Pictorial Essay on Child Abuse at an Inner-City Hospital

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Learning objectives

1. Discuss the role of radiology in a team approach to suspected child abuse.

2. Learn the radiologic findings in child abuse, as seen at an inner-city hospital.

3. Understand pearls and pitfalls in the radiologic evaluation of suspected child abuse.
Background

Skeletal trauma is common in child abuse, and initial skeletal surveys are standard of care in the evaluation of abuse in children <24 months of age.\textsuperscript{1-3} Skeletal surveys have been shown to reveal new information in approximately 11-23\% of all children evaluated for possible physical abuse.\textsuperscript{4,5} A follow-up skeletal survey is recommended 2 weeks after the initial survey if abnormal or equivocal findings are present on the initial radiographs, and when there is clinical suspicion of abuse.\textsuperscript{2,3} The follow-up survey has been shown to identify occult fractures present at the time of the initial evaluation after callus has formed and to clarify equivocal findings on the initial study.\textsuperscript{6,7} The images required for a skeletal survey per American College of Radiology (ACR) guidelines are listed in Table 1.\textsuperscript{8}

Fractures with high specificity for child abuse are classic metaphyseal corner fractures, multiple rib fractures (especially posterior), and sternal, clavicular, and spinous process fractures. Fractures with moderate specificity are multiple fractures, including fractures in various stages of healing, epiphyseal separations, vertebral body fractures and separations, digital fractures, and complex skull fractures. Osseous injuries with low specificity for abuse include subperiosteal new bone formation, clavicular fractures (which can also be highly specific as listed above), long bone shaft fractures, and linear skull fractures.\textsuperscript{9,10}

Normal structures and variants can mimic injuries sustained from abuse, and the radiologist must be aware of the imaging appearances of normally developing bones. For example, Wormian bones and cranial sutures can be mistaken for abusive injury, as can ossification centers, vertebral body wedging, pseudosubluxation, and nutrient canals within the spine. Within the appendicular skeleton, physiologic periosteal reaction, metaphyseal step-off, metaphyseal beak, metaphyseal spur, metaphyseal fragmentation, distal ulna metaphyseal cupping, proximal tibial cortical irregularity, and nutrient vessels can mimic abuse.\textsuperscript{11}

Additional imaging modalities such as ultrasound, CT and MRI can be considered in the evaluation for child abuse, especially if radiographs are equivocal. MRI has been shown to be useful in classifying brain trauma and in identifying cervical spine injury.\textsuperscript{12} 3D CT reformats also improve detection of skull fractures and accessory sutures.\textsuperscript{13} Low-dose chest CT can be performed with a dose of 0.56 mSv, which is less than twice that of a four view chest radiograph (0.29 mSv), and has been shown to identify previously unseen fractures of the ribs, scapula and vertebral bodies in cases of suspected child abuse.\textsuperscript{14}
Findings and procedure details

Role of the skeletal survey for suspected child abuse:

When a child presents to our hospital with signs or symptoms suspicious for abuse, the emergency physician or pediatrician orders a skeletal survey to be performed in the radiology department and interpreted by the radiologist. In some cases, the child has a known fracture based on dedicated radiographs of that particular bone, and in other cases the child may present with another injury such as a bruise or burn, or with failure to thrive. Skeletal surveys are then performed to assess for additional osseous injuries.

Our institution is an inner city Safety Net Hospital, which predominantly treats the underserved. Between January 2011 and December 2013, there were 67 children with suspected abuse who had one or more skeletal survey performed at our hospital. A total of 81 skeletal surveys were performed for these 67 patients. Stakes are high in this group, and an inappropriately low level of clinical suspicion, a misinterpreted radiograph, or inadequate family evaluation and follow-up can be fatal for the patient.

Performing the skeletal survey in practice:

The protocol for skeletal surveys at our institution is listed in Table 2. After the radiographs are acquired, the technologist checks them with the radiology resident and/or attending per ACR guidelines, while the child remains in the radiology department. Additional images can then be acquired per radiologist request.

Additional radiologic studies:

If the patient has suspected head or spinal trauma, CT or MRI is performed. If the patient has suspected intra-thoracic or intra-abdominal trauma, a dedicated ultrasound or CT is performed. CTs are performed using our trauma protocols, which all include intravenous contrast unless there is a contraindication such as allergy or renal failure. For penetrating trauma, oral and rectal contrast are administered. All trauma CTs are checked by the radiologist after initial scan while the patient remains on the CT table, and delayed images are acquired on a case-by-case basis (Figure 1).

