General Aspects of Fractures in Child Abuse

1

1.1 Introduction

The incidence and prevalence of child abuse is unknown. The reason for this is that in nearly every study to establish the incidence and prevalence, researchers use their own definition. Sometimes this is a 'broad definition,' such as that of the World Health Organisation (WHO): '*Child abuse, sometimes referred to as child abuse and neglect, includes 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, development or dignity. Within this broad definition, five subtypes can be distinguished – physical abuse; sexual abuse; neglect and negligent treatment; emotional abuse; and exploitation'* [1]. In other cases a much narrower definition is used by preference. This makes it impossible or nearly impossible to compare the research results for incidence and prevalence. In his report on the occasion of the violent death of Victoria Climbié on 25 February 2000, Lord Laming writes on the incidence and prevalence of child abuse: '*I have no difficulty in accepting the proposition that this problem (deliberate harm to children) is greater than that of what are generally recognized as common health problems in children, such as diabetes or asthma'* [2].

During the postmortem investigation of Victoria Climbié, the pathologist established that her body counted as many as 128 injuries. In his report he declares: '*There really is not anywhere that is spared – there is scarring all over the body.*' Lord Laming's report mentions in particular external visible injuries. In children that suffer a trauma, the skin is – in accidental as well as in non-accidental injury – the organ that is most frequently damaged [3]. However, the presence or absence of injuries is not conclusive in establishing physical child abuse when the parents/caregivers or other persons show particular physically aggressive behaviour. That kind of behaviour itself determines whether you can speak of child abuse. The severity of this behaviour can range from a single very serious life-threatening or even lethal incident to regularly returning occasions of aggressive behaviour, such as beating, burning, biting and kicking, in which there is no life-threatening situation with or without injury. Injury (internal as well as external) is the visible result of that kind of behaviour. The severity of the injuries can range from superficial abrasions and bruising to injuries incompatible with life (Table 1.1).

Physical violence does not have to lead to injury. Yet, it appears that up to 90% of victims of physical child abuse sooner or later sustain injury [4, 5]. However, these injuries are seldom severe, and as a result medical treatment or admittance to hospital is required in only 3.2% of abused children [6]. Only a small proportion of these injuries is pathognomonic for the use of violence, resulting from a recognisable kind of injury pattern, such as a bite injury or the identifiable print of, for example, the sole of a shoe (Fig. 1.1) or 'tramline' bruising (Fig. 1.2). Other injuries can only be objectified based on context and other specifics, such as the child's story or a statement that does not correspond with the child's level of development; a remarkable medical history that is in sharp contrast with the nature, localisation and the extent of the injury; a relation with other older and/or unaccounted for injuries; or conspicuous behaviour of the parents.

In other words: usually it is only possible to differentiate between non-accidental and accidental injury by a detailed answer to the clinical question whether this specific child in these specific circumstances can sustain these specific injuries.

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Table 1.1 Injuries in child abuse

Directly visible external injuries	
	Haematomas and contusions
	Excoriations and lacerations
	Burns
	Scars
	Other anomalies, such as traumatic alopecia
Indirectly – through additional examination – visible injuries	
• Radiology	Fractures
	Intracranial haemorrhages
	Intra-abdominal injuries
• Fundoscopy	Retinal haemorrhages and retinoschisis
• Laboratory tests	Intra-abdominal injuries
• Forensic light sources	Old and new superficial and deeper subcutaneous injuries

After haematomas, contusions of the skin and burns, fractures are the most prevalent injuries in child abuse [7, 8]. Often (maybe even in one in five children) fractures are the first sign of child abuse [9]. Fractures are nearly always the result of the more severe forms of child abuse. Approximately 10% of children under the age of 5 who are seen by a physician in the emergency department in the United States as a result of injury have non-accidental injuries. In other words: anomalies and/or injuries that do not result from an accident, but from child abuse or neglect [10]. In children evaluated in the emergency department on suspicion of child abuse, >30% appears to have fresh or healing fractures [11]. In a study on deceased children between the ages of 1–15 years (average 3.9 years) of air force personnel in the United States, it was found that 55% of these children had been seen by a physician as a result of physical trauma in the month prior to their death [12].

Fig. 1.1 Shoe print (*open arrow*) on the right side in a victim of physical violence (With permission of D. Botter MD, The Netherlands Forensic Institute)

Fig. 1.2 Seven-year-old girl beaten with a stick. On the left side typical tramline haematomas can be seen (*open arrow*)

1.2 Incidence of Fractures in Children

Irrespective of the aetiology, fractures are a regular feature in children. Landin carried out several large studies in Sweden [13, 14]. In 1983, he reported on a retrospective study regarding 8,642 children. It concerned all fractures in children treated over a period of 30 years in Malmö (between 1950 and 1979). In 1997 he added the most recent data to his original study.

