Abstract:
A young child presents to you for care and you have identified a fracture. Now what? What are the steps you need to take to make sure you are not missing abuse, and what are the most common characteristics of an abuse case? What are common pitfalls that result in an incorrect conclusion? This article will offer a practical approach to the assessment and management of the young child or infant diagnosed as having a fracture. This article will focus on the questions to ask that help ascertain the manner of injury and determine whether the history provided is a plausible explanation of the fracture. A general overview of the literature regarding fractures in children is also provided.

Keywords:
plausible; fracture; inflicted; nonaccidental trauma; child abuse

*Division of Emergency Medicine, Northwestern University Feinberg School of Medicine, Ann and Robert H. Lurie Children's Hospital of Chicago, Chicago, IL. †Department of Children & Family Services, Chicago, IL; ‡Eastern Virginia Medical School, Norfolk, VA; §Child Abuse Program, Children's Hospital of The King's Daughters, Norfolk, VA.
Reprint requests and correspondence: Mary Clyde Pierce, MD, Division of Emergency Medicine, Northwestern University Feinberg School of Medicine, Ann and Robert H. Lurie Children's Hospital of Chicago, 225 E Chicago Ave, Box 62, Chicago, IL 60611-2605.
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mpierce@luriechildrens.org (M.C. Pierce), kkaczor@luriechildrens.org (K. Kaczor), Dana.Lohr@illinois.gov (D. Lohr), Kristen.Richter@illinois.gov (K. Richter), Suzanne.Starling@chkd.org (S.P. Starling)

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A Practical Guide to Differentiating Abusive From Accidental Fractures: An Injury Plausibility Approach

Mary Clyde Pierce, MD*, Kim Kaczor, MS*, Dana Lohr, MSW†, Kristen Richter, RN†, Suzanne P. Starling, MD‡§

The evaluation and management of a child or infant with a fracture is a common occurrence in emergency medicine. Management of fractures in children requires more than just treatment of the injury. For children—especially infants and children younger than 3 years of age—management also includes considering the manner of injury (accidental trauma or the result of an abusive act by an adult caregiver). Thus, proper management of a fracture in the young child requires both treatment of the fracture and determination of the manner of injury. Twenty percent of abusive fractures are not identified as such at the initial visit, placing the child back into harm's way.[1] Taitz et al[2] studied young children diagnosed as having a long bone fracture in an emergency department (ED) setting. Of 100 cases, 31 had indicators of abuse, but only 1 child was referred for further evaluation by child protection. Failure to

properly consider the manner of injury can lead to failure to diagnose abuse and, therefore, failure to protect the child from additional harm, including injuries that could prove fatal. Few missed diagnoses in pediatrics have such associated lethality. This is why it is so critical for the emergency medicine clinician to approach each child fracture case with a standardized, objective approach. This method is required to avoid common errors associated with missed cases of child abuse or unnecessary investigations of innocent families. Accurate identification of child abuse is important to facilitate appropriate evaluation, referral, investigation, and outcomes for children and families.[3] One study found that child abuse recurs 35% of the time without appropriate detection and intervention.[4] Because fractures are the second most common presentation of child abuse following soft tissue injuries,[5] it is paramount that the emergency medicine provider has the necessary skills and knowledge to access injury plausibility.

COMMON REASONS WHY CHILD ABUSE IS MISSED

Differentiating accidental fractures from ones caused by child abuse can be difficult. Because the child may be too young or afraid to tell what happened, assessing fractures in young children and infants requires specific skills. In addition, if the child has sustained the fracture from an abusive act, that caregiver is highly likely to conceal the act by offering an accidental cause of the injury or may present with a medical symptom rather than a history of trauma. In fact, most abuse cases do not present with a history of trauma at all, but rather a medical chief complaint such as "not using his arm/leg" or "she won't stop crying," making the diagnosis of trauma all the more difficult.

Errors in decision making also play a significant role. Missed diagnoses of inflicted fractures are attributed to 3 common errors.

1. Preconceived bias: information is perceived or interpreted differently due to bias. Bias can lead to skewed interpretation of the evidence or incomplete data collection. Bias is exhibited with the belief that the family is "a nice family and deserves the benefit of the doubt." In potential abuse cases, it is critical to realize that someone else such as a babysitter or other childcare provider may be hurting the child unbeknown to the caregiver. *The benefit of the doubt must always be given to the child.* Conversely, bias also plays a role when a suspicion of abuse is based on stereotypical features such as poverty or minority status rather than on case facts.[6]
2. Fixation errors: information is ignored or not used due to a foregone conclusion. Fixation errors can lead to ignoring facts or clues that do not fit with the conclusion (be it accidental or abuse). Fixation errors occur when red flags are ignored and an improbable explanation of injury is accepted. In fact, 80% of children who died of abuse were known to a health care professional who did not act.[7] Conversely, not accepting a probable explanation of accidental injury due to a preconceived notion that a certain fracture type is always abuse is also a fixation error. Spiral femur fracture, for example, was previously thought to be caused only by abuse, and in the young, nonambulating infant, abuse is still the most likely cause. However, in the older ambulating child, an accidental spiral femur fracture is possible.[8]
3. Knowledge errors: information is not known, and therefore, incorrect conclusions and diagnoses are made. This type of error occurs when abuse is not on the differential diagnosis because of a knowledge deficit regarding the presentation and evaluation of the potentially abused child. If you do not consider it, you will never identify it.

As with any difficult or potentially upsetting diagnosis in emergency medicine, such as cancer or meningitis, the workup does not depend on whether the family is perceived as being a good family or not. An objective, standardized, and consistent approach to assessing fractures in children is required to avoid common errors associated with missed cases of child abuse or overreporting of abuse in innocent families.

Improving Accuracy in Decision Making: Possible Does Not Equal Plausible

The real question to be answered is whether the case is plausible. The first question is not "Is this possible?" because this approach will lead to incorrect conclusions. Such general decision making will fall short of the accuracy needed in considering the manner of injury and whether this specific child's injury is plausible. Plausibility takes into account the specific details of the child, the injury, the radiographic findings, and the account of events before and after the trauma. This is a critical issue when taking care of a specific child; what may be possible in general may not be at all possible for a

specific case once the details are taken into account. Plausibility requires the specific account of events that accurately reflect the biomechanics required to result in a given fracture morphology. The behaviors, signs, and symptoms that are the physiologic result of the specific fracture also must be present. In cases where a child's actions are blamed as the cause of the trauma, the described action must also reflect the developmental capabilities of the child.[9,10]

Key point: the whole story has to fit, not just the simplistic answer to "Can you get a fracture from falling off a bed?" The specific details of the child, developmental capabilities, history of the events, actions before and after the fall, and the fracture characteristics each must fit the history provided.

