# Orthopedic Aspects of Child Maltreatment

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# **Disclosure Statement**

Jamie Hoffman-Rosenfeld, MD, has no financial relationships with any commercial interests.

# Objectives

The learner will be able to:

- Articulate the concepts involved in the evaluation of orthopedic injuries and their relationship to child abuse.
- Explain the appropriate workup of an infant and a young child with suspicious orthopedic injuries.
- Review specific orthopedic radiologic findings associated with child abuse.

# How often does child abuse involve skeletal injuries?

- Fractures account for 10%-25% of childhood injuries.
- About 25% of fractures in children less than 1 year old are attributed to abuse.
- The percent diminishes with increasing age of the child.

Leventhal JM, Martin KD, Asnes AG: Incidence of fractures attributable to abuse in young hospitalized children: results from analysis of a United States database Pediatrics 2008; 122:602.

### Specificity of Specific Fracture Types

Specificity of Radiographic Findings

**High Specificity** 

• Classic metaphyseal lesions

Rib fractures, especially posterior

Kleinman, Paul K. *Diagnostic Imaging of Child Abuse*, second edition. Cambridge University Press. 2015 (page 10).

# The CML

- Cannot be dated.
- May not be symptomatic.
- ●Disappears in 4-8 weeks.
- The most common fracture identified in fatally abused infants!

## **Description of Fracture is Key!**

- The specific fracture location along the bone (e.g., epiphyseal, diaphyseal, metaphyseal)
- The fracture type (e.g., transverse, oblique, spiral, buckle, CML)
- Whether there is displacement, separation, or comminution of the fracture
- Whether the fracture is open or closed
- Whether there is more than one fracture along the bone or more than one bone
- The extent of callus formation, if present

### Types of Loading Leads to Predictable Fracture Patterns

**Biomedical Condition: Torsion** 

Fracture Type: Spiral/Long Oblique

Bones of children fail more readily under torsion than bending.

Child Abuse and Neglect: Diagnosis, Treatment and Evidence, editor Carole Jenny, MD Chapter on Fracture Biomechanics, Gina Bertocci, PhD

	Accidental and Nonaccidental Femure Fractures in Children		
	Susan A. Scherf, MD; Lins Miller, MD; Nicole Lively, RA; Scott Russingf, MD; Christopher M. Sallivan, MD, MPH; and Paul Torretin, III, MD		
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#### Transverse Fractures of the Femoral Shaft Are a Better Predictor of Nonaccidental Trauma in Young Children Than Spiral Fractures Are

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Ryan Murphy, BS, Derek M, Kelly, MD, Alice Moisan, BSN, Northeet R. Thompson, MD, William C. Warner Jr., MD, James H. Beaty, MD, and Jeffrey R. Savyer, MD Saution performed at the Cambrid Ginic University of Tempore, and Je Benhor Children's Hostind. Membis: Temp

Background: Certain factors configurations, aspecially pixel factorss, are effort through to be indicates of nonconcentration and a childran. The proposed of this study was clearmine whether family monoling tables monopoles, as determined by an objective measurement (factors ratio), was indicative of noncocleantial trauma in young childran. Netbodis: Cincoccutor padietris show are three years of ago ryounger and had a clean. Lisided Fernional shuff fracture trated at an urban postiatic levels in muma center between 2005 and 2013 were identified. Attempositive and iseten factors and the showed by the patient's similar history. The presence or a silvering of all Photoches Services to be present, durate, in indentification (Child Photoches Services) to be present, durate, in indentification (Child Photoches Services) and quarking the likelihood of nonaccidental traums, the orienta of the Modified Matterstrent Classification System were .

Results: 0122 patients identified, ninetylem ent be inclusion ortheria for this study. Of these ninetylems, thyore (541), used ther a Calif Detective Sensice or a Calif A sessment Program consultation boussed or suppected noncoldential trauma. Thirteen (251) sees found to trave noncocidential trauma as determined by Child Protective Sensices or the Child Assessment Program tam and seven (136) land indeterminian (166) hordcores Sensitions or Child Assessment Program investigations. All thirteen galactics with noncocidential trauma, as well as the seven patients with an indeterminate Child hordcores Sensities or Child Assessment Program Integrations, that patients Monthal Mathematic Chalandian Disbectores Sensities or Child Assessment Program Integrations, and possitive Monthal Mathematics Chalandian Disfracture ratios compared with those who had confirmed accidental trauma (p < 0.0002).



