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EMERGENCY RADIOLOGY SPECIAL FEATURE: REVIEW ARTICLE

Paediatric femur fractures at the emergency department: accidental or not?

¹EVA MM HOYTEMA VAN KONIJNENBURG, MD, PhD, ¹THEKLA F VROLIJK-BOSSCHAART, MD, ²ROEL BAKX, MD, PhD and ³RICK R. VAN RIJN, MD, PhD

¹Department of Paediatrics, Emma Children's Hospital, Academic Medical Center, Amsterdam, Netherlands

²Pediatric Surgical Center Amsterdam, Emma Children's Hospital, Academic Medical Center and VU University Medical Center, Amsterdam, Netherlands

³Department of Radiology, Emma Children's Hospital, Academic Medical Center, Amsterdam, Netherlands

Address correspondence to: Ms Eva MM Hoytema van Konijnenburg

E-mail: eva.hoytemavankonijnenburg@amc.nl

ABSTRACT

Only a small proportion of all paediatric fractures is caused by child abuse or neglect, especially in highly prevalent long bone fractures. It can be difficult to differentiate abusive fractures from non-abusive fractures. This article focuses on femoral fractures in young children. Based on three cases, this article presents a forensic evidence-based approach to differentiate between accidental and non-accidental causes of femoral fractures. We describe three cases of young children who were presented to the emergency department because of a suspected femur fracture. Although in all cases, the fracture had a similar location and appearance, the clinical history and developmental stage of the child led to three different conclusions. In the first two cases, an accidental mechanism was a plausible conclusion, although in the second case, neglect of parental supervision was the cause for concern. In the third case, a non-accidental injury was diagnosed and appropriate legal prosecution followed. Any doctor treating children should always be aware of the possibility of child abuse and neglect in children with injuries, especially in young and non-mobile children presenting with an unknown trauma mechanism. If a suspicion of child abuse or neglect arises, a thorough diagnostic work-up should be performed, including a full skeletal survey according to the guidelines of the Royal College of Radiologists and the Royal College of Paediatrics and Child Health. In order to make a good assessment, the radiologist reviewing the skeletal survey needs access to all relevant clinical and social information.

INTRODUCTION

Fractures are a well-known cause for paediatric emergency department presentations. In 2010, 14.7% of all paediatric emergency presentations in the USA were fracture related.¹ Children aged 10–14 years, as well as male children in general, are at highest risk for fractures, which is probably (partially) related to sports participation and male adolescent thrill seeking.^{1,2} The majority of paediatric skeletal fractures are caused by accidental or non-accidental trauma, rarely by diseases such as osteogenesis imperfecta.³ Only a small proportion of all paediatric fractures is caused by abuse.⁴ Intentional abuse as well as neglect both can lead to abusive paediatric fractures.⁴ The chance of abuse is higher in younger, especially pre-ambulatory, children than in older children presenting with a fracture. However, it remains difficult to differentiate abusive fractures from non-abusive fractures in any age category.^{4,5} Child maltreatment, also referred to as child abuse and neglect (CAN), is defined by the World Health Organization (2014) as: “all forms of

physical and emotional ill-treatment, sexual abuse, neglect and exploitation that results in actual or potential harm to the child's health, survival, development or dignity in the context of a relationship of responsibility, trust or power”.⁶ Different subtypes of child maltreatment can be distinguished, including physical abuse and neglect.⁶ Although CAN is a worldwide problem, it is difficult to determine the exact prevalence. Rates vary widely, depending on the study methods and definitions that are used. Child- and parent-reported prevalence rates are much higher than prevalence rates reported by professionals.^{7,8} Child maltreatment has many, short- and long-term, negative consequences for children and their families. Therefore, early identification of children who are maltreated is important to intervene, prevent recurrence and improve outcomes.^{7,9–12} To diagnose CAN, many hospitals have introduced screening methods to improve identification of maltreated children, such as training of personnel, checklists and a screening physical examination.^{13–16} Unfortunately, it can be difficult for

hospital staff to identify maltreatment.^{12,17–19} Several studies have shown that children who were identified as being physically abused had previous, missed opportunities for healthcare professionals to identify the abuse.^{12,17,19–21} In a study of young children with healing abusive fractures, abuse was not recognized during an earlier healthcare visit in a third of the children.¹⁹ Children presented in different care settings, including the emergency department, with, most commonly, physical signs of trauma, such as swelling or bruising.¹⁹ In another study of children with abusive fractures, a fifth of the children had at least one previous physician visit during which abuse could have been diagnosed.¹⁷ Several factors increased the chance of missing the diagnosis of abuse: male sex, an extremity fracture *vs* an axially located fracture and presenting to a primary care or non-paediatric setting *vs* a specialized setting.¹⁷