OBTAINING THE HISTORY OF INJURY

Key, simple, directed history of injury questions can help with an objective assessment of manner of injury and plausibility. This is the who, what, when, where, how, and why of the injury history.

Who was with the child when the injury occurred or the sign or symptom was noticed? Is this the same person providing the history at the hospital? *Pearl*: the amount of detail the caregiver is able to provide is dependent on whether he/she witnessed the event. When a story is being fabricated, the person telling the lie is often prepared with a superficial statement such as "he fell out of bed," but is not prepared to answer detailed questions about the event.

What happened or what was noticed? If some type of fall is part of the history, specific questions such as, "Was the child in motion, How did he/she fall, How did he/she land?" are all keys to understanding the potential types and magnitudes of force the child likely experienced. *Pearl*: when simple follow-up questions such as "Then what happened?" or "In what position did you find the child?" cannot be answered, it is important to question further. A *red flag* is present if the history of injury is vague, changing, or altogether absent. For example, an initial history of "I was in the shower when he fell," morphing into "I was getting his bottle in the kitchen when he fell," should raise a red flag.

When did it happen or when was something abnormal first noticed? This information helps evaluate the timing in seeking care, and if a delay did occur, whether that delay is a red flag (a child exhibiting severe pain with a completely displaced femur fracture, but a history of injury the previous day), or a reflection of the type of injury that may take time to produce prominent signs and symptoms (a subtle buckle fracture of the wrist). *Pearl*: it may be helpful to ask when was the last time the child was acting normal and pain or symptom-free. This may help isolate the time of injury.

Where did it happen? This helps to understand the scenario and scene of the event including surface type if a fall was involved. A red flag is present if the where changes. For example: "I tripped with the baby in the bathroom at the store" vs "I fell with him in the bedroom" would give you 2 completely different fall surfaces.

How did the child behave after the injury of the event was noticed? This is a key question in addressing whether the described actions are congruent with the expected physiologic consequence of the specific fracture characteristics. *Pearl*: the simple follow-up question, "Then what happened?" is a good way to understand the full story and to gain information needed to fully correlate the fracture characteristics with the history of injury. A red flag is present if the person describes an action by the child that is not possible for a given fracture type. For example, "He was fine after he fell down the steps and got up and walked to the couch," is not physiologically possible with a comminuted femur fracture.

Why did you seek care? This helps elucidate the caretaker concerns and what the caretaker noticed. A red flag might be present, for example, if the only reason the child was brought to the ED was because another adult not present at the time of the event came home and realized the child had been injured. The person who brings the child for care is often not the person who has hurt the child. *Pearl*: the person providing the information may not know what actually happened and, in abuse cases, may have no idea someone has hurt the child.

INTERPRETING FRACTURE MORPHOLOGIES

Ability to clinically interpret fracture morphology allows the ED clinician to ask key directed questions and to evaluate whether the history matches and is consistent with the child's injury/fracture. Bones fail in a predictable way according to the type and magnitude of load applied.[11] Each fracture's morphology has an associated required load and magnitude of force that is required to produce it and has specific associated signs, symptoms, and physiologic consequences. Accordingly, the compatibility of the history provided can be ascertained. Decisions regarding the likelihood of the injury event causing the fracture can be objectively made. Because a given fracture morphology produces predictable signs, symptoms, and physiologic constraints, plausibility of the child's described behaviors after the event can be evaluated for congruency.

A fracture's morphology is characterized by the following 4 domains: (1) the bone involved, (2) the type of fracture, (3) whether there is displacement of the fracture fragments, and (4) whether the fracture is healing or acute. Each of these characteristics constitutes the fracture morphology and determines the degree and timing of the development of signs and symptoms at presentation and the degree of physiologic constraint produced by the fracture. A working knowledge of these elements allows the clinician to objectively determine injury plausibility. Additional publications are available regarding fracture biomechanics, including part 1 of this article published in *Clinical Pediatric Emergency Medicine*.[9,10,12,13]

LITERATURE REVIEW

Overview of Fractures in Children and Infants

Fractures caused by abuse predominantly occur in infants and toddlers and are less common in older children.[14,15] Leventhal et al[16] used the Kids Inpatient Database, which contains discharge data for 80% of acute pediatric hospitalizations in the United States. They reviewed fracture data and found that the proportion of fractures attributed to abuse was highest in infants younger than 1 year at 24.9%. The proportion decreased to 7.2% in children 12 to 23 months of age and 2.9% in children 24 to 35 months of age.

Incidence of Fractures in Infants

Leventhal et al[16] evaluated abusive fractures in infants and described the location and prevalence of specific fractures in this population (Figure 1). In children younger than 1 year, skull fractures are the most common fracture site and extremity fractures are the second most common. Of the extremity fractures, femur fractures are the most common, followed by humerus fractures.[16] Leventhal et al[16] found that 17.1% of skull fractures, 30% of femur fractures, and 43% of humerus fractures in children birth to 11 months of age were attributed to abuse. These fractures are common in both accidental and abusive traumas and therefore are not specific for abuse. Some fractures such as metaphyseal and rib fractures are specific for abuse, meaning that they are more commonly caused by abuse rather than accidental means. However, no fracture is completely diagnostic of abusive trauma.[8,9]

Fractures With a High Specificity for Abuse

Certain fractures increase the likelihood that abuse occurred, although no single fracture type alone can distinguish those children who have been