In this period, the chance to sustain a fracture between birth and the age of 16 was 42% for boys and

27% for girls [13]. This means that there is a 2.1% chance for all children to sustain one fracture per year (2.6 for boys; 1.7 for girls). This is regardless of the type and location of the fracture and the treatment required (clinical or outpatient). This percentage does not differ significantly from the reported incidence of 1.6 reported for boys and girls in an English study of children with fractures treated clinically as well as in the outpatient clinic [15].

Of the fractures sustained by children during the first 16 years of their life, 6.8% is severe enough to require admittance to hospital. Recalculated to the chance of one hospitalisation per year, this gives a chance of 0.43%. Slightly less than 20% of children who visit a hospital for sustained injuries appear to have sustained a fracture [16].

1.3 Difference Between Fractures in Children and Adults

1.3.1 Fracture Type and Location

From an anatomical, physiological and biomechanical aspect, the skeleton of young children differs from the adult skeleton. These changes make that growing bone in children reacts differently to subjected forces than fully developed bone.

The main difference between the still developing skeleton of a child and the fully grown adult skeleton is the presence of growth plates in the long skeletal bones. Growth plates consist of cartilage and make a person grow taller. This cartilage is among the weakest parts of the still developing skeleton of the child, and the weakest part of the long bones in the child's skeleton. Due to this weakness and being localised near the joints, the growth plates are the most vulnerable place when the joint is subjected to force. Only when ligaments and tendons are stronger than bone, which is often the case in growing bone, fractures can occur in this location. The damage then consists of a fully or partially torn off metaphysis (resulting in the 'classical metaphyseal lesion', see Chap. 5). When the fully grown skeleton is subjected to the same forces, it more likely results in damage to the ligaments around the joint.

The presence of larger and more extensive haversian canals make the child's bone more malleable than adult bone. Consequently, immature bone (in particular the shaft of the long bones) can bow instead of break. This means that in children specific types of fracture of the shaft are found that are typical for growing bone. This concerns in particular the so-called incomplete fractures (see also Chap. 5):

- 'Bowing' fractures: in very young children there can be such plastic deformation of the bone that it bows past the point at which, based on the elasticity of the bone, spontaneous recovery is feasible. In these cases, there is no radiologically visible damage in the cortex, neither to the tension nor to the compression side. The fracture will only be visible by the bowing of the diaphyseal segment (Fig. 1.3a and b).
- 'Buckle' fracture or torus fracture (damage to the cortex at the compression side): In axial compression of a bone that has very limited ability to bow, a child can sustain a torus fracture at the shaft-metaphyseal transition (Fig. 1.4). These fractures are stable by nature and when immobilised will heal within 2–3 weeks.
- 'Greenstick' fracture (damage to the cortex at the tension side): this type of fracture can occur when the bone is bowed past the point that spontaneous recovery is possible. It concerns an incomplete fracture on the tension side of the bone and plastic deformation with an intact cortex and intact periosteum at the compression side (Fig. 1.5). In these cases, the force that caused the damage of the cortex on the tension side is insufficient to cause a complete fracture.

In adults, the impact of a comparable amount of energy will cause a fracture as a result of the compression and bowing components, resulting in damage to the cortex on the tension and the compression side, a so-called complete fracture. Complete fractures do occur in children (see Chap. 5). Complete fractures of the shaft can be classified with the aid of the direction of the fracture line in respect to the long or central axis of the bone:

- Transverse, possibly with fragmentation: the fracture line occurs more or less perpendicular to the long or central axis of the bone.
- Oblique: usually the fracture line occurs oblique at an angle of 30–45 degrees in relation to the long or central axis.