Role of the Department of Children's and Families (DCF):

In cases of suspected child abuse, the primary physician is mandated by law to consult the Department of Children and Families (DCF). An individual from DCF is assigned to each case, and an investigation is performed. Observations and diagnoses made by the primary physician, as well as laboratory and radiologic results, are used in the
investigation. The DCF representative usually visits the patient's home or the suspected site of abuse, and ultimately determines whether each incident was abuse-related.

Results of retrospective review at our institution:

Of the 67 children with suspected abuse imaged with skeletal survey between 2011 and 2013, 32 (47.8%) had radiographic evidence of at least one skeletal injury, including fractures and periosteal reaction. The locations of osseous injury are listed in Table 3. After evaluation by the primary physician and DCF, 18 of the 67 children (26.9%) with suspected abuse were deemed to have been victims of physical abuse. Seven of these patients had skeletal trauma on their skeletal survey (38.9%), and 11 did not (61.1%). Therefore, of the 32 cases of skeletal trauma as seen on skeletal surveys, 7 were from abuse (21.9%) and 25 were accidental (78.1%).

Seven patients had more than one osseous injury: 5 were confirmed cases of abuse, 1 was accidental, and 1 was a patient with osteogenesis imperfecta with suspicious femur and rib fractures who was lost to follow-up at our institution (Figures 2 and 3). All metaphyseal corner fractures were from abuse (N=6) (Figure 4). The most commonly seen fracture was parietal skull fracture (N=15), and only 1 such fracture was from abuse, while 14 were accidental (Figure 5). The second most commonly encountered fracture was of the femur (N=8); 4 femoral fractures were from abuse, 3 were accidental, and the etiology of 1 was uncertain (Figure 6).

In 16 of the 18 cases of child abuse, one or both parents were the abusers, and custody of the child was taken from the parent(s) in 13 instances. One child was abused at daycare, and the other with the father’s family.

Follow-up skeletal surveys:

Twelve of the 67 patients evaluated for child abuse with skeletal survey had a short-interval follow-up skeletal survey performed within 5 weeks of the initial study.

- 4 patients did not have an osseous injury on either the initial or follow-up survey, but 2 were deemed to be cases of abuse (in the first case the father admitted to shaking the baby, and in the other case the patient had an unexplained bruise and burn).
- 6 patients had fracture(s) on the first study and no additional fracture identified on the second study: 2 were cases of abuse and 4 were cases of accidental trauma.

1. One patient had a parietal fracture and other areas of suspected periosteal reaction on the initial survey, and on the follow-up survey the additional areas of concern appeared normal. This was a case of accidental trauma.
2. In another patient with a tibial fracture, the follow-up skeletal survey showed normal findings which often mimic child abuse, including metaphyseal step-offs and distal ulnar metaphyseal cupping (Figure 7). The patient was asymptomatic at these locations and the tibial fracture was deemed accidental.

- 2 patients had fracture(s) on the initial study and new or additional fracture(s) identified on the follow-up radiographs: both were cases of abuse.

Another child presented to our institution for follow-up of suspected humeral and femoral abnormalities on radiographs from an outside hospital, and the skeletal survey showed physiologic periosteal reaction of the bilateral femoral diaphyses. The patient presented in 2014, which was outside of the study period, but the images are shown in Figure 9 to demonstrate that this finding is more often physiologic than abuse-related.9-11

**Timing of examinations:**

At our hospital, the pediatric radiologist is on site and available to read skeletal surveys Monday through Friday from 8 am to 5 pm. For pediatric studies performed overnight and on the weekend, the on-call radiology resident issues a preliminary report, and the pediatric radiologist is available by page to the resident on call. Twenty-one of the 81 skeletal surveys performed between 2011 and 2013 were performed at night or on the weekend, and were therefore preliminarily read by the resident. Although the attending can view the images by request and will later review them, it is important for the resident to be familiar with the above-mentioned intricacies of the skeletal survey.