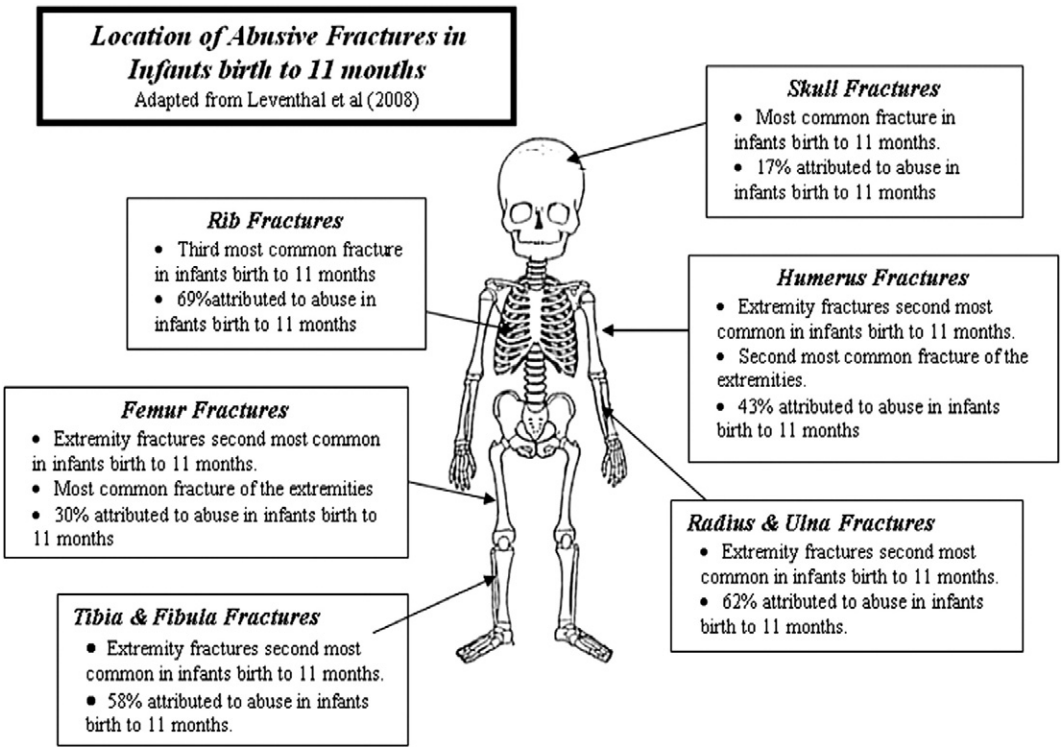

Figure 1. Location of abusive fractures in infants. Data from Leventhal et al.[16]

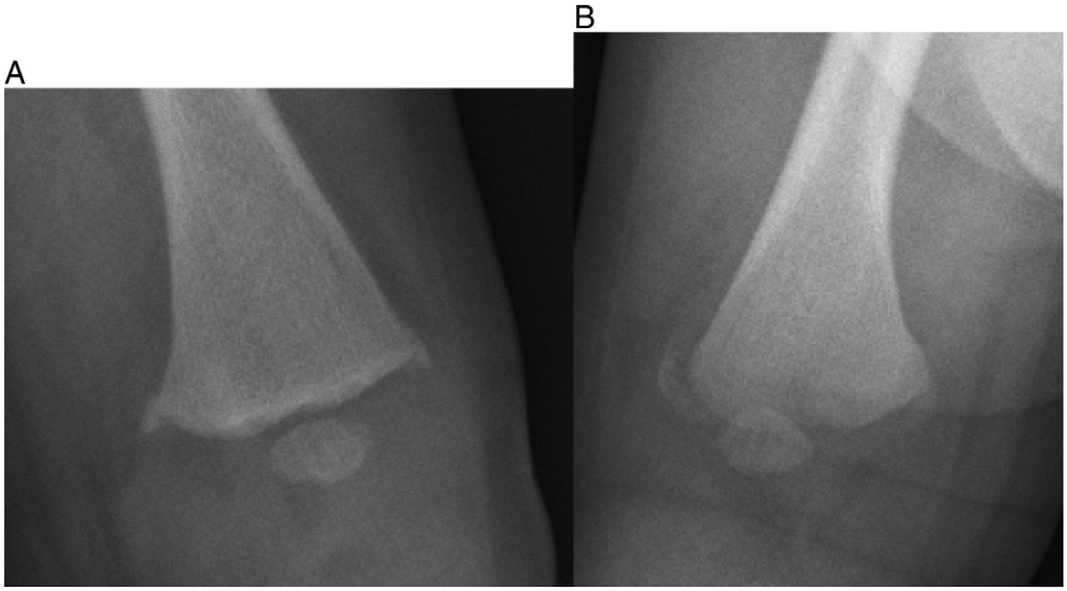

Figure 2. A, Classic metaphyseal lesion with appearance of "corner" or "chip" fracture due to angle of beam. (Courtesy of Berkeley Bennett, MD, and Eva Rubio, MD.) B, Classic metaphyseal lesion with appearance of a "bucket handle" due to radiographic angle of beam. (Courtesy of Berkeley Bennett, MD, and Eva Rubio, MD.)

victims of abuse from those who have experienced accidental trauma.[5] Fractures that are specific for abuse because they are more often caused by abuse than accidental trauma include metaphyseal, rib, scapular, sternal, and pelvic fractures.[10,17]

Metaphyseal Fractures

Classic metaphyseal lesions occur in the metaphysis of a long bone. The term *classic metaphyseal lesion*, is also called a "corner fracture" or "bucket-handle fracture." This is due to the different radiographic appearances, depending on fracture and angle of beam (Figure 2A, B). The classic metaphyseal lesion occurs most often in children younger than 1 year[18,19] and is highly specific for abuse when it occurs in children of this age group.[10,17] Worlock and Stower[20] compared fracture patterns in 35 children who had abusive fractures with fracture patterns in 116 children who had accidental fractures. Eleven percent of the abusive fractures were metaphyseal, whereas none of the fractures found in the accidental injuries group were metaphyseal. Metaphyseal fractures are also the most frequently found long bone fracture in infants who die with evidence of abuse.[21] A study of 31 infants younger than 11 months who died of inflicted injuries found 72 fractures of the long bones, of which 64 (89%) were classic metaphyseal lesions.[21]

The most common long bone sites for the classic metaphyseal lesion are the distal femur (medial aspect), proximal tibia, distal tibia, and proximal humerus.[22] The metaphysis is the area where maximum growth occurs, which makes this area particularly vulnerable to injury caused by tensile or shearing forces.[10,12,18,19,23-25] These types of forces act on the metaphysis of the bone when a child is forcefully pulled, twisted, or yanked by an extremity and/or when the child is shaken violently,[12,18,19] causing the bone in the vulnerable metaphyseal area to separate.[10,18,19,25]

The classic metaphyseal lesion is highly specific for child abuse in infants because the tensile and shearing forces necessary to cause this injury are unlikely to occur from accidental causes.[19,23,24] Dwek wrote that "children who are not toddling or walking generally cannot exert this type of force by themselves to cause this type of fracture" and "this fracture does not result from falls and has never been reported as a result of infant falls in multiple studies."[26]