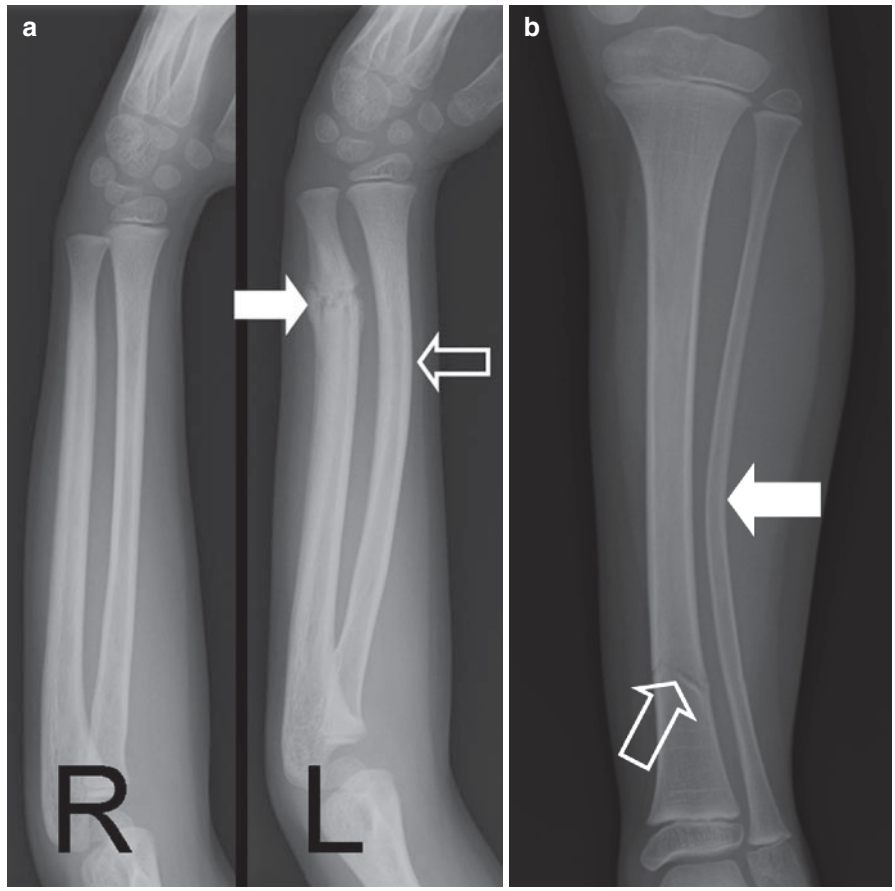

Fig. 1.3 (**a**) Bowing fracture of the left radius (*open arrow*) in a little girl with a healing fracture of the distal ulna (*arrow*). For comparison, a view of the healthy right side which shows anatomical alignment. (**b**) Five-year-old girl with unknown trauma. There is a transverse fracture of the distal tibia (*open arrow*) and a bowing fracture of the fibula (*arrow*)

- Spiral: one could say that the fracture circles around the central axis, and the fracture line runs oblique in relation to the central axis.

With conventional radiology, it is not always possible to distinguish between an oblique and a spiral fracture.

1.3.2 The Healing and Remodelling of Fractures

After a fracture, the periosteum stays intact in children more often than in adults, because in children the periosteum is relatively thicker, stronger and more biologically active. When the periosteum stays intact, a continuity of tissue will grow over the location of the fracture. This results in a more stable fracture and reduces the chance of dislocation. Essentially, here the periosteum functions as a natural splint.

Moreover, a child's periosteum has greater potential to form bone than that of an adult. This adds extra stimulus to the healing process, resulting in faster remodelling of fractures in children than in adults. Low-grade deviations in alignment will be corrected faster, and even in gross deviations in alignment excellent remodelling can occur.

1.4 Fractures: Differential Diagnosis

During childhood, fractures are usually the result of accidents [17]. The differential diagnosis, apart from a witnessed fall or accident (as seen by an independent person) or periosteal reactions that resemble a healing fracture, is very comprehensive (Table 1.2). The table does not presume to be complete, but gives an overview of the most prevalent causes as described in the literature.

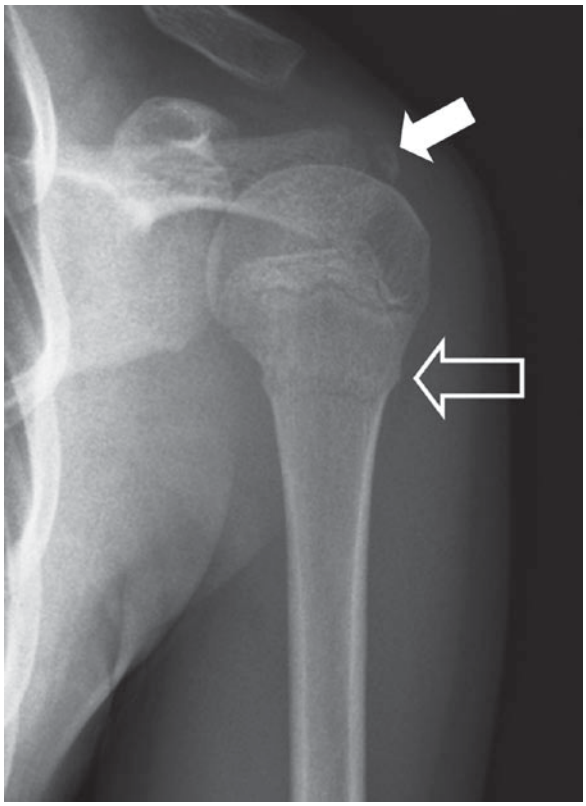

Fig. 1.4 Torus fracture of the proximal part of the left humerus (*open arrow*). Furthermore, in this patient an ossifying nucleus of the acromion can been seen (*arrow*), which is normal for the age of the patient

Fig. 1.5 Greenstick fracture of the tibia (*open arrow*)

Table 1.2 Differential diagnostics of fractures and periosteal reactions in childhood [51–53]