Most publications on CAN focus on fractures with a high probability of being caused by abuse, such as (posterior) rib fractures.⁵ When diagnosed in day-to-day clinical routine, these fractures in general will lead to a thorough work-up for possible child abuse. Long bone fractures are more prevalent and have a lower probability of abuse. This makes it more difficult to correctly identify abuse, especially in older children.²²

This article will focus on long bone fractures, with a specific focus on femoral fractures. Based on three cases from different hospitals, a forensic evidence-based approach will be presented to discern between accidental and non-accidental causes of femoral fractures.

CASE DESCRIPTIONS

Case 1

A 3-year-old male was presented to the emergency department in the evening because of an injury to his left leg. His parents reported that after playing with his sister, he refused to take a shower and wanted to run away. His father tried to stop him by grabbing him at his right leg and as a result he tripped. During the fall, he rotated on his left leg and a crack was heard. His mother and his 7-year-old sister observed the incident. He was in pain and his parents immediately took him to the emergency department. There was no documented medical or psychiatric history, and there were no previous incidents or fractures recorded for neither him nor his sister. The parents seemed shocked about what had happened. They were married, and his mother worked in evenings and his father was currently without a job. Physical examination showed a painful male child, well kempt, well-nourished, growth in accordance with his age. His left upper leg was swollen and in exorotation. At full body physical inspection, part of the Emma Children's Hospital's routine examination in children presented at the emergency department, there were no bruises, injuries or scars found on his body. A radiograph of his left leg showed a spiral fracture of the left femur (Figure 1), which was treated with immobilization in a spica cast.

The patient was discussed in the hospital multidisciplinary child protection team, which included a doctor from Child Protective Services (CPS). The team concluded that the history was plausible and consequent. Other than the unemployment of the father, no risk factors for CAN were observed. Therefore, it was concluded that it was most likely that the spiral fracture of the left femur of this 3-year-old male was accidental.

Figure 1. Radiograph of the left femur of a 3-year-old male showing an oblique mid-diaphyseal femur fracture. There is no indication for an underlying bone disorder/disease.

Case 2

A 2-year-old male was presented to the trauma room of the emergency department because of an injury to his left leg. His mother reported that she had found him crying, lying next to her bicycle in the garden. It was unclear what had happened, and there were no witnesses of the incident. Physical examination showed a painful and scared male child, with a swollen and painful left upper leg. There were no haematomas, injuries or scars on the body at full body physical inspection. A radiograph of his left leg showed a spiral fracture of the left femur

Figure 2. Radiograph of the left femur of a 2-year-old male showing an oblique mid-diaphyseal femur fracture. There is no indication for an underlying bone disorder/disease.

(Figure 2). He was admitted to the hospital and treated with Bryant's traction for 10 days followed by immobilization in a spica cast. During admission, additional information was collected. He had no documented medical or psychiatric history, and there were no previous incidents or fractures recorded. When asked about the circumstances of the accident again, the mother reported that he had been playing in the garden, unsupervised. Mother and grandmother were inside the house. His grandmother heard him crying and found him underneath a fallen bicycle. Both his parents lived in the grandmother's house; both had a full-time job; and his grandmother took care of him. CPS had been involved until the past year, because his father had been in detention. After discussion in the hospital multidisciplinary child protection team, it was concluded that the cause of the spiral fracture of the left femur of this 2-year-old male was unclear. Several risk factors for non-accidental injury were present: discrepancies in the history, a complicated social situation and previous involvement of CPS. Therefore, a full skeletal survey was performed to identify any additional fractures. Except for the known femur fracture, there were no abnormalities on the skeletal survey. The CPS worker who had been involved with the

family previously and the general practitioner of the family were contacted. Both never had any suspicions of CAN.