Imaging studies are essential in diagnosing metaphyseal fractures because there is usually no outward physical evidence of these fractures. There are ample data from autopsies and clinical studies of metaphyseal fractures, which have consistently demonstrated a lack of bruising or soft tissue swelling and only cause pain when severe.[22,27,28] For these reasons, metaphyseal fractures typically are not detected until discovered by imaging. Follow-up x-rays 2 weeks after the initial study are also recommended because additional metaphyseal fractures may be identified at this time.[29]

Metaphyseal fractures heal by gradual bone absorption across the metaphyseal margin, and

many have healed by 6 weeks.[30] The quick healing time and lack of treatment required can make these fractures seem less serious than they really are. However, their importance should not be overlooked because of their strong correlation with child abuse. Carty wrote, "metaphyseal fractures usually heal without long-term consequences and in that sense are not important, but they must be regarded as sinister because of their associations."[27]

Rib Fractures

Rib fractures are commonly seen in cases of abusive trauma and have a high specificity for abuse when found in young children.[17] Leventhal et al[16] found that rib fractures were the third most common fracture in children younger than 1 year and that 69% of rib fractures in this age range were attributed to abuse. A systematic review of 7 studies of abusive fractures found that after controlling for motor vehicle crashes, violent trauma, and postsurgical cases, there was a 71% probability that a rib fracture was caused by abuse.[15] A second study found that a rib fracture in a child younger than 3 years had a positive predictive value of 95% for the diagnosis of nonaccidental trauma.[31]

The low incidence of accidental rib fractures can be explained by the fact that the infant's chest is more malleable than that of an older child. As a result, their ribs will deform rather than break, unless major force is exerted.[32] Most rib fractures in infants are thought to occur by anterior-posterior compression and are often associated with intracranial injuries.[33] This mechanism of injury most commonly results in rib fractures in the posterior and lateral regions,[34] requiring substantial force.[35]

Often, children with rib fractures do not present with a history of trauma, but instead, have respiratory complaints, gastrointestinal problems, irritability, or mental status changes related to intracranial injury. Therefore, the fractures are usually clinically unsuspected until detected by imaging.[10] When there is no displacement of bone fragments, acute rib fractures are often hard to diagnose and may go undetected on x-ray until callus formation, 7 to 10 days after the injury. For this reason, it is recommended to have follow-up x-rays taken within 2 weeks of the suspected abuse.[36] To increase sensitivity, specificity, and accuracy in detecting rib fractures, standard chest x-rays along with right and left oblique views are recommended (Figure 3A, B).[31,37]

Caregiver explanations may include that the fractures were caused by birth trauma or falls, but a literature review indicates that these incidents rarely result in rib fractures. One study screened for birth injuries in 35 000 infants and found no rib fractures.[38] Falls from heights and complex falls can cause rib fractures, but posterior and lateral rib fractures are more likely to be attributed to child abuse.[17,34,39]

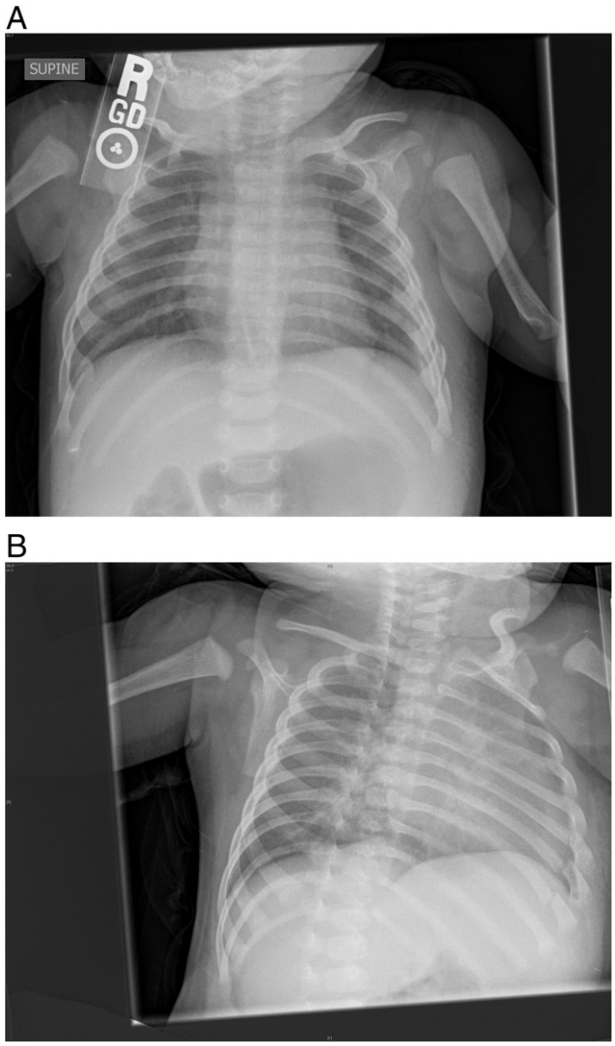

Figure 3. A, Anteroposterior view of chest—a minimum of 3 rib fractures are present but subtle. B, Oblique view of the same chest—the 3 "subtle" fractures of the sixth, seventh, and eighth left lateral ribs are obvious on the oblique view.

Fractures Common in Both Abusive and Accidental Trauma: Skull and Long Bone Fractures

Skull Fractures

A parietal linear fracture is the most common skull fracture type in both abusive and accidental injuries.[15] Approximately 30% of skull fractures in children younger than 2 years are due to abuse.[16,40-42]

Certain factors raise suspicion for abuse. Multiple skull fractures and bilateral skull fractures have been found more frequently as a result of abuse rather than accidental injury (Figure 4A, B).[41,43] Growing fractures, depressed fractures, and associated intracranial injury are other factors that should also raise suspicion for abuse.[40] In cases where the fracture results from abuse, infants usually present with a symptom such as scalp swelling or vomiting. A history of trauma is often absent, or the caregiver may construct a history of trauma after identification of the fracture.[10]