# The Presence of Bruising Associated with Fractures

- More than 80% of metaphyseal fractures had no associated bruising!
- The absence of associated bruising does not imply that the force required to produce the fracture was trivial.

#### Does bruising help determine which fractures are caused by abuse? Child Maltreat. 2009 Nov;14(4):376-81.

Valvano TJ, Binns HJ, Flaherty EG, Leonhardt DE.

#### Abstract

To determine whether the presence or absence of bruising can be used to differentiate between abusive and nonabusive fractures, a retrospective study was conducted of patients with acute fractures referred to a child abuse team. A bruise and fracture were considered associated if both occurred on the same body site. Chart summaries, excluding information on bruising, were reviewed by 2 abuse experts to assign cause of injury. Of the 180 participants, fractures of 38 (62%) were categorized as abusive and 67 (38%) as nonabusive. Bruising associated with a fracture was found for 26% of abused and 25% of nonabused children. Most children (61%) had no bruises anywhere on the body, and this did not differ significantly by cause of injury. The sensitivity of a bruise associated with a fracture to predict abuse was only 26%. The presence or absence of bruising was not useful to differentiate between abusive and nonabusive fractures.

### **Transverse Metadiaphyseal Fracture**

- Left on bed while mother was in bathroom; she heard a thump and returned to find the baby on the floor.
- Irritable, noted swelling of leg.
- ${\scriptstyle \odot}$  Promptly brought the baby to the ED.
- X-ray revealed femur fracture.

### Types of Loading Leads to Predictable Fracture Patterns

Biomedical Condition: Compressive

Fracture Type: Buckle/Impaction

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### Six Day Old with Proximal Femur Fracture

- 6 day old infant noted by family to have extreme irritability after the visit to the pediatrician
- Pain with touching and movement of right leg, swelling
- Brought to community hospital where swelling and ? bruising noted
- X-ray reveals proximal femur fracture

# **Past Medical History**

- Scheduled C-section for breech presentation
- Delivery hastened when non-stress test monitoring detected decreased fetal movement.
- Father peeked over the drapes in the DR and noted that rump was delivered first.
- Nuchal cord X3 and cord around torso
- Apgars 9 and 9

### Review of DR and Nursery Records

- ${\scriptstyle \odot \, No}$  snap or pop recorded
- ${\scriptstyle \odot \, No}$  details of delivery maneuver
- Normal entry and discharge nursery exam

# Pediatric Visit on Day #6

Pediatrician reports that lower extremity and hip exam was normal.

# **Parent History**

- Since birth, seemed to cry only during diaper change.
- Crying stopped when he was swaddled.
- Father noticed more movement on the left side;
  "I think he's going to be a lefty."

# **Learning Points**

- Fractures can happen from delivery, including femur fractures.
- O C-section is not necessarily protective!
   O
- Presentation of parturitional femur fracture might be delayed.
- Even good doctors can miss things.
- Use all sources of information available to put the puzzle pieces together – in this case, the family's photo and video clip were essential.

### References

- Morris, et. al. Birth associate femoral fractures: incidence and outcome, *Journal of Pediatric Orthopedics* (2002) 22: 27-30.
- Shigeki Matsubara, et. al. Femur fracture during abdominal breech delivery. Arch Gynecol Obstet (2008) 278:195–197.
- Cebesoy, et. al. Bilateral femur fracture in a newborn: extreme complication of cesarean delivery. Arch Gynecol Obstet (2009) 279:73–74.

# 4 <sup>1</sup>/<sub>2</sub> Month Old With Shoulder Swelling

- Father notified by the babysitter that the shoulder is swollen and arm not moving.
- Generally healthy
- Five day history of fever and fussiness
- Mother noted that he wasn't moving as much as usual for several days but did not notice any particular limb injury.