Fractures	
Trauma	Birth trauma Accidental Non-accidental – non-intentional (neglect) Non-accidental – intentional (abuse)
Anomalies in collagen forming	Osteogenesis imperfecta Copper deficiency Menkes syndrome Bruck syndrome
Congenital mineral-based defects	Prematurity: metabolic bone disease of prematurity Neuromuscular diseases Vitamin-D-resistant rickets (or hypophosphatemic rickets) X-linked hypophosphatemia Liver defects (e.g. Alagille syndrome) Malabsorption Familial osteoporosis Osteopetrosis Cole Carpenter syndrome Congenital CMV-infection
Acquired mineral-based defects	Vitamin-D-deficiency based on nutritional defects: rickets Use of diuretics, glucocorticoids and methotrexate Intoxications (e.g. lead) Cerebral paresis and spasticity
Other diseases with increased risks	Congenital insensitivity to pain, e.g.: • Spina bifida • Congenital pain insensitivity Stress fractures
Periosteal reactions	
Radiological differential diagnosis not related to fractures	Normal variants: • For example, the physiological periosteal thickening of the long bones (femur, tibia, humerus) in neonates and young infants Congenital syphilis Osteomyelitis Septic arthritis Osteoid osteoma en other tumours Leukaemia Vitamin-C-deficiency: scurvy Caffey's disease: infantile cortical hyperostosis Mucopolysaccharidosis Sickle-cell anaemia Anomalies related to the use of vitamins • Hypervitaminosis A • Vitamin-E therapy Treatment with prostaglandin E Metastases of a neuroblastoma Use of intra-osseous vascular access needles

When differentiating between fractures in children it is important to work in a structured manner. Central to the process is taking a detailed history. Furthermore, the age and level of development of the child should be taken into consideration (Chaps. 6 and 7): the younger the child, the more limited his/her mobility, and the more probable that the cause is non-accidental (Sects. 1.4.2 and 1.5). In the differentiation, biomechanical aspects should also be taken into consideration (Chaps. 2–5). Other factors that should be taken into account are the distribution of the fractures over the skeleton and the context in which the fractures were sustained. Table 1.3 provides an aid to make an evaluation and reach a differentiation between the various causes of the fractures.

Table 1.3 Evaluation of fractures in young children

Fractures	Type Location: • Axial of peripheral • Symmetric/asymmetric • Weight-bearing/non-weight-bearing parts the skeleton Number Age (known and unknown recent and old fractures) Other injuries
Skeleton	Configuration of the bones and the whole skeleton Bone density Other findings suggesting skeletal lesions, such as 'wormian bones'
Child	Age and level of development Underlying pathology
Anamnesis	Plausibility of the anamnesis: • Age and level of development • Accidental and non-accidental fractures • Disease-related fractures versus non-accidental fractures • Fracture biomechanics

1.4.1 Spontaneous Fractures: Pathological Fractures?

In the literature terms such as spontaneous and pathological fractures are frequently used (Fig. 1.6). In this context, Torwalt et al. describe a 4-year-old boy with cerebral paresis and palsy after a non-accidental brain injury [18]. The postmortem radiographs of this boy show fractures at various stages of healing in the left humerus and both femurs, tibiae and fibulae. Based on a comprehensive investigation, child abuse, accidents, metabolic diseases, other primary and secondary bone diseases and pathological fractures could be excluded. Torwalt et al. concluded that in this boy the conclusion was spontaneous fractures secondary to osteopenia. They define spontaneous fractures as 'fractures that occur without a clear demonstrable external (= traumatic) cause' [18]. One speaks of a pathological fracture in a clinical sense when, for whatever reason, the bone has been weakened by a disorder [19].

From a clinical point of view, the use of terms such as 'spontaneous' and 'pathological' in relation to the occurrence of fractures is understandable and acceptable. However, the use of these terms as an explanation for the occurrence of a fracture is from a biomechanical point of view an approach that is too limited, and as such incorrect. From a biomechanically point of view, fractures occur primarily when the stress on the bone exceeds its capacity to absorb stress. As a result it bows, or even breaks. The type of fracture is determined by factors on the side on which stress is exerted as well as on the side that has the stress-absorbing capacity (see also Chap. 5). 'Spontaneous' and 'pathological' only pertain to the capacity of the bone to absorb stress. Based on its use, one implicitly concludes that even with minimal trauma or during normal care it is possible for weakened bone to sustain a fracture.

From a forensic point of view, the use of either term may lead to apparent certainties when based on these terms one has to differentiate between accidental and non-accidental causes. Hereby the context of the origin of the fracture is totally not taken into consideration. When a fracture is found in a child, the presence of the disorder that results in a decreased capacity to absorb stress (see, e.g. Table 1.2 and Chaps. 6 and 7) says nothing about the stress that can be exerted and the context in which the stress was exerted. The anamnesis and the clinical/radiological symptoms should determine the differentiation between accidental and non-accidental stress. In other words: also a child with proven bone defects can have fractures resulting from child abuse.