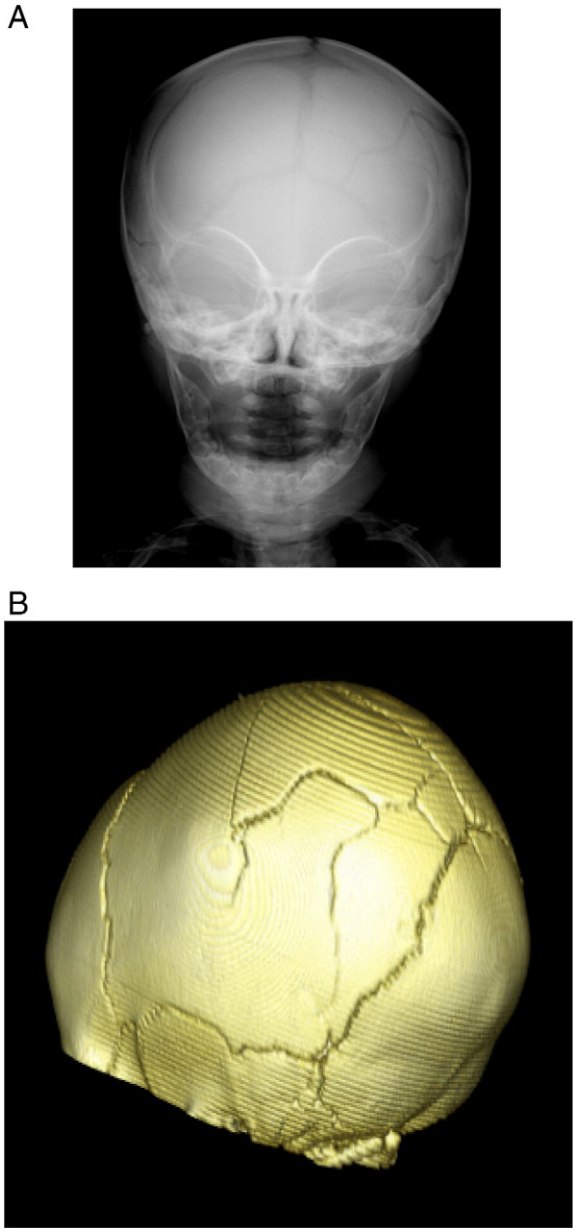

Figure 4. A, Plain radiograph of skull fracture. B, Computed tomography 3-dimensional reconstruction of same fracture in panel A.

Because skull fractures are not specific for abuse, the history given by the caregiver becomes particularly important when identifying the cause. If a fall is offered as an explanation, the characteristics of the fall should be discussed with the caregiver to determine injury compatibility with the history provided. When accidental skull fractures do occur, they are typically caused by falling from a distance of 3 to 6 ft, such as falls from baby chairs or infant carriers placed on tables and from standing adults' arms.[40] Most falls from short distances do not result in skull fractures in infants. A study of 3357 falls in infants younger than 6 months found that *serious injury*, defined as a concussion or fracture, occurred in less than 1% of the falls.[44] There are several reports of fractures resulting from bed falls or other short distances less than 3 ft, but in each case, the infant hit a hard surface such as a radiator, table corner, or toy while falling.[10,45,46]

Birth trauma is another explanation that may be offered for skull fractures in young infants.[42] In uncomplicated deliveries, skull fractures at birth are very rare. Rubin[47] studied 15 435 births and found a single skull fracture. Bhat et al[38] studied 35 000 births and found 4 skull fractures. Vacuum extraction or forceps use at birth increases the chance of head injuries including cephalohematoma and skull fracture. Skull fractures are also found in approximately 5% of infants who undergo vacuum extraction.[48] However, most skull fractures that result from birth trauma are uncomplicated linear fractures of the parietal bone and are often not detected at birth.[42] Determining birth history and the difficulty of delivery are key when evaluating a very young infant with an unexplained skull fracture. Kleinman and Barnes[49] wrote that an uncomplicated linear skull fracture caused by birth trauma is indistinct by 2 months of age and no longer visible on x-rays at 6 months.

Femur Fractures

Femur fractures are the most common of the extremity fractures in infants; 30% of femur fractures in this age range are caused by abuse.[16] Smaller studies have found between 17% and 60% of femur fractures in children younger than 1 year were caused by abuse.[8,50,51] Abuse becomes an uncommon cause of femur fractures once the child begins walking[8]; therefore, the context of the history is key. Loder et al[52] analyzed almost 10 000 pediatric femur fractures and found that nearly all of the fractures attributable to abuse occurred in children younger than 2 years.

The femur is the largest bone in the body, and it can be fractured by both high- and low-energy mechanisms. Common accidental causes include motor vehicle collisions and falls.[8,10,53] In children younger than 3 years, the most common cause of femur fracture is a fall, followed by abuse.[54] Of interest, children whose femur fracture resulted from child abuse, a motor vehicle crash, or an auto-pedestrian accident were 16 to 20 times more likely to have associated injuries than those with femur fractures as a result of a fall.[54] Rewers et al[54] found that 55% of children with abusive femur fractures also had additional injuries including injuries to the head and neck, chest, abdomen, and face. These findings support the premise of increased risk and severity of forces applied to an abused infant or child.

Femur fractures are rarely caused by birth trauma, with a reported incidence of 0.13 per 1000 live births.[55] No specific fracture site or pattern has been found, which allows differentiation between accidental and abusive femoral fractures.[8,10,53] However, spiral fractures in nonambulatory infants are highly suspicious for abuse because an infant cannot generate the twisting mechanism necessary to cause a spiral fracture.[8,10,53]

Humerus Fractures

Leventhal et al[16] found that the humerus was the second most common extremity fracture in children younger than 1 year and that 43% of humerus fractures in children in this age range were attributed to abuse. However, 60% of spiral humerus fractures are attributable to abuse in children younger than 15 months.[56] Farnsworth et al[57] found that falls are the most common cause of humerus fractures, and in children younger than 3 years, humerus fractures occurred after the child fell from a bed, couch, or other object 3 to 6 ft high. Humerus fractures are rarely caused by birth trauma, with a reported incidence of 0.2 per 1000 deliveries.[38] When abuse is the cause, children often present with unknown mechanisms of injury and histories that change,[56,58] although in a study by Strait et al,[58] half of the children with a humerus fracture caused by abuse had a history of a fall, underlining the importance of obtaining a careful history.