# **Physical Exam**

- Pain with movement
- ${\scriptstyle \odot} Swelling and tenderness at left shoulder$
- $\odot$  Bruise on right mandible
- Dried blood in left ear concha

## Other Evaluations and Laboratory Tests

- Ophtho exam normal
- Head CT normal
- Skeletal survey normal

### Left Shoulder Salter 1 Fracture/ Dislocation of the Proximal Humerus

- $\odot$  Epiphyseal separation injury
- Moderate specificity for child abuse according to Kleinman
- ${\small { \bullet } } {\small Considerable traction forces required } \\$

# DIAGNOSTIC IMAGING OF CHILD ABUSE

#### SECOND EDITION

#### Paul K. Kleinman, M.D.

Professor of Radiology and Pediatrics Director, Pediatric Radiology Director, Imaging Center for Child Abuse and Neglect University of Massachusetts Medical Center Worcester, Massachusetts

with 930 illustratio

### Kleinman's Discussion of Epiphyseal Separation, Page 80

- "suggest that a continuum exists between the CML and the epiphyseal separation of the proximal humerus"
- "the degree of force required to cause epiphyseal separation is likely to be greater than those causing the cml"
- "it is reasonable to assume that the traction, torsion, acceleration and deceleration forces commonly applied during infant assaults result primarily is osseous disruption without significant epiphyseal displacement...when massive injury occurs, a mainly cartilaginous injury with epiphyseal separation results"

### Dénouement

Six year old son of babysitter reported seeing the babysitter's husband swing the baby like a teddy bear because he wouldn't stop crying.



### Fracture Assessment and Injury Plausibility

- Possible is not the same as plausible; must consider all features of the history.
- What is the particular type and magnitude of loading required for the particular type of fracture?
- Is the history described in a clear and consistent fashion with details?
- ${\scriptstyle \odot}$  What was the child's response, symptoms, etc.?
- Was there an appropriate caretaker response or was there a delay in seeking medical care?

# 6 <sup>1</sup>/<sub>2</sub> Month-Old Twins with Fractures

- Twins were in the crib together.
- This baby cried and father reached over other twin to lift this baby from the crib.
- Heard a snap; thought his bracelet had hit the crib side rail.

### 6 ½ Month-Old Twin Initial Presentation

Could this be an accident???

### Skeletal Survey Results of Asymptomatic Twin

- Healing left distal femur fracture
- Left tibial spiral fracture with periosteal reaction
- Right humerus periosteal reaction along diaphysis
- Toddler brother thick periosteal reaction around distal right humerus

## Conclusions

- Children who have been physically abused often sustain bony fractures.
- Different fracture types have been described as having a high probability for abuse while others are more nonspecific.
- No one fracture *in isolation* is specific for physical abuse.
- The details are in the history!

### 5 Month Old with Marks on Skin

- 5 month old brought to the ED because of bruises to the buttocks.
- ${\scriptstyle \odot}$  Previously healthy without chronic health conditions
- One prior ED visit at 2 months of age because of bruises to buttocks; the father said he fell while holding the baby and she fell against the foot of the bed.
- The mother works and leaves the baby in the care of the father; they live with the maternal grandmother.
- The grandmother reports that the father spends many hours in the bedroom with the baby; bedroom door closed and baby crying.

# Findings

- Healing left metacarpal fracture
- Healing right posterior 11<sup>th</sup> rib fracture
- Edema of gluteal soft tissue and anus inflammation
- Right parietal skull fracture

# PEDIATRICS

Development of Guldelines for Skoletal Streves in Young Children With Frenters forme N. Wood, Ohndhapo Fakeye, Clinis Fendmer, Valerie Mondestin, Russell Localia and David M. Rabin Pednarice 2014;134:45, originally published online June 16, 2014; DOI: 10.1542/peds.2013-2342

OBJECTIVE: To develop guidelines for performing initial skeletal survey (SS) in children 24 months old with fractures, based on available evidence and collective judgment of experts from diverse pediatric specialties.



# Differential Diagnosis

- Osteogenesis Imperfecta
- Prematurity
- Vitamin D Deficiency Rickets
- Osteomyelitis
- Disuse Osteopenia
- Scurvy, Menkes, Copper Deficiency
- Accidental Injury
- Temporary Brittle Bone Disease

### Infant with Knee Pain and Fever

- Pain noted when placed in exersaucer.
- Seen by pediatrician and diagnosed with soft tissue injury.
- Developed high fever and taken to an urgent care center; X-rays and blood tests done.
- Called back and told to go to CCMC because of + blood culture and fracture seen on X-ray.

