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REVIEW

A brief history of fatal child maltreatment and neglect

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Abstract Child abuse encompasses four major forms of abuse: physical abuse, sexual abuse, psychological abuse, and neglect. The United States retains one of the worst records of child abuse in the industrialized world. It has also been determined that a large portion of these cases are missed and go undocumented in state and federal reporting agencies. In addition, disparate risk factors have been identified for physical abuse and neglect cases, but substance abuse has been found to be a significant factor in all forms of abuse. Fatal child maltreatment and neglect investigations require a multi-pronged and multidisciplinary approach requiring the coordination and information gathering from various agencies. A major difficulty in determining the accidental or non-accidental nature of these cases is that the account surrounding the events of the death of child is acquired from the caretaker. In this review, we outline common diagnostic characteristics and patterns of non-accidental injuries and neglect as a result of nutritional deprivation.

Keywords Child maltreatment · Neglect · Etiology of non-accidental trauma · Risk factors

Introduction

The term child abuse encompasses four major categories of non-accidental abuse, physical abuse, neglect, psychological abuse, and sexual abuse [1]. Among industrialized nations, the United States (US) retains the worst record on non-accidental child abuse [2]. For the fiscal year 2012, there were approximately 686,000 victims of child abuse in the US, a national rate of 9.2 per 1,000 children [2, 3]. According to the US Department of Health and Human Services, an estimated 1,750 children died of maltreatment in 2011, which is a rate of 2.1 per 100,000 children [3, 4]. Although overall rates of US based child abuse have seen a slight decline (~4 %) in the past 5 years, the breakdown of abuse types (e.g., physical, neglect, etc.) and abuse demographics (most vulnerable ages, etc.) has remained relatively steady. Nationally, the overwhelming percentage of abuse cases (71 %) are consistently recorded as neglect alone or in combination of other types of abuse, while approximately 48 % of all cases are recorded as physical abuse alone or in combination with other forms of maltreatment [2]. Children ≤2 years old represent over 30 % of all victims [2, 3]. Studies including all forms of child abuse conducted over the last 5 years show abuse at similar levels for both boys and girls, although the most recent data suggest that girls are victimized in slightly higher percentages (~51 %) [2], but other sources cite boys as being victims of abuse more often than girls particularly in toddlers [5]. However, these disparities in the literature are likely the result of data source incongruities and collapsing of age categories.

The UNICEF Innocenti Report [6] statistics reported that 3,500 children under the age of 15 died annually from child abuse (physical abuse and neglect) in industrialized nations. The US, Mexico, and Portugal had 10–15 times higher than average rates of child abuse deaths. Interestingly, these high rates of child maltreatment deaths were also associated with higher than average adult assaults in these nations. Poverty, stress, alcohol, and drug abuse were consistent factors associated with child maltreatment deaths [4].

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To date, much research has been generated in an attempt to identify specific risk factors associated with child maltreatment homicides [7–9]. However, various federal and state government reporting systems are said to systematically under report and/or ascertain child maltreatment fatalities [3, 10–12]. Missed inflicted injuries and our inability to accurately predict child maltreatment fatalities are not a recent phenomenon and have been a concern reported since the early 60s [5, 11, 13–15]. In addition, recent literature has shown that deaths due to child neglect and physical abuse are associated with different risk factors that should be addressed independently in our current reporting systems [16]. Furthermore, the correct identification of deaths due to neglect is extremely challenging [17–20]. This review will focus on non-accidental physical abuse and fatal neglect with a special emphasis on skeletal manifestations, and how these types of trauma have been identified and analyzed across disciplines.

Non-accidental physical abuse

Non-accidental child abuse or non-accidental injury (NAI) is defined as, "encompassing those acts that cause actual physical harm or have the potential for harm" [1]. Non-accidental neglect refers to situations in which resources such as food and medical care are available, but fail to be provided to a child. For clinicians, forensic scientists and other workers that may interact with potential victims of abuse the positive identification of abuse comes from four major areas, recognition of injury patterns, victim verification, victim age assessment, and the absence of adequate mechanistic explanations [21, 22]. Even in the face of this four-pronged approach, the determination of NAI, and the identification of abuse are diagnostically challenging. The most effective scenario involves several tiers of experts (clinicians, law enforcement, medical examiners, and forensic anthropologists) that are well versed in the indications, and an organized methodology of assessment.

Identifying NAI and its manifestations

Victim age

Identifying the age of the victim should be the initial step when investigating the manifestations of NAI. The inverse relationship between victim age and rates of abuse is well established, and as such, skeletal injury in children <2 years of age should be of immediate interest [23–28]. It has been estimated that 50–69 % of all fractures in children under 1 are the result of abuse [29, 30]. The pliability of infant bodies at this age means that skeletal traumas require a significant amount of force [31, 32]. Once more, the anatomy of infant bones with the diaphysis, capped by cartilaginous growth plates and bony epiphyses lends itself to characteristic types of injuries under mechanisms commonly associated with abuse [22, 33, 34]. For example, one of the most characteristic traumatic patterns are the metaphyseal injuries or bucket handle/corner fracture of the distal femur, proximal and distal tibia, and proximal humerus commonly generated by excessive gripping, pulling, torsional twisting, and violent shaking [22, 35, 36].

However, extreme caution should be taken when diagnosing abuse in young children from radiographs [37]. Studies demonstrated that as many as 37 % of occult fractures may be missed upon initial radiographic exam [38, 39]. For living victims, two sessions of skeletal imaging separated by 11–14 days are recommended by the American College of Radiology Standards. Fractures that fail to appear on initial exams can be visualized once healing begins. Accelerated healing rates characterize infant and children skeletons due to their vascularity and osteogenic activity [40]. The accelerated rate of healing in these young victims can also inhibit detection of abuse in forensic skeletal analysis, as older injuries heal over. Rate of healing has a linear relationship with the child's age and thus, the younger the infant or child, the faster the healing. In a newborn, for example, femoral diaphyseal fractures can heal within 3–4 weeks, while it would take 12–16 weeks to heal in an adolescent [5, 40]. Metaphyseal bone turnover has also been shown to be faster [41].