Tibia/Fibula

Leventhal et al[16] found that 58% of tibia/fibula fractures in children birth to 11 months of age were caused by abuse. In nonambulating infants, this fracture location is concerning. Abusive fractures can occur when the child is grabbed by the leg or when the leg is twisted.[10,59] As the child begins to walk, accidental tibia and fibula fractures become relatively common skeletal injuries.[10]

Radius/Ulna

Leventhal et al[16] found that 62% of radius/ulna fractures in children birth to 11 months of age are caused by abuse. Radius and ulna fractures are uncommon in infants because of the conditions necessary to cause this fracture. In an older child, forearm fractures most often occur from falling onto an arm that is outstretched to break the fall. However, infants lack this reflex, termed the *parachute reflex*, until 8 to 9 months of life.[60] Therefore, fractures in a young infant do not occur by this mechanism, making fractures of the radius and ulna suspicious for abuse. Abusive fractures can result when a caregiver grabs or yanks the child by the arm.[10]

RISK FACTORS FOR ABUSE

Certain factors increase the likelihood that injuries occurred from abuse including patient age, presence of multiple injuries, and frequent hospital visits. A delay in seeking care may also indicate the possibility of child maltreatment. A history of previous injuries and multiple ED visits raises the possibility of abuse.[61] Kellogg[3] listed specific historical features that increase the likelihood of abuse.

Incompatible or Inconsistent History

Explanations that are concerning for abuse include the following:

- No explanation or vague explanation for a significant injury
- An important detail of the explanation changes dramatically
- An explanation is inconsistent with the pattern, age, or severity of the injuries
- An explanation is inconsistent with the child's physical and or developmental capabilities
- Different witnesses provide markedly different explanations for the injury or injuries

Age of the Child

The probability that a fracture occurred from abuse is much higher in children younger than 18 months than that in older children. Worlock and Stower[20] found that 80% of abusive fractures occurred in children younger than 18 months and estimated that 12.5% of children with abusive fractures in this age group maybe victims of child abuse. Kemp et al[15] performed a systematic review

TABLE 1. Proportion of abusive fractures in infants 0 to 11 months of age from the Kids Inpatient Database.[16]

	1 Fracture		2 Fractures		3 Fractures	
Age (mo)	No. of Infants	% From Abuse	No. of Infants	% From Abuse	No. of Infants	% From Abuse
0-11	5076	18.5%	477	55.1%	298	85.4%

of the literature on patterns of abusive fractures and found that 25% to 56% of fractures in children younger than 1 year were due to child abuse. Radius, ulna, tibia, and fibula fractures are also more likely to have been caused by abuse than accidental injury among children 0 to 11 months of age.[16]

Multiple Fractures

The likelihood of abuse increases when a greater number of fractures are sustained (Table 1).[10,16] Although it is often assumed that falls or other accidental injuries frequently cause multiple fractures, Pierce and Bertocci[9] emphasized, "A common

TABLE 2. Summary of red flags and risk indicators for abuse in children with fractures.

Risk Indicators for Abuse	Red Flag	Explanation	References
Age	<18 mo	80% of fractures from abuse occur in children younger than 18 months.	20
Chief complaint	Medical	Having no history of trauma has a high sensitivity (97%) and positive predictive value (92%) for abuse.	64
Trauma history quality	Vague or poor	Poor quality of history often reflects a story that is being fabricated.	3,65,66
Fracture characteristics	Do not match	Bones fail in a predictable way according to the type and magnitude of load applied.	10-13,65,66
Child behaviors	Improbable or impossible	History inconsistent with the child's developmental capabilities and/or the physiologic constraints caused by the fracture are indicative of a fabricated story.	3,10
Delay in seeking care?	Obvious injury, delay is red flag	Usually when the fracture is obvious with displacement, the signs and symptoms are also obvious so a delay in seeking care would be a red flag in such cases.	3,65,66
Skin findings	Atypical/unexplained	Statistically significant differences exist in bruises caused by abusive vs accidental trauma. Note that the absence of bruising is common in abuse and does *not* mean that abuse did not occur.	28,67-72
Multiple fractures	Correlates with major trauma	(Self-explanatory)	9,10,6
Healing fractures	Reflects prior injury	(Self-explanatory)	24,61-63
High-specificity fractures	Classic metaphyseal lesion, posterior rib, sternum, scapula	Fracture types are more highly specific to abuse mechanisms than accidental mechanisms, unless reliable, corroborated, plausible history exists, ie, EMS transport for motor vehicle crash with resultant sternal fracture.	10,17

TABLE 3. The "HITS" of injury plausibility provide 4 key questions to address when determining the plausibility of a given fracture.

H—History consistency	Is history told consistently, or does the story change?
I—Injury compatibility	Is the fracture morphology compatible with the biomechanical loading required to produce that specific fracture type?
T—Timing congruency	Is the timing of the described development of signs, symptoms, and actions congruent with the severity of the injury and the physiologic consequences produced by the fracture?
S—Skin findings	Are there bruises/other skin injuries that are consistent with the provided history, and do skin findings reflect accidental injuries or are they atypical and unexplained?

misconception is that if the trauma was bad enough to cause one fracture, it could cause a second fracture or additional injuries." Short of a motor vehicle crash or a pedestrian being hit by a vehicle, more than one fracture, and/or additional injuries are uncommon, "except in the case of inflicted trauma."[9] Leventhal et al[16] in their study of 13 870 children birth to 36 months of age found that the likelihood of abuse increased 4 to 6 times in children who had 3 or more fractures as compared with 1 fracture. Infants 0 to 11 months of age represented 42% of the study, and the table below illustrates the occurrence of multiple fractures in this age group.[16]

Healing Fractures

Fractures in various stages of healing are also suspicious for abuse because it suggests that the child was injured on more than one occasion.[62-64] Loder and Bookout[24] found that 13% of abused children younger than 6 years had old and new fractures in various stages of healing.

SUMMARY: OVERVIEW OF APPROACH AND RED FLAGS

Table 2 provides a summary of key red flags for identifying children at risk for abuse who are diagnosed as having a fracture. Table 3 provides 4 key questions to address when determining injury plausibility of fracture. If any red flags are present, further evaluation is prudent. Further evaluation includes a psychosocial assessment by a trained social worker and/or a trained child abuse pediatrician, to identify psychosocial risk factors. Additional studies may include a skeletal survey, computed tomography of the head, abdominal computed tomography, and laboratory testing. The need for each study is determined by the age of the child, the presence of other signs or symptoms, and history details. The purpose of a skeletal survey is to evaluate for occult osseous injury. It is indicated for all children younger than 2 years being evaluated for a suspicion of abuse regardless of signs or symptoms. In a study analyzing 703 skeletal surveys, 10.8% had additional, unexpected injuries identified. In infants younger than 6 months, the rate was highest at nearly 16%.[62,73] In older children, a skeletal survey is indicated when the child has been severely beaten or killed.

