

Review Article

Abuse as a Cause of Childhood Fractures

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Summary

Background: It is well known that physical abuse of children all too often escapes detection. Fractures are among the potential consequences of physical abuse but are also common in childhood because of accidents. A question frequently addressed to the Medical Child Protection Hotline (*Medizinische Kinderschutzhotline*) is how fractures due to abuse can be distinguished from accidental fractures.

Methods: This review is based on pertinent publications retrieved by a search in PubMed and in the Cochrane Database, as well as on the authors' experience in a pediatric emergency department with ca. 29 000 consultations per year and in a child protection outpatient clinic with ca. 100 consultations per year.

Results: Fractures due to abuse are especially common among infants; their incidence is estimated at 56.8/100 000 among infants less than six months old and 39.8/100 000 among infants aged 6 to 11 months. In consideration of the age of the child, the type of fracture, the history, and other factors, a high probability of abuse can be suspected in many cases, so that further measures can be initiated.

Conclusion: All physicians involved in the care of children (even if only occasionally) should be aware of the major indicators of likely physical abuse and of the available opportunities for counseling and intervention. Failures to diagnose child abuse are associated with high rates of recurrence and mortality.

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Fractures in children have an important role in calls to the Medical Child Protection Hotline (*Medizinische Kinderschutzhotline*). In order to be able to give valid answers to callers, we conducted a literature search that forms the basis of this review article. The review is intended for all physicians who treat children with fractures and provides an aid for deciding in which children a differentiated investigation of suspected abuse will need to be undertaken in appropriate institutions (1). Further (differential) diagnostic aspects that will have to be considered as a second step are not the subject of this review. They are explained comprehensively elsewhere (2–4).

Methods

We conducted selective literature searches on commonly asked questions to the Medical Child Protection Hotline in PubMed and the Cochrane Database. Our search terms in the literature databases Medline and Cochrane were “fractur*” AND “abus*” or “mal-treat*”. For the period since 1 January 2003, we found 1413 references; additionally, we searched the references of relevant articles for older studies. Two authors (OB, VC) evaluated a total of 86 full-text articles. Furthermore, experiences gained in a pediatric emergency department with some 29 000 patients admitted every year and a childhood protection outpatient clinic with some 100 patients per year also contributed to this review article.

Epidemiology

In a recent study, the fractures in 31 (5.6%) of altogether 551 children with fractures (<36 months) were confirmed as caused by abuse (the proportion of fractures caused by accidents owing to neglect was not investigated) (5). Silbert et al. in a retrospective analysis from 1996 to 1998 found for Wales an incidence of abuse-related fractures of 56.8/100 000 in children younger than 6 months (95% confidence interval: [31.8; 81.5]) and of 39.8/100 000 [27.3; 51.9] in children aged 6–11 months (6).

The physicians who provide initial care in this setting have special responsibilities in the context of child abuse, because abuse is often recurrent and associated with high mortality (7). According to a retrospective study by Jenny et al. (8), 4 in 5 fatal cases of child abuse could have been prevented if

TABLE

Proportions of abuse-related fractures according to (1)

	0–11 months	12–23 months	24–36 months
	Total number of fractures (proportion of fractures related to abuse, weighted percentages)		
Ribs	809 (69.4)	96 (28.5)	96 (27.6)
Radius/ulna	261 (62.1)	103 (19.8)	293 (4.7)
Tibia/fibula	493 (58.0)	192 (16.1)	384 (4.7)
Humerus	518 (43.1)	545 (6.8)	2108 (1.6)
Femur	1257 (30.5)	761 (4.8)	2008 (2.5)
Clavicle	227 (28.1)	65 (16.7)	95 (6.0)
Skull	3363 (17.1)	948 (8.6)	1575 (3.7)

action had been taken at the first presentation to the practice/hospital.