**Table 1:** Standard skeletal survey for suspected child abuse per American College of Radiology (ACR) guidelines

**APPENDICULAR SKELETON**

- Humeri (AP)
- Forearms (AP)
- Hands (PA)
- Femurs (AP)
- Lower legs (AP)
- Feet (AP)

**AXIAL SKELETON**

- Thorax (AP, lateral, right and left, obliques) to include ribs, thoracic and upper lumbar spine
Pelvis (AP), to include the mid lumbar spine
Lumbosacral spine (lateral)
Cervical spine (lateral)
Skull (frontal and lateral)

ADDITIONAL VIEWS IF NEEDED

Towne view of the skull and
Lateral views of selected joints

Table 2: Our institution’s skeletal survey protocol for suspected child abuse

APPENDICULAR SKELETON
Right and Left Humerus AP only
Right and left Forearm AP only
Right and Left Hand AP only
Right and Left Femur AP only *
Right and Left Tib/Fib AP only
Right and Left Foot AP only **

AXIAL SKELETON
Ap Chest
BOTH obliques of the Chest
AP Abdomen ***
Lateral Cervical spine
Lateral Thoracic spine
Lateral Lumbar spine ****
Ap and BOTH laterals of Skull

ADDITIONAL VIEWS IF NEEDED

Lateral views of selected joints
*Femurs can be performed together if pt. 12 months old or younger

**Feet can be performed separate or together, no age discrepancy

***AP Chest and Abdomen can be done as a babygram only if pt. 12 months old or younger
****Lateral T and L spine can be done together if pt. 12 months old or younger

**Table 3: Location of osseous injury on skeletal survey**

<table>
<thead>
<tr>
<th>Site of osseous injury</th>
<th>Abuse</th>
<th>Accidental</th>
<th>Lost to follow-up</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metaphyseal corner fracture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibia</td>
<td>3</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Femur</td>
<td>2</td>
<td></td>
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<td>2</td>
</tr>
<tr>
<td>Radius</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Non-metaphyseal corner fracture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parietal skull</td>
<td>1</td>
<td>14</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Femur</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Tibia</td>
<td>1</td>
<td>4</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Humerus</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Rib(s)</td>
<td>1</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Clavicle</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Metacarpal(s)</td>
<td>1</td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>Occipital skull</td>
<td>1</td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>Radius</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>15</td>
<td>25</td>
<td>2</td>
<td>42</td>
</tr>
</tbody>
</table>
Fig. 1: 20-month-old boy with "multiple bruises concerning for abuse." •(A and B) Skeletal survey demonstrated fracture of the distal right clavicle (arrow) (A), and fractures of the 2nd, 3rd, and 4th metacarpals of the right hand (arrows) (B). •(C and D) The patient also had elevated liver function enzymes. Right upper quadrant ultrasound demonstrated a hypoechoic focus adjacent to gallbladder fossa (arrow) (C), corresponding to a liver laceration on trauma-protocol CT (arrow) (D). •Investigation by Department of Children and Families (DCF) revealed child abuse, and the patient was placed in foster care. •This case shows a role for additional imaging modalities, including ultrasound and, if necessary, CT.
Fig. 3: 7-week-old boy with history of "decreased leg extensions." On physical examination the patient had generous fontanelles. •(A and B) Head US (A) and CT (B) showed extra-axial collections (arrows). •(C) Brain MRI showed a complex subdural collection, suspicious for abuse (arrows). •(D) Chest radiographs showed bulbous appearance of right posterior 7th and 11th ribs, suspicious for healing rib fractures (arrows). •(E) Extremity radiographs demonstrated periosteal reaction along the left femoral diaphysis, which can be seen physiologically or with child abuse. •The patient was diagnosed with osteogenesis imperfecta (OI), and was lost to follow-up our institution after the mother transferred the patient's care to another hospital. Even in the setting of OI, these injuries are suspicious for child abuse, and although the Department of Children and Families (DCF) was consulted, the results of the investigation are unknown to us.

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Fig. 4: 8-month-old girl presents to the Emergency Department with her father. Skeletal survey was ordered for suspected child abuse: "Report of violent shaking by mother, witnessed and reported by father." *(A and B) Whole leg radiographs were obtained by the technologist, and evaluation for fine bony detail was limited due to the large field-of-view. *(C, D, E, and F) The radiologist requested dedicated knee and ankle radiographs (ankles not shown), which revealed bilateral medial distal femoral metaphyseal corner fractures (arrows), classic lesions in child abuse. •This case emphasizes the importance of adhering to the skeletal survey protocol, including dedicated 2-view knee radiographs. Fractures were difficult to see on entire leg radiographs. •Department of Children and Families (DCF) conducted an investigation and deemed the case positive for child abuse and the patient was placed in foster care.
Fig. 5: 6-month-old boy presented with parents after a reported fall from his bed. (A) Radiograph showed a right-sided skull fracture (arrow). There were no additional findings on skeletal survey (B) CT showed a non-displaced fracture of the right parietal bone (straight arrow), and scalp hematoma (curved arrow). Department of Children and Families (DCF) conducted an investigation and deemed the injury to be from accidental trauma, and the patient was discharged with his parents.