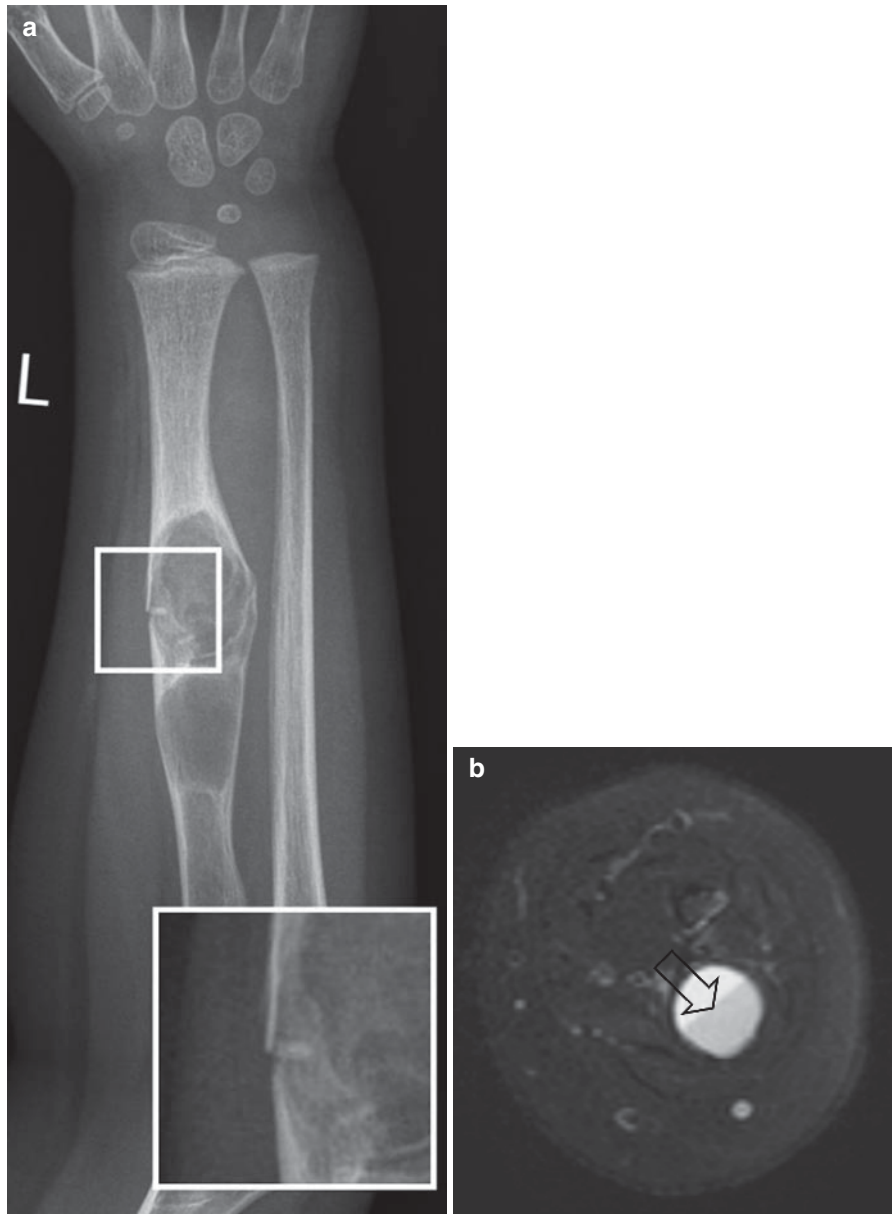

Fig. 1.6 (**a**) Five-year-old boy with a pathological fracture of the left radius (see inset) after a fall. (**b**) T2-weighted MRI of the radius shows a fluid-fluid level (*open arrow*), corresponding with an aneurysmal bone cyst. The diagnosis was histologically confirmed

1.4.2 Cause of Fractures in Relation to Age and Level of Development

Between the ages of 1 and 4 years and in older children (>10 years), an accident is the most common cause of fractures [17]. In the group of children of 1–4 years, fractures of the upper extremities and the clavicle are most common, due to the reflex of the child to catch oneself on the stretched arm when falling. In children over 10 years of age, the number of traffic accidents will be higher than in younger children. Only rarely will one find fractures resulting from accidents in children of less than 1 year of age [20]. When a child grows up, it will become more mobile and enterprising, and the risk for accidental injury increases [21].

1.5 Fractures in Child Abuse

Rang poses that as many as 25% of fractures in children of less than 3 years of age will result from child abuse and/or neglect [17]. Fractures resulting from child abuse occur predominantly in children of less

than 1 year of age [22]. Based on various studies, it is estimated that 50–69% of all fractures in children of less than 1 year old are the result of child abuse [23, 24]. It was also shown that children in this age group are at a high risk of being abused again, even after an intervention took place [25].