He was released home without further child protective measures and was seen several times in the outpatient clinic for routine follow-up visits. The fracture healed without any complications. Although, in this case, the differential diagnosis CAN was rejected, an argument could be made for parental neglect. In order to prevent recurrence, the subject of parental supervision was discussed with both parents.

Case 3

A 12-week-old male was presented to the emergency department because of a swollen left upper leg. According to the parents, he seemed painful during diaper change, and that afternoon, they noted that his left upper leg looked somewhat swollen. Upon asking, the parents did not report a trauma in the history; there were no previous incidents or fractures recorded; and there was no other medical history. Physical examination showed a swollen left upper leg, with no other lesions or bruises. A radiograph revealed a mid-diaphyseal oblique femur fracture, and there were no signs of subperiosteal new bone formation or callus formation, leading to the diagnosis of a "fresh" fracture (Figure 3). There were no signs of an underlying bone disorder. Because of the absence of an explanation for this fracture and the young age of the child, it was decided to perform a full skeletal survey to screen for any other non-accidental fractures. The skeletal survey yielded an additional metaphyseal corner fracture of the right distal radius and multiple

Figure 3. Radiograph of a 12-week-old male showing transverse fracture of the proximal femur. There is no indication for an underlying bone disorder/disease.

Figure 4. Radiograph of the right wrist, of the same child as in Figure 3, shows a metaphyseal corner fracture of the distal radius (arrow).

rib fractures (Figures 4 and 5). The hospital multidisciplinary child protection team performed a full work-up, and the case was referred to CPS who in turn involved police authorities. After thorough investigation, child abuse was proven and judicial prosecution followed. The outcome of the latter is unknown to the authors.

DISCUSSION

We described three cases of young children who presented to the emergency department because of an isolated femur fracture. Although in all cases the fractures had a similar location and appearance, the clinical history and developmental stage of the child led to three different conclusions. In the first two cases an accidental mechanism was a plausible conclusion, although in the second case the social system in which the child lived was cause for concern. In the third case, a non-accidental injury was diagnosed and fitting legal prosecution followed. When children present to the emergency department because of a trauma without a clear mechanism, it is very important to take a detailed history and perform a complete physical examination as soon as possible. It can be very informative to speak to any eyewitnesses separately and, if the child is old enough, the child itself as well. A detailed report should be written in the record, as this could be very important later on in the clinical and forensic course. In addition to the current event, it is also important to know about any other diseases, trauma or child protection involvement in the past, as well as existing risk factors for child maltreatment in general (Table 1).^{23–26} Important “red flags” in the clinical history and physical examination that are associated with abusive femur fractures are: unknown or unwitnessed trauma, unknown trauma mechanism, history inconsistent with the injury, more than 24 hours delay in seeking medical care and additional injuries such as bruises or fractures.²⁷

The use of a screening instrument for CAN at the emergency department could be considered in order to increase detection

rates.¹⁴ However, it is important to note that these instruments do not identify all maltreated children.^{13,28}

(NON)-ACCIDENTAL FEMUR FRACTURES

A common, but incorrect, idea is that a spiral femoral fracture is almost a definite sign of physical abuse. The presence of a spiral fracture only implies that a torsional force, either accidental or non-accidental, was applied to the femur.²⁷ Radiological findings alone cannot distinguish between accidental and non-accidental fractures.

In a retrospective study of young children presenting with femur fractures by Capra *et al*,²⁹ the most common trauma mechanism was fall from a height. The authors²⁹ concluded that femur fractures can occur even with low velocity injury. Femur fractures due to abuse happen predominantly in children under 1 year of age.^{5,27,30} In the studies included in the meta-analyses of CORE-INFO (Cardiff University, UK), the mean age of abused children was much lower than of non-abused children and fractures due to abuse were significantly more common in children who were not mobile.⁵ For children between 0 and 18 months of age, the positive-predictive value of a femur fracture being due to confirmed or suspected abuse was 51.5% (95% confidence interval 34.1–66.1%), the odds ratio for abuse was 1.8 (95% confidence interval 1.2–2.7).^{5,30} A different systematic review of Wood *et al*²⁷ found a lower but still substantial risk of abuse of 16.7–35.5% in children under 12 months of age with a femur fracture not related to motor vehicle accidents. The prevalence of abuse in older children with a femur fracture is lower.^{5,27,30} In children aged 0–36 months with a non-motor-vehicle-related femur fracture, Wood *et al*²⁷ found a prevalence of abuse of 11.6–50%. According to CORE-INFO,³⁰ a third of isolated femur fractures in children under 3 years of age were due to abuse. For children aged between 12 and 48 months, the positive-predictive value of a femur fracture being due to confirmed or

