Definition of child abuse

- Definition of child abuse
- Federal law (Child Abuse Prevention and Treatment Act)
  - “…any act or failure to act resulting in imminent risk of serious harm, death, serious physical or emotional harm, sexual abuse, or exploitation of a child by a parent or caretaker who is responsible for the child’s welfare.”
- State law
  - Civil
    - Conditions that obligate mandated reporters
    - Definitions for taking custody
  - Criminal
    - Forms of maltreatment that are punishable
Four types of maltreatment

- **Physical abuse** (non-accidental trauma or NAT)
  - 1946 Caffey described classic findings of abuse of infants
  - 1962 Kempe described “battered child syndrome”
- Neglect
- Sexual abuse
- Emotional abuse

Epidemiology

- Orthopaedic surgeons care for approximately 1/3 of NAT victims
- Probably underdiagnosed
- 2nd most common cause of mortality in infants (after SIDS) and children (after accidents)
- Recent JAAOS article suggesting NAT diagnosis algorithm: Overall prevalence of 1.54% for NAT in children admitted to the hospital for fracture. Inpatient + predictors of NAT: younger age, black race, concomitant rib fracture, intracranial injury, burns.
Evaluation

- How can the MD discern whether an orthopaedic injury is a manifestation of NAT?
  - Often difficult
  - Some characteristics are associated with NAT
    - Frequently non-specific or non-sensitive
    - Literature is confusing and mostly retrospective

Mechanisms of physical abuse that cause skeletal injury

- Shaking (AP compression of ribs)
- Forced flexion/extension of spine (spine injury)
- Torsional and tractional forces of extremities (shearing injury of metaphyses)
Evaluation

- History
  - < 3 year old (although this is being re-evaluated)
  - Vague explanation
  - Inexplicable or unwitnessed injury inconsistent with clinical findings & developmental abilities
  - Delay in seeking care
  - Unusual or evasive parent response

- Social History
  - Any SES, but more common in lower SES (more specifically patients with Medicaid)
  - Unplanned pregnancy
  - Parental substance abuse
Evaluation

- Past medical history
  - Osteopenia
  - Metabolic disorder
  - Pre-term pregnancy
  - Special needs
    - Behavioral problems
    - Developmental delay
    - Pre-term birth
    - Physical disabilities

Evaluation

- Non- Musculoskeletal PE
  - Skin (carefully examine and document before covering with cast)
    - Bruises (buttocks, perineum, trunk, back of head, legs)
    - Multiple bruises in various stages of healing
    - Bites
    - Burns
    - Patterns
Evaluation

- Non-Musculoskeletal PE
  - Head
    - Complex skull fracture
    - Subdural hematoma
    - Retinal hemorrhage
    - Cognitive disabilities
  - Chest / Abdomen / Pelvis
    - Posterior rib fractures
    - Pneumothorax
    - Rupture of organ
    - Sexual abuse

- Musculoskeletal findings with high specificity for NAT
  - Metaphyseal fracture
  - Posterior rib fractures
  - Scapular fracture
  - Spinous process avulsion
  - Sternal fracture

- Musculoskeletal findings that have moderate specificity for NAT
  - Multiple fractures
  - Fractures in various stages of healing
  - Complex skull fractures
  - Digital fractures
  - Vertebral compression fractures
  - Epiphyseal separation

- Musculoskeletal findings that are common in NAT but low specificity
  - Long-bone fracture in child
  - Clavicle fractures
  - Linear skull fractures
Evaluation

- Musculoskeletal findings with high specificity for NAT
  - Metaphyseal fracture
  - Posterior rib fractures
  - Scapular fracture
  - Spinous process avulsion
  - Sternal fracture

Metaphyseal Fracture

- Subepiphyseal microfractures through the most immature portion of metaphyseal bone (primary spongiosa)
  - Not a cartilage injury
Metaphyseal Fracture

- Highly specific for NAT
  - Twisting injury
- Corner or bucket handle appearance
  - Mineralized disk that is visible on xray
NAT vs. toddlers fracture

