < 12 mons age – 50/100,000
  - < 36 months age – 21.9/100,000
- 30% - TBI only
- 42% - fractures only
- 28% - both fractures and TBI

Leventhal, Pediatrics July 2010; 126:e104
Screening for Skeletal Injuries

Radiographic survey

- Better characterization of fractures
- Allows “dating”
- More sensitive for subtle metaphyseal injuries
- Best for infants and children <4 yrs
High Suspicion Lesions

- Rib fractures
- Classic metaphyseal lesions
- Unusual fractures (sternum, scapula)
- Fractures of different ages
- Bilateral fractures
- Any fracture that is inconsistent with the history given
Classic Metaphyseal Lesion

- Microfractures through the immature spongiosa
- Subtle, minimally displaced
- Not seen in accidental trauma in infants with healthy bones
Liberal use of AP and lateral views of knees and ankles is advocated.
Classic Metaphyseal Lesions

- Are these fractures specific for NAT?
  - Yes
  - Except:
    - Low segment C-section
    - Clubfoot therapy
    - Normal variants (all around knee)
    - Conditions with bone fragility
Infant with clubfoot

Physiologic bowing (15 months old)

Kleinman, AJR May 2009;192:1266

L. Swischuk
Pay attention to bone mineralization

Copper Deficiency (TPN cholestasis, prematurity)
Osteogenesis Imperfecta

- Rare – 1:20,000 births
- Types I – IV
  - I, II – blue sclerae
  - III – severe osteopenia
  - IV - rare, family hx, wormian bones, bony deformity, abnormal teeth common
Classic metaphyseal fractures uncommon in OI – bones usually abnormal on radiographs
Osteogenesis Imperfecta
Congenital Infections

- Syphilis
- CMV
- Rubella
Diffuse Periostitis (Caffey Disease)
Ddx: Vit A toxicity, Scurvy, Normal
Rickets

• Vitamin D deficiency epidemic in U.S.
• Rickets – must show radiographic changes
  – Can Vit D insufficiency without radiographic findings be associated with bone fragility?
• No association between Vit D insufficiency and:
  – Child abuse
  – Multiple fractures
  – Rib fractures
  – Metaphyseal fractures

Schilling, Pediatrics May 2011; 127:835
Rib Fractures

- Rare in healthy infants
  - 82% - caused by abuse
  - 8% - accidental (major trauma)
  - 7% - fragile bones (OI, rickets, prematurity)
  - 3% - birth trauma


- Other retrospective case series
  - Rib fractures in children under the age of 3 highly predictive of NAT
Rib fractures in NAT

- Mechanisms
  - Forceful AP compression
  - Direct blow
Oblique views increase sensitivity for rib fractures by 17%

Ingram et al, Emerg Radiol 7:42, 2007
Follow-Up Imaging

- Repeat CXR or bone survey in 2 weeks
  - Added information in 12%
    Adikesavalu, Ped Rad 2006
  - Fractures not previously seen
    - Ribs, metaphyseal
      Kleinman, AJR 167:893, 1995
    - Improved dating information
- Limited skeletal surveys may be adequate
  - Chest with obliques, extremities
Is CT worthwhile?
Bone Scintigraphy

- More sensitive for rib fractures
- Nonspecific
- Can miss:
  - Metaphyseal lesions
  - Skull fx
- Cannot date fx
Whole Body MRI

- 1.5 T, sagittal and coronal STIR
- 167 fxs in infants less than 1 yr
  - Seen on both BS and MRI 27.5%
  - Bone survey only 40.7%
  - WB-MRI only 31.7%
- WB-MRI had low sensitivity
  - Classic metaphyseal lesions 31%
  - Rib fractures 57%

Perez-Rosello, AJR, Sept. 2010; 195:744
Femur Fractures

Risk factors
- Age under 18 month
- Evidence of prior trauma
- Suspicious history

0 risk factors – 4% chance
1 24% chance
2 87% chance
3 92% chance

History and patient demographics must be considered

Pediatric Orthopedic Injuries

- Remember the characteristic patterns and locations of injury
- Use CT for complex fractures that may require ORIF
- Comparison views frequently help identify “occult” fractures
- MRI may be worthwhile for occult injuries
Conclusion

• Imaging plays a critical role in the detection and documentation of child abuse
• Best evaluated by a multidisciplinary team
• Post mortem radiographs may be valuable
• Recognizing conditions that mimic abuse may prevent unnecessary traumatization of families