Figure 5. Oblique radiograph of the chest, of the same child as in Figure 3, shows multiple healing bilateral rib fractures. Lateral rib fractures of the right third and fourth ribs show callus formation (arrows). Rib fractures of the left third to sixth ribs show signs of remodelling (arrowheads). The difference in stages of healing is interpreted as a sign of repeated incidents.

Table 1. Often-reported risk factors for child maltreatment^{23–26}

Parents	Child	Family, community
Very low education	Disability	Three children or more
Unemployment	Developmental delay	Non-biological caregivers in family
Substance use	Twins	Social isolation
Psychiatric problems	Chronic disease	Disadvantaged neighbourhood
Intimate partner violence		
Single parenthood		
Low income		
History of maltreatment in family of origin		

suspected abuse was 11.7% (95% confidence interval of 6.1–17.3%).^{5,30} Mid-shaft femur fracture was the most common fracture location in abused and non-abused children; in children under 3 years of age, there were no differences in the type of fractures between abused and non-abused children; in children aged under 15 months, spiral fracture was the most common fracture due to abuse.⁵ Wood et al²⁷ found no association between the femur fracture type and position and the likelihood of abuse, with the exception that (mid/proximal) diaphyseal fractures may be less associated with abuse, whereas distal metaphyseal fractures may be more associated with abuse. A recent study used the results of the meta-analysis of CORE-INFO to determine the expected proportion of suspected or confirmed abuse for children aged 0–18 months presenting with an isolated femur fracture.³¹ Based on the meta-analysis data, the authors expected that 50.1% (95% confidence interval of 34.1–66.1%) of the children were a victim of child abuse; however, less than half of these children were referred for skeletal survey.³¹

DIAGNOSTIC WORK-UP

If, based on the clinical history, physical examination and radiographic study, the differential diagnosis includes child abuse, then there are set radiological guidelines which should be followed. The Royal College of Radiologists and the Royal College of Paediatrics and Child Health have published guidelines, which in 2014 were adopted by the European Society of Paediatric Radiology.^{32,33} According to these guidelines, all children under the age of 2 years should undergo a full skeletal survey (Table 2), and in children between the ages of 2–4 years, a skeletal survey should be considered. In children above the age of 4 years, a skeletal survey is not indicated. The skeletal survey, with the exception of the skull radiograph ideally should be repeated after 2 weeks. The rationale behind the repeat skeletal survey is three-fold; first, to detect fractures, as a result of callus formation, that were not visible on the first skeletal survey. Second, to differentiate normal variants from findings initially reported as, potential, fractures. Third, to help build a potential timeline. It is advised to book the repeat study at the time of the initial study. In case the guideline is not followed, it is advised to record the reason for non-adherence in the patient's record.³² Despite the fact that guidelines are readily available, a recent study in a large number of hospitals in the USA showed that there was substantial variation in the proportion of children receiving the appropriate radiological work-up after a diagnosis or high likelihood of abuse.³⁴ Overall, only half of all

children underwent a skeletal survey, and teaching hospitals and hospitals with a high caseload of injured children performed more skeletal surveys.³⁴ Other studies in the USA, UK and Netherlands showed similar results.^{31,35–37}

For the reporting radiologist, it is important that, just like in all other cases, the radiology request clearly states the indication for the skeletal survey, including details on current clinical problems, mode of presentation and relevant (medical-, family- and social) history.³² Furthermore, it is important to consult with colleagues and convey any concerns. Good communication is essential between healthcare professionals and towards the patient and caretakers. With respect to

Table 2. Protocol for skeletal surveys in case of suspected physical child abuse (The Royal College of Radiologists and Royal College of Paediatrics and Child Health)³²

Anatomical site	Radiographs ^a
Skull ^b	AP, Lateral
	On clinical indication: Towne
Cervical spine	Lateral
	On clinical indication: AP
Thorax	AP (including clavicles)
	Oblique (left and right)
	Lateral (spine)
Abdomen, lumbar spine and pelvis	AP including both hip joints
	Lateral (spine)
Upper extremities ^c	AP both upper arms
	AP both forearms
Lower extremities ^c	AP both upper legs
	AP both lower legs
Hands	PA
Feet	AP

AP, anteroposterior; PA, posteroanterior.