### Femur Fracture in Infants: A Possible Accidental Etiology

ADSTRACT. Tensoriel fractures in nonabulatin fants are generally fell to be attributable to abuse provide the starting of the starting of the starting report to appropriate social service and law enforce agencies, and logic involvement. This paper descri agencies, and logic involvement. This paper descri distal fenoral metaphysiol fractures extending the growth plate after playing in an infant stati activity comber called an forware relative possible the growth plate be consistent with the general

ATION. CML, classic metaphyseal vral fractures are reported in 12% to 29% of sically abused children<sup>1</sup>. Femoral fractures nonambulating infrants, particularly spiral are believed to be highly specific for in-yury. This association has been replicated in 1983, a retrospective chart review of all ar fracture found that 30% were attributable that are been at a university hospital and that are any sense at a university of the data and that any of the size of the data and the size of graphs did not distinguish between abused bused children, as the most common site of

nabused children, as the most common e for both was the mid-diaphysis. The a

application of a torsional force res-ual torsion with abuse, or twisting iall. As is the case with ed fractures of the ferr and distal third.<sup>5</sup> Lev cospective chart review yea ferr guis 60%

old, the femur frac nty Child Pr ise. During arned that b sible physic tigation, it v edly played (Evenflo, Pii ing an injur tionary activ a prod OH) be eir legs. For and is

### Views on Skeletal Survey

 Metaphyseal fracture not well seen; minimal irregularity and sclerosis noted.

site of

Subperiosteal fluid collection/abscess

### **Osteogenesis** Imperfecta

- Heterogenious disorder with defects in CollAl and CollA2, the genes that encode for Type 1 collagen which supports the framework of bone.
- Denovo mutations and autosomal recessive variants may account for absent family histories.
- Diagnosis suggested by family history, blue sclera, dentinogenesis, short stature, and radiographic evidence of osteopenia.

- Most common fracture type is transverse diaphyseal fractures of long bones.
- Unusual to have multiple long bone fractures or rib fractures in infancy without other stigmata, either radiographic or clinical.
- If fractures continue in a protected environment, consider additional workup.
- Abuse is more common than OI.

# Prematurity

- Decreased bone mineralization at birth which normalizes after the first year of life.
- Particular risk: <1500 grams, <28 weeks, prolonged TPN (>4 weeks), BPD, steroids and diuretics.
- Osteopenia presents between 6 and 12 weeks of life.
- ${\scriptstyle \odot}$  Premature babies are at risk for abuse.

# Vitamin D Deficiency

- Vitamin D insufficiency (<30 ng/ml) is common in otherwise healthy infants and toddlers.
- Despite this, Rickets is uncommon.
- The claim that Vitamin D insufficiency or deficiency is commonly mistaken as abuse is unsupported.
- Studies of patients with Vitamin D deficiency without evidence of Rickets does not show increased fracture prevalence.
- Fractures in Rickets are in older, mobile infants = insufficiency fractures.

Laboratory Evaluation: The clinical evaluation should guide the laboratory evaluation. In children with fractures suspicious for abuse, serum calcium, phosphorus, and alkaline phosphatase should be reviewed, although alkaline phosphatase may be elevated with healing fractures. The physician should consider checking serum concentrations of parathyroid hormone and 25hydroxyvitamin D, as well as urinary calcium excretion (eg, random urinary calcium/creatinine ratio) in all young children with fractures concerning for abuse, but these levels should certainly be assessed if there is radiographic evidence of osteopenia or metabolic bone disease.

### 4 Month Old with Multiple Fractures

- •4 month old, grandmother points out to mother that she is not moving her arm.
- After 4 days, taken to outside hospital.
- Humerus fracture diagnosed.
- Skeletal survey done but other fractures not identified.
- Admitted to CCMC.

### History

- Maternal cholestasis of pregnancy
- Induced and delivered at 36 6/7 weeks
- Tight nuchal cord
- Delayed transition with TTN, transfusion, phototherapy
- Defense expert opines: metabolic bone disease of prematurity, maternal cholestasis, Hypophosphatemic Rickets

# **Defense Witness Hypothesis**

- •Hypophosphatemic Rickets
- Prematurity
- Maternal Cholestasis
- Chest Physiotherapy

### Toddler with Facial Injuries Brought for Evaluation

- •Left 10<sup>th</sup> posterior rib fracture
- Compression fracture of lumbar vertebrae
- Lumbar compression fractures
- Right posterior acetabular fracture
- Head CT with soft tissue swelling

### Investigation

- Child too young to be interviewed.
- Mother maintained he fell in the bathtub.
- Mother arrested for endangering but nobody could be charged with the abuse/assault.
- Newborn baby removed once the mother delivered.

# After the Family Court Trial....

- Mother informed her attorney of domestic violence.
- She said her boyfriend would slam the boy's head against the bathtub and slam him onto his butt.