After soft tissue injuries, fractures are the second most common finding in physical abuse. We agree with the estimate of Herrmann et al., that “fractures (...) (signify) particularly violent abuse as they require substantial physical strength” (4). In our estimation, it is mostly outbursts of frustration, of feeling over-stretched/unable to cope, or of anger in a parent or other carer that serve as triggers for abuse—often paired with the subsequent desire to want to undo the damage. Furthermore, fractures can occur if (very young) children are insufficiently protected against dangers—that is, as a result of neglect. By contrast, in our experience, intentional systematic torture of children is rarer.

The question if the resultant injury was intentionally inflicted or not does not play an important part in a child’s prognosis. Even a single instance of loss of self control mostly arises within a system of promotive factors that will continue without intervention and therefore promotes recurrent behavior. This association should be the guiding principle for the approach taken by physicians administering initial care. In our view, the responsibility for assessing the risk of recurrence lies with the youth welfare services.

The opinion that is occasionally expressed—that having to present with the child in a hospital would constitute a salutary shock to parents and that the abuse would stop automatically afterwards—contradicts the available evidence and can be life-threatening for affected children.

The objective of treating fractures therefore should be not only to achieve a medically and functionally flawless result, but also to trigger the necessary protection for the child.

“Awareness is the most critical component to making a diagnosis” (9).

Biomechanical aspects

In order to assess a fracture mechanism, a basic understanding of the biomechanical characteristics of

children’s bones is required. Crucial differences to adults are the greater elasticity of children’s bones and a softer cortical bone. Furthermore, fracture types and locations in children occur with a different distribution to those in adults. For a basic overview, we refer readers to the standard volumes of pediatric trauma medicine (1, 10) and the overview of the biomechanical aspects by Pierce et al. (11).

- The diaphyseal bending fracture (“greenstick fracture”) occurs only in childhood.
- Typical childhood fractures also include metaphyseal buckle (torus) fractures, which are indicative of prior axial loading of the bone. They often occur on the distal radius after attempting to break an accidental fall. Such falls are notably rarer in children before they start to walk, and the medical history should be critically reviewed in this setting.
- This is even more the case for femur fractures. These are rare in children in absolute terms (10). Before a child can walk, such fractures are very likely to be the result of abuse (51% [0.34; 0.66], n = 275) (12).
- Spiral fractures arise as a result of a twisting force applied to the bone. For a long time, such fractures were seen as particularly suspicious for abuse because for the twisting force to be applied, violence from another person was seen as the prerequisite. However, spiral fractures also occur as a result of accidents (for example, as the typical “toddler’s fracture”—the tibial shaft fracture—as a result of a fall when the main load is on the leg, which is subjected to a rotational force.
- Epiphyseal dislocations in infants and toddlers are often the result of abuse because they require great force (4).

The often described history that a child contracted a fracture alone in its cot or cot bed is not plausible (4). If children try to pull a stuck leg out from between the cot’s wooden bars the bone is subjected to a tensile load—which is exactly the opposite of what would be required for a spiral fracture to occur. Pediatric bones are much more stable to tensile loading



Figure 1: Supracondylar humerus fracture in a toddler (13 months, premobile), for which no trauma history was provided. This finding should always trigger a closer investigation into the circumstances.



Figure 2: The history of the distal femur shaft fracture in an infant aged 3 months was reported to be an unobserved fall from the parental bed (70 cm), which also resulted in cranio-cerebral trauma. Further diagnostic evaluation (skeletal screening, ocular fundus examination) did not yield any further findings. The history is inadequate for the injuries, however, and the child protection / youth welfare services were involved in the further risk assessment.

than to compression (11), and it is difficult to imagine that a child would voluntarily continue the movement in spite of the pain that precedes any fracture by a long while.

Distinguishing accidental injuries from inflicted injuries

In a retrospective nationwide analysis of a US database of pediatric inpatients, Leventhal and colleagues showed that of 15 143 fractures in children younger than 36 months, abuse in 1817 cases (12%) was the second most common cause after falls. *Table 1* shows the proportion of inflicted fractures by affected bone and age group (13).