Posterior rib fractures

- Very unusual fracture in infants in general
- Found in 5-27% of abused infants & children
- Highly specific for NAT
  - 3rd most common fracture in abused infants (after limb and skull)
  - Etiology in infants < 12 months
    - NAT 82%
    - Notable trauma 8%
    - Birth trauma 2%
    - Osseous fragility 8%
- Caused by thoracic compression, but don’t occur with CPR
- Rarely accompanied by external evidence of trauma
- Unsuspected in up to 80% of cases
- May be difficult to detect on x-ray
Posterior rib fractures

Posterior Rib Fracture
Evaluation

- Musculoskeletal findings that have moderate specificity for NAT
  - Multiple fractures
  - Fractures in various stages of healing
  - Complex skull fractures
  - Digital fractures
  - Vertebral compression fractures
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Multiple fractures

- 50% single fracture
- 33% 2-3 fractures
- 17% > 3 fractures
Fractures in various stages of healing

- 50% of all abused children
- 70% of abused children < 1 year old
- Dating the fracture
  - Induction
    - Soft tissue hemorrhage and swelling
  - Soft callus
    - Reparative stage
    - Periosteal reaction seen beginning 10-14 days
    - Sclerosis at fracture margin begins 2-3 weeks
  - Hard callus
    - Conversion of periosteal and endosteal new bone to lamellar bone with bridging of fracture line
    - Periosteal new bone begins incorporating 4-6 weeks
- Remodeling
Dating of fractures

<table>
<thead>
<tr>
<th>Histologic Stages of Fracture Healing [1]</th>
<th>Study Feature</th>
<th>Weeks After Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I, induction and II. inflammation (0–3 weeks)</td>
<td>Fracture gap widening</td>
<td>4-6</td>
</tr>
<tr>
<td></td>
<td>Sclerosis at fracture margin</td>
<td>4-6</td>
</tr>
<tr>
<td>Stage III, soft callus (2–6 weeks)</td>
<td>Periosteal reaction presence</td>
<td>4-7</td>
</tr>
<tr>
<td></td>
<td>Callus presence</td>
<td>4-7</td>
</tr>
<tr>
<td>Stage IV, hard callus (2–13 weeks)</td>
<td>Callus density greater than cortex</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Bridging</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Periosteal reaction incorporation</td>
<td>14</td>
</tr>
<tr>
<td>Stage V, remodeling (3 months–2 years)</td>
<td>Remodeling^</td>
<td>9</td>
</tr>
</tbody>
</table>

Acute Fracture
Soft Callus Stage

Hard Callus Stage
Complex skull fractures

Digital fractures

Nimkin K et al. Radiology 1997; 203:233-6
Vertebral Fracture / Dislocation

Evaluation

- Musculoskeletal findings that are common in NAT but low specificity
  - Long-bone fracture in pre-ambulatory child
  - Clavicle fractures
  - Linear skull fractures
Long bone fracture in infant

Clavicle fracture
Linear skull fracture

Patterns of injury

- Long-bone fracture in child < 2 years old
  - More likely NAT than accidental if these occur prior to ambulation & in absence of metabolic bone disease
  - 43% of fractures in children < 3 years old associated with abuse
- Fractures uncommonly seen in NAT
  - Distal radius / ulna
  - Clavicle
  - Hand and foot
  - True physeal fractures
Patterns of injury

- No pathognomonic fracture pattern
- 2% if children with accidental fractures are < 18 mos old
- 86% of children with accidental fractures are > 5 years old
- More likely NAT:
  - multiple fractures
  - midshaft or metaphyseal humerus fracture
  - care-giver reports change in behavior, but no accident
- More likely accidental
  - Clavicle fractures
  - Distal extremity fractures in children > 1 year old
  - Supracondylar humerus fractures
  - Femur fractures in children > 1 year old who fell while running

Differential diagnosis of skeletal findings of NAT

- Accidental injury
- Normal variants
  - Physiological periosteal reaction
- Birth trauma
- OI
- Congenital indifference to pain
- Demineralization from paralysis
- Menkes’ syndrome
- Osteomyelitis
- Congenital syphilis
- Rickets
- Scurvy
- Vitamin A intoxication
- Leukemia
- Prostaglandin periostitis
- Temporary Brittle Bone Disease (most experts agree this doesn’t exist)
- Caffey’s disease (infantile cortical hyperostosis)