Unfortunately, it appears that in these young, often non-mobile, children fractures will often show hardly any clinically conspicuous symptoms such as swelling, redness of even a pseudoparesis, they may even have an occult course [26–28].

However, in young children child abuse remains not only unnoticed due to its occult course, but also because violence as a possible cause is not or inadequately considered, or is rejected on non-plausible grounds [29].

Between 1995 and 1999, Banaszkiewicz et al. carried out a retrospective study in all children under the age of 1 year which were brought into the emergency department of their hospital due to sustained fractures. The data of 74 children in total were re-evaluated. The average age of the children was 5 months (2 weeks to 1 year). Forty-six children had sustained a skull fracture. In 28 children there was a fracture of the long bones. After analysis, it appeared that the attending physician failed to assess possible child abuse correctly in nearly 30% of these children. In nearly 50% of children, the medical data did not show that child abuse had even been considered, whereas in retrospect child abuse would have been a plausible explanation in the differential diagnosis.

Oral et al. carried out a similar retrospective dossier study in 653 children of 3 years and younger who presented with a fracture over the period 1995–1999 [30]. The aim of their study was to establish whether in this group of children physicians inquired sufficiently into the cause of the fractures. Revision showed that, based on the data in the dossier, in 42% of children it had not been possible to exclude child abuse as the cause of the fracture. The missing data concerned:

- Information on the presence of (independent) eye witnesses at the moment the fracture was sustained.
- Information on previous injuries.
- Revision of previous medical data.
- Description of associated injuries.
- An evaluation to see whether the reason provided and the injury of the child could be explained when taking into account the level of development of the child.

Consequently, Oral distinguished four groups:

- Accidental injury (63%)
- Non-accidental injury (‘inflicted injury’) (13%)
- Missed non-accidental injury (23%)
- Missed accidental injury (0.6%)

Factors that had a positive influence on identifying child abuse were:

- The age of the child
- Multiple fractures
- Examination by a paediatrician

Fractures have been described in 55% of young children who had been victims of physical abuse [31, 32]. Non-accidental fractures in children indicate the use of severe violence, which emphasises the importance of identification. It is not always easy to differentiate between accidental and non-accidental fractures; however, it is crucial for a responsible intervention [33]. In a systematic review of the literature by Kemp et al., the predictive value of fractures as a sign of child abuse has been evaluated. Other indications, such the child’s age or the injury that could lead to suspected child abuse were not taken into account. After a selection was made from 439 publications, 32 were analysed [34]. Based on this systematic analysis, they concluded amongst others that rib fractures had the strongest correlation with child abuse; in 71% of cases (95% CI 42–91%) with rib fractures it was a case of child abuse. They also found that none of the fractures were pathognomonic for child abuse.

As such, the skeletal lesions found in child abuse may be similar to lesions found after an accident. Whether a fracture results from child abuse is determined by a combination of:

- The type of fracture
- The age and level of development of the child (see Table 7.3)
- The manner in which the fracture was sustained (according to known data)
- The statement of the child, the parents or the caregivers regarding the origin of the fracture

When the above-mentioned combination shows discrepancies between the combined first three factors and the last one, the statement of the parents, child abuse is probable.

Radiological dating of fractures and performing the correct radiological examination are eminently important

for an adequate diagnosis and protection at the moment that child abuse is suspected. Fractures as a result of violence can be found throughout the entire skeleton, are often present in multiple places, and may show various stages of healing on skeletal radiographs [20, 24, 35, 36]. Since in cases of child abuse it often happens that there is a delay in seeking medical help, dating may be complicated by further loading of the fracture by movement, additional injuries and renewed fractures. The more or less objective radiological dating (see Chap. 9) can spot inconsistencies regarding subjective anamnestic dating and the explanation of the injury [37].

1.5.1 Specificity of Fractures in Child Abuse

According to Kleinman, child abuse should always be considered in the following fractures or bone anomalies [38]:

- Periosteal reactions of the bone and newly formed bone
- Metaphyseal injuries
- Injuries to the growth plate
- Fractures of the diaphysis
- Dislocations

Hobbs mentions the following fractures as suspect [39]:

- Multiple and complicated skull fractures with a fracture width >3 mm
- Injuries to the epiphysis and metaphysis
- Fractures of ribs, scapulae and sternum
- Multiple fractures

In his opinion these fractures are more suspect than simple, uncomplicated fractures, shaft fractures of the long bones and fractures of the clavicle. Furthermore, Hobbs further maintains that fractures are more suspect when they occur together with other injuries; for example: a simple fracture (such as of the humerus) combined with multiple unexplained haematomas.

Child abuse should be considered in case of [40]:

- Multiple fractures in various stages of healing, even when no associated trauma is present, such as haematomas and (sub)cutaneous injuries.