Several factors have consistently been reported in systematic reviews that may help the physician providing initial care to assess the etiology (13–16). These should in part be asked of the parents, in part medically assessed, and carefully documented:

- Are the medical history (mechanism of the accident), the child’s developmental stage, and the fracture consistent? Abuse as the cause of fractures is particularly common in children who have not yet started to walk (*Figure 1*)!
- Does the medical history stay the same even after the question has been asked several times over?
- Is the child being presented without any delay?
- Does the child have several fractures/fractures of different stages or further injuries that cannot be explained as the result of an accident?

Rib fractures are often related to abuse at any age. A poor condition or signs of dystrophy in an infant can provide further indications of maltreatment. Consequently, it clearly emerges that in children with fractures, a thorough medical history should always be followed by a detailed examination of the entire body.

Metaphyseal corner fractures

The injuries known in the English-language literature as classic metaphyseal lesions (CML) or metaphyseal corner fractures are also known as bucket handle fractures (17). Because the fracture gap runs parallel to the x ray path, it is often only the peripheral parts of the fracture, which extend towards the diaphysis, that are identifiable and account for the fracture’s typical look of a corner fracture or a bucket handle fracture, depending on the x ray path. These have a particular position of importance because they are considered as almost pathognomonic for a non-accidental—that is, inflicted—origin (4, 18–20). They occur most commonly on the proximal and distal tibia and fibula, in the distal femur, and on the proximal humerus (2, 4). Periosteal hematomas or a raised periosteum are not usually detectable. The normal variant of a perichondral bone cuff can extend beyond the epiphyseal plate and can appear radiologically as a metaphyseal fracture. A follow-up radiograph is useful in this setting (18).

Kleinman describes the mechanism of trauma as combined tensile and torsional stress owing to violent tearing or levering (18). The only differential diagnoses described in the literature are birth trauma (breech births and uncomplicated cesarean section) and treatment of club foot (21, 22).

In the following sections, we will discuss the most common accidental and abuse-related (henceforth referred to as “inflicted,” to facilitate easier reading) trauma mechanisms and discuss the available evidence in the etiological classification.

Long bones

Femur

In the setting of femur fractures, the proportion of inflicted injuries is particularly high—especially because as a result of accidents and in absolute terms, such

Figure 3: Metaphyseal buckle fracture of the distal tibia. The 13-month old child allegedly jumped from a low chest (it was not able to walk yet) and was presented on the following day because the leg was held in a protective posture to relieve pain. This case also requires further diagnostic evaluation in order to rule out abuse.



fractures are rare in children (10) (*Figure 2*). Many accidental mechanisms such as traffic accidents or falls from a great height are obvious and can be reported in detail when taking a medical history. In a systematic review in children younger than 36 months who presented with femur fractures (n = 279), the probability of abuse—after traffic accidents had been excluded—was 12% (0.07 to 0.19) to 50% (0.16 to 0.84) (15).

Several authors are in agreement that “changing nappies” or “sudden crying in the cot” do not constitute credible medical histories for femur fractures (4, 17, 19).

Lower leg

In children not yet able to walk, tibia fractures often occur in the shape of the described metaphyseal corner fractures. Coffey and colleagues reported abuse as the cause in 23 (96%) of 24 children younger than 18 months with any fracture of the tibia or fibula (23) (*Figure 3*). A typical trauma mechanism in this context is that children are violently dragged from their cot by

the lower leg (tensile stress with/without torsion) or thrown on to a hard surface (bending stress, compression/buckling stress).

Humerus

Several studies found in children <36 months with humerus fractures a high proportion of inflicted injuries. Kemp et al. in their systematic meta-analysis of four studies including 154 children younger than 3 years found confirmed abuse in 30 children. The meta-analysis showed a probability of abuse for any humerus fracture of 48% [0.06; 0.94] (24). In this setting, epiphysiolysis may escape notice on radiological diagnostic evaluation, but in the hands of experienced examiners it is detectable on ultrasonography (25, 26). The identified mechanism on the basis of parents' comments was violent gripping and dragging children by their upper arm.