Brill PW in Kleinman PK. Diagnostic Imaging of Child Abuse
Physiologic Periosteal Reaction

- Seen in up to 1/3 during first few months of life
  - Not < 1 mo
  - Peaks 6 mo
- Due to rapid bone growth
- Femur, humerus, tibia
- Bilaterally symmetric
Metaphyseal Fracture from Breech Delivery

Osteogenesis Imperfecta

- Inherited disorder due to abnormal quality or quantity of type I collagen
- Salient features include:
  - Positive family history
  - Abnormal temperature regulation
  - Short stature, growth retardation
  - Easy bruising, fragile skin
  - Blue sclerae
  - Deafness or hearing impairment
  - Dentogenesis imperfecta
  - Bone fragility, osteoporosis, fractures
  - Ligamentous laxity
  - Progressive scoliosis

Ablin AJR 1990; 154:1035-46
Osteogenesis Imperfecta

Wormian (extrasutural) bone
Deminerlization from paralysis

- Myelodysplasia, spinal cord injury
- May occur during PT & ROM exercises
- Disabled children at increased risk of NAT

Menkes’ Syndrome

- X linked recessive (boys only)
- Decreased absorption of copper from the GI tract results in decreased cytochrome oxidase activity in the mitochondria
- Sparse, coarse hair
- FTT, seizures
- Most die in 1st 2 years of life
- Vessel tortuosity, may get intracranial infarctions and subdural collections
- Wormian bones
- Lesions that mimic corner fractures
Neonatal osteomyelitis

Syphilis

- Transplacental transmission
- Symmetrical bilateral osteomyelitis
  - Metaphysitis
  - Diaphyseal periostitis
  - Epiphyseal fx
  - Wimberger sign
  - Destruction of medial proximal tibial metaphysis
Rickets

- Vitamin C deficiency
- Not seen before 6 mo. due to maternal stores
- Ground glass osteoporosis
- Wimberger ring around epiphysis
- Subperiosteal hemorrhage

Scurvy
Vitamin A Intoxication

Leukemia
Prostaglandin induced periostitis

- Given to maintain ductus arteriosus patency in infants with congenital ductal-dependent heart disease

Caffey’s Disease (infantile cortical hyperostosis)
Imaging

- Up to half of fractures associated with NAT may be clinically occult in children < age 2
- Fractures that are highly specific for NAT may not be apparent on initial imaging (metaphyseal corner fractures, posterior rib fractures, scapular fractures, sternal fractures)

Skeletal Survey

- The skeleton is the most common site of injury is imaged in abused children
- Up to half of fractures seen on skeletal surveys are clinically occult
Skeletal Survey

< 2 y old
High detail, well-collimated
- AP chest
- AP upper extremities
- PA hands
- AP lower extremities
- AP ankles
- AP feet
- AP and lateral skull
- AP pelvis
- AP and lateral spine
- Add lateral view of extremity if high suspicion of fracture

Follow up skeletal surveys

- Repeat skeletal survey (2 weeks later)
  - Yields additional information in majority of cases where suspicion of abuse is high but inconclusive
  - Most of the additional fractures detected are metaphyseal or rib fractures (high specificity for NAT)
  - Additional information gained about the age of previously detected fractures
Other studies

- Computerized tomography or MRI of the head
- Bone densitometry not very helpful
  - no age-adjusted reference values
- Labs
  - CBC, serum calcium, phosphorus, and alkaline phosphatase, liver function studies, amylase, lipase, UA
  - serum 25-hydroxy-vitamin D (if test for rickets is indicated)
  - Serum copper and ceruloplasmin concentrations (if test for copper deficiency is indicated)
Summary

- Diagnosis of NAT may be challenging
- Orthopaedic manifestations are common but findings overlap with many other conditions
- Metaphyseal fractures (corner or bucket handle) and posterior rib fractures are the most highly specific for NAT

Bibliography

- Predictors for Nonaccidental Trauma in a Child With a Fracture- A National Inpatient Database Study. JAAOS
Thank you!

Radiology credits: Sandra Gorges, MD
Slides: Michelle James, MD