Table 1.4 Specificity of skeletal injuries in child abuse, highest specificity applies in infants (Reprinted from [54]. With permission)

Specificity	Type of fracture/skeletal lesion
High specificity	Classic metaphyseal lesion Rib fractures, especially posterior Scapular fractures Spinous processes fractures Sternal fractures
Moderate specificity	Multiple fractures, specifically bilateral Fractures of different ages Epiphyseal separation Vertebral body fractures and subluxations Digital fractures Complex skull fractures
Common but low specificity	Subperiosteal new-bone formation Clavicular fractures Long bone shaft fractures Linear skull fractures

- Damage to the epiphysis and metaphysis, possibly multiple as in the inflicted traumatic brain injury formerly known as ‘Shaken baby’ syndrome.
- (A) single or multiple rib fracture(s).
- The presence of periosteal new-bone formation.
- A skull fracture, with or without signs of intracranial trauma.

Kleinman presents the following overview on the specificity of radiological findings regarding child abuse (see Table 1.4). He poses that it is likely for child abuse to be the cause when in lesions of average or low specificity there is no explanation for the cause of the trauma or when the explanation does not correspond with the nature of the trauma.

1.5.2 The Value of Haematomas in Differential Diagnosis

The little that is known about the presence of haematomas in relation to fractures in children has been learned through the fractures that resulted from child abuse. This leads to the perception that haematomas are sustained at the same time as fractures: the force required to cause a fracture will in all likelihood also result in haematomas. The reverse of this reasoning is that a

lack of haematomas is proof that it took only very little force to break the bone and, as such, that the fracture results from a metabolic illness or from osteogenesis imperfecta [41–43]. Mathew et al. did a prospective study into the presence of haematomas around the location of the fracture in 88 children that showed no signs of bone pathology and found in total 93 fractures (49 boys, 39 girls; age 12 months to 13 years and 11 months) [44]. All children were seen within 24 h after the fracture had been sustained. Only in eight fractures haematomas were found in the initial phase. No haematomas were found in fractures that showed no dislocation or in fractures that were well covered by soft tissue. In 13 other fractures, haematomas appeared within 24 h after hospitalisation. Ultimately, 25 (28%) fractures were accompanied by haematomas 1 week after the fracture was sustained. According to Mathew et al., based on the lack of haematomas it is impossible to distinguish between fractures that are the result of bone disease and fractures resulting from child abuse. It appears that in acutely sustained fractures in children, local haematomas are less common than one would expect; however, based on the absence of haematomas, child abuse should not be excluded.

Starling et al. also did not find any relation between fractures and the presence of haematomas. After skull fractures had been excluded, it appeared that in less than 10% of children had fracture-related haematomas [45].

1.5.3 Characteristics of the Anamnesis

Most physicians will be able to identify children as victims of child abuse when they fall into the most severe clinical category of child abuse, such as young non-mobile children that sustained multiple fractures without identifiable cause. The problems arise mainly in children that sustained less severe trauma and have less obvious symptoms. To this category belong children that have just one fracture and no clear story of child abuse [46].

1.5.3.1 Anamnesis in Children

In child abuse the child is often not able to explain how the injuries were sustained. This applies in particular to children in a life-threatening situation. Such a situation makes conversation with the child (virtually) impossible. Besides, many children with serious trauma resulting from child abuse are preverbal. When children are able to relate the situation, there is a fair chance that they will keep silent out of loyalty to the parents or out of fear for the perpetrator.

1.5.3.2 Patient History

When child abuse is suspected, it is important to pay attention to the patient history of the child and the other family members. In case of child abuse it is possible that the child has sustained (multiple) previous trauma and has prior hospitalisations. Various studies have shown that approximately 50% of all children in which child abuse was established had been seen by a physician for (in retrospect suspect) injuries [32]. Also, an abused child who returns to a non-safe home setting has a 30–50% chance to suffer additional trauma and an increased risk for lethal violence (up to10%) [47].

Very regularly earlier trauma and hospitalisation are seen in other members of the family, such as the other parent, other children or between siblings. This may proof that the violence is also directed at them. When compared to other men, it appears that men who maltreat their wife will frequently also maltreat their children. Women who were abused by their husband appeared to be twice as likely to maltreat their children compared to non-abused women. Seventy-six percent of the physically abused children allegedly used violence against a sibling [48].

1.5.3.3 The Origin of the Injuries

When a child makes a direct and spontaneous statement on how the injury was sustained, he or she will most likely tell the truth. This also applies to a witness that makes a statement regarding the origin of the injury. Yet, the statement of the witness should be closely examined, since the person will speak from his/her own set of values. On the one hand, the witness may play down what has been observed, on the other hand, it may be exaggerated. Also, the witness may serve his or her own self-interest by giving the statement.