Figure 4 shows a spiral fracture of the humerus in an infant. Because a history was lacking it was not possible to determine the etiology. For this reason, the child protection / youth welfare services were informed in order to assess the risk to the child.

Forearm

In mobile children, forearm fractures are usually accidental. The typical mechanism implicated is hyper-extension trauma as a result of trying to break a fall. The resultant compression and bending stress often results in a greenstick or buckle fracture of the radius, and, if the stress/load is extreme, also of the ulna (27).

Inflicted fractures of the forearm are mostly transverse shaft fractures. The child's age is crucial in this setting: in children younger than 3 years these fractures are at least in principle always suspicious for abuse (13). They occur as so-called defensive fractures (warding off blows), especially if an accompanying soft tissue injury indicates the effects of a physical object (stick).

Rib fractures

Rib fractures are highly predictive of abuse, and in infants they are often accompanied by shaken baby syndrome/abusive head trauma. Kemp et al. reported a probability—after excluding traffic accidents, witnessed severe trauma, and postoperative cases—for children of all age groups of 71% ([0.42; 0.91], n = 233). Their localization (anterior, lateral, posterior) does not allow for a definite differentiation (24, 28). Rib fractures after cardiopulmonary resuscitation in children are rare (29).

Skull fractures

Skull fractures are among the most common injuries in infancy and early childhood (13). A linear skull fracture without intracranial injury can even occur after a fall from a low height (the parental bed, for example) on to a hard surface. In most cases, a clearly described history of the accident will be credible. Relevant intracranial injuries, complex and bilateral skull fractures



Figure 4: Spiral fracture of the humerus of unknown origin in an infant. The proportion of abuse in this constellation is high.



Figure 5: A distal femur fracture (short arrow) was diagnosed in a 16-month old toddler. The parents did not report any injury and presented their child only on the following day, in spite of severe pain. However, the image additionally shows an older proximal tibial fracture (long arrow) that is definitely more difficult to detect. The child was not yet walking, which made an accidental pathogenesis—combined with the lacking medical history—extremely unlikely. In consideration of psychosocial aspects, we diagnosed severe and prolonged abuse. Consequently, the child protection / youth welfare services implemented a protection plan for the child.

mostly occur after severe, undoubtable accidents or as a result of severe abuse (for example, in combination with shaken baby syndrome/abusive head trauma as a so-called shaken impact) (24, 30, 31). Midfacial fractures are notably rarer, but physical violence is a relevant differential diagnosis in this setting too (32, 33). However, a case series showed that “banal” occipital falls can also be a cause of severe intracranial injuries (34).

Periosteal reactions

Subperiosteal new bone formation on the long bones can occur as a reaction to experienced trauma but also as physiological periostitis in infants. The distinction from a traumatic injury is possible primarily on the basis of the symmetrical findings, the clear restriction to the diaphysis, and the absence of actual fractures. In inflicted injuries, the metaphysis is often involved (19).

Hematomas

Careful examination of the skin can provide further indications of possible abuse. Hematomas on the ears, the scalp (above an imaginary hat brim line), oral mucosa, buttocks, neck, and genitals are particularly often related to abuse (35, 36). A word of caution: in premobile infants, accidental hematomas are extremely rare.

What to do if indications of abuse are substantial Further radiological diagnostic evaluation

The occurrence of multiple or several-stage fractures is an important indicator for abuse (*Figure 5*). However, older fractures in particular often escape the clinical examination. For this reason, international standards exist for radiological diagnostic evaluation in children younger than 2 years in whom abuse is suspected (so-called skeletal survey). A “babygram”—that is, capturing the entire child in one single image—is obsolete.