^aAdditional views can be performed at the discretion of the attending radiologist.

^bSkull radiographs should be obtained even if a CT of the skull has or will be performed.

^cAdditional coned views of the joints can show metaphyseal lesions in more detail.

the radiological procedure, it is advised that all involved personnel are adequately trained; this includes a certain level of knowledge about child abuse and its consequences, in performing the skeletal survey. The hospital protocols should describe how to deal with parents/caretakers (who in many cases will also be seen as potential perpetrators) and when the skeletal survey can be performed (especially with respect to out-of-hours services). The radiological technicians should work in a team of two, and each technician should record her/his name on the procedure. After the standard protocol is obtained, the radiologist should review all films and, if necessary, order additional radiographs before the patient leaves the department of radiology. It is important to be aware of the fact that these radiographs can become part of legal proceedings.³² In addition to the radiological work-up, a paediatrician should always complete a full diagnostic work-up for all paediatric fractures that raise suspicion of CAN, including any additional testing such as laboratory testing for bone health, CT head and fundoscopic examination if appropriate.³⁸ It is important to note that although certain types of fractures have a high specificity of abuse (such as rib fractures or classic metaphyseal lesions), no fractures are absolutely indicative of child abuse.³⁹

RADIATION EXPOSURE

One issue that is often raised, both by referring physicians and parents/caretakers, is radiation exposure involved in the skeletal survey.⁴⁰ Given the attention in paediatric radiological literature and the scrutiny with which e.g. CT requests are dealt with by paediatric radiologists, this is a logical question.⁴¹ Radiation exposure—for this discussion, the effective dose that is not only determined by the amount of radiation but also by the sensitivity of the organ for radiation damage—is measured in millisievert (mSv). Although the imaging protocol is standardized, the effective dose depends on many parameters such as patient size, distance between the tube and patient, the type of detector used and the type of equipment used. This results in a different exposure for the same procedure between institutions. Estimates for a single full skeletal survey from the American College of Radiology range from 0.3 to 3 mSv.⁴² Bajaj and Offiah,⁴³ in their

recent article, report a range of 0.9–1.8 mSv for the same protocol. The repeat skeletal survey almost doubles the radiation dose. The question now is, how can this be compared with other forms of radiation, e.g. background radiation, and what does this figure mean with respect to the risk of cancer development? In daily life, everybody is exposed to natural background radiation. The Beir VII report states that if 100,000 persons were being exposed to a single dose of 100 mSv at the age of 5 years, respectively, 852 male children or 1347 female children would die of that single exposure (for further discussion, we will use the number 1,000 per 100,000) (table 12D-2).⁴⁴ Given the radiation dose of a single skeletal survey, this would mean an excess number of deaths due to cancer of 3–30 children per 100,000 persons resulting from this skeletal survey. This has to be put in the perspective of the lifetime risk of cancer death, which, at birth, is approximately 20.7%.⁴⁵ This shows that the excess number of deaths due to a skeletal survey is almost negligible. Another way to present the risk is the excess risk per mSv exposure. Brenner et al⁴¹ reported a lifetime cancer mortality risk of 0.014% per mSv for an exposed neonate. This would mean an increase in lifetime cancer mortality risk of 0.0042–0.042% as a result of a skeletal survey at the neonatal age. This excess risk needs to be weighed against the risk of missing child abuse and its detrimental consequences.^{21,40}

CONCLUSION

In conclusion, any doctor, including radiologists, treating children should be aware of the possibility of CAN in children with injuries, especially in young and non-mobile children presenting with an unknown trauma mechanism. If a suspicion of child abuse or neglect arises, consultation with a colleague is mandatory and a thorough diagnostic work-up should be performed, including a full skeletal survey according to the guidelines of the Royal College of Radiologists and the Royal College of Paediatrics and Child Health. In order to make a good assessment, the radiologist reviewing the skeletal survey needs access to all relevant clinical and social information. Although certain fractures have a high specificity for abuse, no fractures are absolutely indicative of child abuse.

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