The history of injury to be obtained includes how the injury occurred, the biodynamics of the event, subsequent behaviors of the child, described development of symptoms or signs, and when medical care was sought. Plausibility requires that the story is told in a consistent manner with clear details, and the individual child's specific fracture characteristics and subsequent behavior are accounted for in the history of injury. Plausibility also requires that all other injuries identified (including the skin) be accounted for in the history of injury. A standardized and objective approach can improve accuracy in decision making that benefits the abused child and the innocent family.

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REFERENCES

1. Ravichandiran N, Schuh S, Bejuk M, et al. Delayed identification of pediatric abuse-related fractures. Pediatrics 2010;125:60-6.
2. Taitz J, Moran K, O'Meara M. Long bone fractures in children under 3 years of age. Is abuse being missed in emergency department presentations? J Paediatr Child Health 2004;40:170-4.
3. Kellogg ND. American Academy of Pediatrics Committee on Child Abuse and Neglect. Evaluation of suspected child physical abuse. Pediatrics 2007;119:1232-4.

4. Skellern CY, Wood DO, Murphy A, et al. Non-accidental fractures in infants: risk of further abuse. J Paediatr Child Health 2000;36:590-2.
5. Nirav PK, Baldwin K, Wolfgruber H, et al. Child abuse and orthopaedic injury patterns: analysis at a level I pediatric trauma center. J Pediatr Orthop 2009;29:618-25.
6. Lane WG, Rubin DM, Monteith R, et al. Racial differences in the evaluation of pediatric fractures for physical abuse. JAMA 2002;288:1603-9.
7. A nation's shame. Fatal child abuse and neglect in the United States. Fifth Report, U.S. Advisory Board on Child Abuse and Neglect. April 1995;XXIII-XXXVI:7–18.
8. Schwend RM, Werth C, Johnston A. Femur shaft fractures in toddlers and young children: rarely from child abuse. J Pediatr Orthop 2000;20:475-81.
9. Pierce MC, Bertocci G. Fractures resulting from inflicted trauma: assessing injury and history compatibility. Clin Pediatr Emerg Med 2006;7:143-8.
10. Kaczor K, Pierce MC. Abusive fractures. In: Jenny C, editor. Child abuse and neglect: diagnosis, treatment, and evidence. St. Louis, MO: Saunders Elsevier; 2011. p. 275-95.
11. Gomez NJA, Mahum AM. Biomechanics of bone. In: Nahum AM, Melvin JW, editors. Accidental injury. New York, NY: Springer-Verlag; 2002. p. 206-7.
12. Pierce MC, Bertocci G, Vogeley E, et al. Evaluating long bone fractures in children: a biomechanical approach with illustrative cases. Child Abuse Negl 2004;28:505-24.
13. Bertocci G. Long bone fracture biomechanics. In: Jenny C, editor. Child abuse and neglect: diagnosis, treatment, and evidence. St Louis, MO: Saunders Elsevier; 2011. p. 317-25.
14. Kemp AM. Fractures in physical child abuse. Pediatr Child Health 2008;18:550-3.
15. Kemp AM, Dunstan F, Harrison S, et al. Patterns of skeletal fractures in child abuse: systemic review. BMJ 2008;337: 1518.
16. Leventhal JM, Martin KD, Agnes AG. Incidence of fractures attributable to abuse in young hospitalized children: results from analysis of a United States database. Pediatrics 2008; 122:599-604.
17. Kleinman PK, editor. Diagnostic imaging of child abuse. 2nd ed. Chicago, IL: Mosby 1998. p. 9.
18. Kleinman PK, Marks SC, Blackbourne B. The metaphyseal lesion in abused infants: a radiologic-histopathologic study. AJR 1986;146:895-905.
19. Bilo RA. The extremities. In: Bilo RA, Robben SGF, van Rijn RR, editors. Forensic aspects of paediatric fractures. Verlag Berlin Heidelberg: Springer; 2010. p. 83-5.
20. Worlock P, Stower M. Fracture patterns in Nottingham children. J Pediatr Orthop 1986;6:656-60.
21. Kleinman PK, Marks SC, Richmon JM, et al. Inflicted skeletal injury: a postmortem radiologic-histopathologic study in 31 infants. AJR 1995;165:647-50.
22. Kleinman PK. Problems in the diagnosis of metaphyseal fractures. Pediatr Radiol 2008;38:S388-94.
23. Merten DF, Radkowski MA, Leonidas JC. The abused child: a radiological reappraisal. Radiology 1983;146:377-81.
24. Loder RT, Bookout C. Fracture patterns in battered children. J Orthop Trauma 1991;5:428-33.
25. Alexander CJ. Effect of growth rate on the strength of the growth plate shaft junction. Skeletal Radiol 1976;1:67-76.
26. Dwek JR. The radiographic approach to child abuse. Clin Orthop Rel Res 2011;467:776-89.
27. Carty HM. Fractures caused by child abuse. J Bone Joint Surg 1993;75-B:849-57.
28. Peters ML, Starling SP, Barnes-Ely ML, et al. Inflicted skeletal trauma: how often are bruises found near fractures? Arch PediatrAdolesc Med 2008;162:877-81.
29. Kleinman PK, Nimkin K, Spevak MR, et al. Follow-up skeletal surveys in suspected child abuse. AJR 1996;167:893-6.
30. Kraft JK. Imaging of non-accidental injury. Orthop Trauma 2011;25:109-18.
31. Barsness KA, Cha ES, Bensard DD, et al. The positive predictive value of rib fractures as an indicator of non-accidental trauma in children. J Trauma Inj InfectCrit Care 2003;54:1107-10.
32. Bilo RA. Ribs. In: Bilo RA, Robben SG, van Rijn RR, editors. Forensic aspects of paediatric fractures. Verlag Berlin Heidelberg: Springer; 2010. p. 49-78.
33. Bulloch B, Schuber CJ, Brophy PD, et al. Cause and clinical characteristics of rib fractures in infants. Pediatrics 2000; 105:e48-51.
34. Kleinman PK, Schlesinger AE. Mechanical factors associated with posterior rib fractures: laboratory and case studies. Pediatr Radiol 1997;27:87-91.
35. Garcia VF, Gotschall CS, Eichelberger MR, et al. Rib fractures in children: a marker of severe trauma. J Trauma 1990;30: 695-700.
36. Bennett BL, Chua MS, Care M, et al. Retrospective review to determine the utility of follow-up skeletal surveys in child abuse evaluations when the initial skeletal survey is normal. BMC Res Notes 2011;4:354.
37. Ingram JD, Connell J, Jay TC, et al. Oblique radiographs of the chest in non-accidental trauma. Emerg Radiol 2000;7:42-6.
38. Bhat BV, Kumar A, Oumachigui A. Bone injuries during delivery. Ind J Pediatr 1994;61:401-5.
39. Chadwick DL, Bertocci G, Guenther E. Injuries resulting from falls. In: Jenny C, editor. Child abuse and neglect: diagnosis, treatment, and evidence. St Louis, MO: Saunders Elsevier; 2011. p. 570-8.
40. Hobbs CJ. Skull fracture and the diagnosis of abuse. Arch Dis Child 1984;59:246-52.
41. Meservy CJ, Towbin R, McLaurin RL, et al. Radiographic characteristics of skull fractures resulting from child abuse. Am J Roentgenol 1987;149:173-5.
42. Bilo RA. Head. In: Bilo RA, Robben SG, van Rijn RR, editors. Forensic aspects of paediatric fractures. Verlag Berlin Heidelberg: Springer; 2010. p. 15-47.
43. Merten DF, Osborne DR. Craniocerebral trauma in the child abuse syndrome: radiological observations. Pediatr Radiol 1984;14:428-33.
44. Warrington SA, Wright CM. Accidents and resulting injuries in premobile infants: data from the ALSPAC study. Arch Dis Child 2001;85:104-7.
45. Johnson K, Fischer T, Chapman S, et al. Accidental head injuries in children under 5 years of age. Clin Radiol 2005;60: 464-8.
46. Lyons TJ, Oates RK. Falling out of bed: a relatively benign occurrence. Pediatrics 1993;92:125-7.
47. Rubin A. Birth injuries: incidence, mechanisms, and end results. J Obstet Gynecol 1964;23:218-21.
48. Simonson C, Barlow P, Dehennin N, et al. Neonatal complications of vacuum-assisted delivery. Obstet Gynecol 2007;109:626-33.
49. Kleinman PK, Barnes PD. Head trauma. In: Kleinman PK, editor. Diagnostic imaging of child abuse. 2nd ed. Mosby 1998. p. 285-342.
50. Thomas SA, Rosenfield NS, Leventhal JM, et al. Long-bone fractures in young children: distinguishing accidental injuries from child abuse. Pediatrics 1991;88:471-6.