International recommendations strongly support computed tomography scanning (37, 38). The German-language guidelines rely on a much lower radiation exposure (39). They include radiographs of the upper arms, forearms, hands, thighs, lower legs and feet, the entire spine and pelvis on one plane, the thorax from posterior to anterior oblique and of the skull in two planes (40). In the DRK Kliniken [Hospitals] Berlin | Westend, we forego during initial skeletal screening any images of spine and pelvis, which require high doses of radiation. Karmazyn et al. showed that doing so does not miss any relevant findings (40).

Where the clinical significance of the findings is not clear, the investigation is repeated two weeks later. Especially rib fractures may become visible

BOX

Medical Child Protection Hotline (*Medizinische Kinderschutzhotline*): +49 (0) 800 192 1000

- This German telephone hotline (+49 [0] 800 192 1000) provides healthcare professionals with telephone advice by physicians 24/7 regarding all questions relating to child protection (www.kinderschutzhotline.de).
- The project is financed by the Federal Ministry of Family Affairs, Senior Citizens, Women and Youth and implemented by Ulm University Medical center, the DRK Hospitals Berlin | Westend, and Medical Center—University of Freiburg.

Key messages

- Child abuse is a relevant differential diagnosis in all pediatric fractures. Fractures in infants have to be checked out as a matter of principle.
- Question the mechanism of the accident and the history.
- In all suspicious cases, involve a child protection group.
- In case of doubt, seek advice.
- Inform the child protection / youth welfare services if the child's safety cannot be guaranteed with complete certainty.

only over time. Skeletal scintigraphy yields slightly better diagnostic results but is associated with four times the radiation dose compared with repeated skeletal screening. In the individual case, however, it may provide additional information (especially in the context of rib fractures) (2, e1).

Hoytema van Konijnenburg and colleagues calculated for the protocol of the European Society for Pediatric Radiology (ESPR) an increase in the personal risk of cancer of 0.0042–0.042% (e2). Radiation exposure according to the German protocol is far below that as long as CT scanning is avoided. Against the high mortality associated with missed child abuse (7), the trade-off is obvious.

Multiprofessional diagnostic evaluation

Medical diagnostic evaluation in suspected physical abuse requires a multiprofessional team as a matter of principle. This expertise can be expected in institutions with child protection groups or child protection clinics that are accredited by the German Medical Society on Child Abuse and Neglect (Deutsche Gesellschaft für Kinderschutz in der Medizin, DGKiM) (e3). In these institutions, it is possible to achieve the required diagnostic reliability for the child who is primarily affected, and possibly siblings, while all possible differential diagnoses and psychosocial aspects are considered. This article cannot discuss these aspects in detail because of space restrictions, hence we refer readers to the excellent review by Jacobi et al. (e4).

If parents reject a relevant referral or a risk to a child's wellbeing cannot be averted by deploying the resources within the medical system, the child protection / child welfare services must be informed immediately. In 2012, the law on cooperation and information in child protection provided the unequivocal authorization to do so (e5). The legal framework and interventions of youth welfare services have been described in detail by Maywald, for example (e6). At this point, we would urge anyone concerned to seek expert advice wherever there is any doubt (*Box*).

Conclusion

In case of an implausible medical history, delayed presentation, additional injuries or injuries in different stages of healing, and generally in children who have not yet started to walk, abuse has to be excluded as the differential diagnosis for fractures. In 1962, Charles Henry Kempe, in his first publication of the battered child syndrome in 1962, set out a demand that, even now, says everything there is to say (e7):

“Physicians, because of their own feelings and their difficulty in playing a role that they find hard to assume, may have great reluctance in believing that parents were guilty of abuse. They may also find it difficult to initiate proper investigation so as to assure adequate management of the case. Above all, the physician's duty and responsibility to the child requires a full evaluation of the problem and a guarantee that the expected repetition of trauma will not be permitted to occur.”

Conflict of interest statement

Professor Fegert received honoraria in the context of a publication by Springer and Hogrefe.

The remaining authors declare that no conflict of interest exists.

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► **Supplementary material**

For eReferences please refer to:
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