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**Fig. 6:** Three cases of femoral shaft fractures, two positive for child abuse. These cases also highlight the importance of clinical history and Department of Children and Families (DCF) investigation, especially with nonspecific musculoskeletal trauma such as diaphyseal fractures. (A) 11-month-old boy presents to the ED with a tender and swollen leg after "falling off the bed." •Dedicated right femoral radiographs showed a comminuted fracture of the distal femoral diaphysis (not shown). •Skeletal survey (shown) subsequently showed a mildly-displaced impaction fracture of the left femur (curved arrow) in addition to the comminuted right femoral fracture (straight arrow). •After the DCF investigation, the child was placed in foster care for child abuse. (B) 11-month-old girl presented to the Emergency Department with "history of pain and femur fracture." •Left femur radiographs showed femoral diaphyseal fracture (arrow). •Subsequent skeletal survey showed no other abnormality. •After investigation, the injury was deemed to be accidental. (C & D) 8-month-old girl presented to the Emergency Department with "left thigh swelling." •Left femur radiographs and skeletal survey showed comminuted left femoral fracture (arrow) (C). •Follow-up skeletal survey 6 weeks later showed new buckle
fractures of the distal left femur (straight arrow) and proximal left tibia (curved arrow) (D).
•After DCF investigation, the child was placed in foster care for child abuse.

Fig. 7: 5-month-old girl presented to the Emergency Department "not moving left leg equally" after falling out of her crib. •(A and B) Left femur and left tibia/fibula radiographs were ordered, which showed a proximal tibial metaphyseal fracture (arrows) (A). The fracture was not well seen on the lateral radiograph, but a metaphyseal step-off was noted at the distal femoral (arrow) (B). •(C and D) The second skeletal survey (performed 2 weeks later for follow-up) showed the following: a metaphyseal step-off at the distal right femur (arrow) (C), and distal ulnar metaphyseal cupping (arrow) (D). •Department of Children and Families (DCF) investigation was initiated for possible neglect, and ultimately the patient was discharged from DCF, and the parents retained custody of the
The tibial fracture was deemed consistent with the described mechanism of injury. This case highlights the importance of understanding the radiographic appearance of normal variants, including metaphyseal step-off and distal ulna metaphyseal cupping.

**Fig. 2:** 4 month-old girl brought to the Emergency Department (ED) with a chief complaint of unresponsiveness. Brain CT was normal (not shown). (A & B) Skeletal survey was performed and showed healing posterior right 7th rib fracture (arrow) (A), and suspected fractures of the distal tibial metaphyses (arrows) (B). (C & D) Dedicated ankle radiographs confirmed presence of bilateral distal tibial fractures (arrows).
by Department of Children and Families (DCF) revealed child abuse, and the patient was placed in foster care.

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**Fig. 8:** A 6-week-old boy was brought to an outside hospital with a complaint of irritability, and he subsequently had radiographs that showed "abnormalities of the humerus and femur." A skeletal survey was subsequently ordered at our hospital for further evaluation. • The survey revealed periosteal reaction along the bilateral femoral diaphysis (arrows) and no additional osseous abnormality. • Clinically, the etiology was deemed to be physiologic and not abuse, which coincides with observations that periosteal reaction has a low specificity for child abuse.

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Conclusion

Appropriate multi-disciplinary evaluation for abuse can save a child's life. When a skeletal survey is ordered, it is imperative for the technologist and radiologist to adhere to the skeletal survey protocol as recommended by the American College of Radiology (ACR), so as to image the osseous structures with adequate detail. The radiologist can also guide further imaging with additional radiographs, alternate imaging modalities, and follow-up studies. In addition to identifying fractures, the radiologist often will need to appropriately classify normal and variant anatomy.

In our review, about a quarter of the patients evaluated for abuse with skeletal survey were determined to be victims of abuse. Of the abused children, 38.9% had skeletal trauma and 61.1% did not. All 6 corner fractures seen on skeletal surveys were from abuse, and 5 of the 7 patients with multiple fractures were confirmed cases of abuse. The most commonly encountered fracture was parietal skull fracture, which was rarely associated with abuse (1 of 15 cases positive for abuse). The next most common fracture was femoral diaphyseal fracture, which was associated with abuse 50% of the time.

Many children seen at our hospital for osseous injury arrive with parents or caregivers with concurrent psychiatric or drug-related problems. In addition, these children may have multiple caregivers, even underage relatives, and the time or location of the sustained injury may be unknown. Our patient population is at risk for both accidental and non-accidental trauma, and appropriate evaluation and home visits are necessary to provide a safe environment for the child.
References