The following items should be considered during the anamnesis:

- While the anamnesis is taken, there may be contradictions between the statements of: the child and the parent(s), between both the parents, or between

parents and witness. Sometimes no explanation is given, since allegedly no witness was present.
- Also, the statements may constantly vary, when further prompted or when taken on consecutive days.
- Parents may give different statements to different people, or withdraw statements.
- Sometimes when the child is given a physical or radiological examination, previous injuries are found for which the parents are not able to give an adequate explanation.
- The statement may be in contradiction with the level of development of the child.
- The nature and/or location of the injury may be in contrast with the statement of the parents.
- The parents' statement only explains part of the injuries.
- According to the statement, the child himself/herself or one of the siblings is responsible for the injury.

1.5.3.4 Seeking Medical Help

In child abuse, one of the main characteristics of the anamnesis is that medical treatment was only sought at a late stage. The latency period can vary from hours to days after the injury was sustained. This is due to various reasons: shame, wrongly evaluated situation, hope for spontaneous recovery, and hope that the injury will no longer be recognisable as resulting from child abuse. Also, other persons besides the parent(s) may seek help, such as the grandparents or a teacher. Finally, help may be sought from others than their own general practitioner or paediatrician, without providing an plausible reason. Often this help is sought at odd times, such as during the evening.

1.5.3.5 Attitude and Reaction of the Parents

The contradiction between the severity of the injury and the reaction of the parent may have to the injury can be conspicuous. They may totally overreact to a minor injury. On the other hand, the caregiver may have hardly any or a very inadequate (remote, indifferent) reaction to (very severe) injuries. A parent who maltreats may completely overreact and sometimes react aggressively to innocent questions. For that matter, the non-maltreating parent may react in a similar manner. When child abuse is brought into the conversation, the parent may threaten to deny the child medical care.

When a physician wants to speak to the parents about a specific injury, he should be aware of a number of matters. It does not take long for parents to realise that the physician doubts their statement and may suspect child abuse. This applies to parents who maltreat as well as to parents who do not maltreat. This may cause the parents to take a defensive attitude directly at the start of the interview. The reactions may vary from denial and a tendency to isolation and then proceed via anger, bargaining and resignation to acceptance. Also, the physician will have to be aware that the parent to whom he speaks may be ignorant of the maltreating behaviour of the partner.

1.5.4 Perpetrators and Victims

Starling et al. were the first to initiate a study into the specific characteristics of perpetrators who cause fractures in children [45]. They evaluated the data of 194 children (age: 0–13.9 years; median 6 months) with in total 630 fractures. The median number of fractures per patient was 2 and the maximum was 31. In 153 children (79%) the perpetrator could be identified. Nearly 68% of perpetrators were male. Of all known perpetrators, 45% appeared to be the biological father.

Furthermore, there appeared to be a significant difference ($p=0.003$) between the median age of the children who had been abused by a male (4.5 months) and by a female perpetrator (10 months). In 44 of the 194 children, the primary injury was non-accidental skull-/brain trauma. Since it is not known whether the age of victims of non-accidental skull-/brain trauma differs from that of children with other non-accidental fractures, further study was done after the children with non-accidental skull/brain trauma were excluded. However, this analysis still showed a significant difference ($p=0.004$) between the median age of children abused by a male (5 months) or a female perpetrator (12 months).

1.6 The Role of the Radiologist When Child Abuse Is Suspected

It is essential that the radiologist who evaluates the characteristics of the fracture(s) has sufficient knowledge of the clinical history of the patient. Collaboration with other specialists (such as paediatricians or forensic physicians) has added value for the evaluation. In

order to determine whether a fracture results from child abuse, the radiologist will need to reconstruct the reported trauma and evaluate the plausibility of the statement [49].

The radiologist will be expected to be able to [50]:

- Detect the radiological anomaly that suggests child abuse in suspect as well as in non-suspect cases.
- Distinguish between radiological abnormalities suspect for child abuse and other pathologies and normal variants.
- Evaluate whether the fracture and the underlying trauma mechanism are compatible with the statement of the child and/or parents regarding its origin.
- Date fractures within the limitations of scientific knowledge.

Finally, one could argue that the radiologist involved should support the Public Prosecutor in securing that justice takes its course.

1.7 Ethical Dilemmas in Suspicion of Child Abuse

In view of the potentially serious consequences of physical violence, it is important that child abuse is identified at an early stage. However, it is equally important to prevent that child abuse is diagnosed wrongly or on false grounds:

- Because an accident or disorder is seen as the most plausible or even only explanation for the found anomalies. This may lead to disruption of the family as a result of incorrectly applied measures of child protection or unjust legal prosecution of the parents.
- Because there is a coincidence of, on the one hand, the conclusion that an accident is the most plausible or even only cause of the injury that was found and, on the other hand, child abuse as the most plausible reason for other injuries or the behaviour of the child. In these cases, there is a risk that giving a plausible reason for the skeletal abnormalities may lead to the exclusion, on unjust grounds, of child abuse as plausible reason for the other abnormalities or the behaviour of the child. Consequently, the child will not be protected against a recurrence of the child abuse that is present.

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