51. Hui C, Joughin E, Goldstein S, et al. Femoral fractures in children younger than three years: the role of nonaccidental injury. J Pediatr Orthop 2008;28:297-301.
52. Loder RT, O'Donnell PW, Feinberg JR. Epidemiology and mechanisms of femur fractures in children. J Pediatr Orthop 2006;26:561-6.
53. Scherl SA, Miller L, Lively N, et al. Accidental and nonaccidental femur fractures in children. Clin Orthop Relat Res 2000;376:99-105.
54. Rewers A, Hedegaard H, Lezotte D, et al. Childhood femur fractures, associated injuries, and sociodemographic risk factors: a population-based study. Pediatrics 2005;115:e543-52.
55. Morris S, Cassidy N, Stephens M, et al. Birth-associated femoral fractures: incidence and outcome. J Pediatr Orthop 2002;22:27-30.
56. Shaw BA, Murphy KM, Shaw A, et al. Humerus shaft fractures in young children: accident or abuse? J Pediatr Orthop 1997; 17:293-7.
57. Farnsworth CL, Silva MS, Mubarak SJ. Etiology of supracondylar humerus fractures. J Pediatr Orthoped 1998;18:38-42.
58. Strait RT, Siegel RM, Shapiro RA. Humeral fractures without obvious etiologies in children less than 3 years of age: when is it abuse? Pediatrics 1995;96:667-71.
59. Bilo RA. The extremities. In: Bilo RA, Robben SG, van Rijn RR, editors. Forensic aspects of paediatric fractures. Verlag Berlin Heidelberg: Springer; 2010. p. 98.
60. Haslam RH. The nervous system. In: Nelson WE, editor. Nelson textbook of pediatrics. 15th ed. Philadelphia, PA: WB Saunders 1996. p. 1667-738.
61. Snyder KR, Currie ML, Stockhammer TF. Interviewing caregivers of suspected child abuse victims. In: Jenny C, editor. Child abuse and neglect: diagnosis, treatment, and evidence. St. Louis, MO: Saunders Elsevier; 2011. p. 51-9.
62. Duffy SO, Squires J, Fromkin JB, et al. Use of skeletal surveys to evaluate for physical abuse: analysis of 703 consecutive skeletal surveys. Pediatrics 2011;127:e47-52.
63. O'Neill JA, Meacham WF, Griffin PP, et al. Patterns of injury in the battered child syndrome. J Trauma 1973;13: 332-9.
64. King J, Diefendorf D, Apthorp J, et al. Analysis of 429 fractures in 189 battered children. J Pediatr Orthop 1988;8: 585-9.
65. Hettler J, Greenes DS. Can the initial history predict whether a child with a head injury has been abused? Pediatrics 2003; 111:602-7.
66. Pierce MC, Bertocci GE, Janosky JE, et al. Femur fractures resulting from stair falls among children: an injury plausibility model. Pediatrics 2005;115:1712-22.
67. Leventhal JM, Thomas SA, Rosenfield NS, et al. Fractures in young children. Distinguishing child abuse from unintentional injuries. Am J Dis Child 1993;147:87-92.
68. Sugar NF, Taylor JA, Feldman KW. Bruises in infants and toddlers: those who don't cruise rarely bruise. Arch Pediatr Adolesc Med 1999;153:399-403.
69. Carpenter RF. The prevalence and distribution of bruising in babies. Arch Dis Child 1999;80:363-6.
70. Labbe J, Caouette G. Recent skin injuries in normal children. Pediatrics 2001;108:271-6.
71. Feldman KW. Patterned abusive bruises of the buttock and the pinnae. Pediatrics 1992;90:633-6.
72. Pierce M, Kaczor K, Aldridge S, et al. Bruising characteristics discriminating physical child abuse from accidental trauma. Pediatrics 2010;125:67-74.
73. Maguire S, Mann MD, Sibert J, et al. Are there patterns of bruising in childhood which are diagnostic or suggestive of abuse? A systematic review. Arch Dis Child 2005;90:182-6.