Patterns

While no single injury is diagnostic for NAI, there are patterns and syndromes that have been repeatedly positively associated with abuse. The following well established patterns and injuries; shaken/battered baby (child) syndrome, cranial and lower limb combinations, and thoracic combinations along with the most recent data from the literature, will be discussed here. A thorough examination by body loci can be found in Bilo et al. [22] volume, Forensic Aspects of Pediatric Fractures, Differentiating Accidental Trauma from Child Abuse. In addition, Abel [34] compiled a list of the most common types of skeletal trauma from the literature that is suggestive of child abuse, which is presented in Table 1.

Shaken baby syndrome or battered baby (child) syndrome

Shaken baby syndrome (SBS) was originally described by Caffey [42] as "whiplash shaken infant syndrome" and represents one specific form of child abuse. This form of child abuse is overwhelming associated with children under the age of 1 [26, 30]. The exact location of any skeletal injuries generated by shaking trauma depends upon

Table 1 Skeletal trauma suggestive of child abuse, assuming child is non-ambulatory (reproduced with permission from Abel [34])

Element	Location	Type/description	Mechanism
Cranium	Parietal Frontal Occipital	Simple linear, wide, complex, depressed, diastatic, growing, and/or multiple fractures that cross suture lines	Direct impact
Vertebra	Spinous process	Avulsion	Hyperflexion Hyperextension
	Centrum	Wedge fracture	Compression
		Dislocation/subluxation	Hyperflexion Hyperextension
Sternum	Any portion	Transverse	Direct force
1st Ribs	1st Ribs, lateral	Transverse	Acute axial load
Other ribs	Any location, but especially posterior (head, costotransverse process) and axillary	Frequently multiple and bilateral	Shaken baby syndrome and direct impact High specificity for abuse
Clavicle	Lateral	Transverse	Sudden traction on the arm
Scapula	Blade	Transverse	Direct force
	Acromial process		Severe twisting/shaking
Long bones	Metaphysis	Corner/bucket-handle avulsion fracture	Traction injury from shaken baby syndrome High specificity for abuse
Humerus	Diaphysis	Any fracture except supracondylar, and periosteal reaction in children under the age of three	gripping and twisting, direct impact
Hands	Metacarpals Phalanges	Torus	Squeezing, forced hyperextension, trampling
Femur	Diaphysis	Any type (but especially spiral), periosteal reaction in children under the age of three	Gripping and twisting, direct impact
Tibia/fibula	Metaphysis	Any fracture or periosteal reaction in children under 1 year of age	Gripping and twisting, direct impact

where on the body the victim was held by the perpetrator. The cranium, ribs, as well as the diaphysis and metaphysis of long bones are the most common locations for skeletal injury in SBS [43]. In cases where the shaking motion is conducted while the infant is held by the chest, a pattern involving the ribs and cranium may appear. Specifically, posterior and lateral rib fractures located around the rib head and tubercle, in combination with any of the following cranial fracture types; bilateral, diastatic, depressed, fractures that cross suture lines, may be seen [42–44]. If the infant is held by the extremities and shaken, cranial injuries may be accompanied by long bone injuries such as spiral diaphyseal fractures, subperiosteal hemorrhages, and metaphyseal fractures (e.g., corner/bucket handle avulsion fractures) that result from the traction shearing forces [44]. For a thorough discussion focused solely on fractures associated with SBS see Kleinman [35], Caffey [42], and Lancon et al. [43].

In cases of non-accidental pediatric trauma, SBS accounts for as many as 50 % of deaths [45]. In many cases, soft tissue injuries may be the only evidence of trauma, and like skeletal injuries, these soft tissue injuries may occur in clusters—namely head injuries: subdural, subarachnoid, and retinal hemorrhages [46, 47]. Retinal hemorrhages have been found to be conclusive evidence in the absence of adequate explanations such as a vehicular accident, and common household falls have been found to not produce enough force to result in these types of injuries [48]. In most cases there is no outward sign of injury or cranial fractures and the most common explanation provided by the caretaker is that "the baby was fine and suddenly went into respiratory arrest or seized" [48].

The determination of SBS and its associated injury patterns is not without controversy. In 2011, Supreme Court justices Ginsburg, Sotomayor, and Breyer issued dissenting opinions in the SBS case of Cavasos v. Smith. In

this dissent, they clearly state their opinion that "there was inadequate scientific evidence to come to a firm conclusion on most aspects of causation, diagnosis, treatment, or any other matters pertaining to SBS" [49]. In this same opinion, the justices go on to question the commonly held opinion that the finding of subdural hemorrhages and retinal hemorrhages in an infant was strong evidence of SBS. These dissenting opinions are reflected in a small but growing body of literature that questions the causative links between the shaking mechanisms and the observed injuries [50]. For the most part, child abuse and its injuries are analyzed after the fact, and therefore the nature of child abuse research is based on case or retrospective studies. This is problematic when attempting to conduct scientific research as critical components and variables such as the confirmed cause of trauma, the consistent presence of reliable control groups, and sufficient information on injuries may be inconsistent across studies. While this does not preclude the ability of researchers to statistically associate certain types of injuries with abuse mechanisms, in many instances it does prevent the definitive identification of these injury manifestations as unique evidence of abuse. For more information on Daubert analysis of SBS, see Tuerkheimer [51], Moreno and Holmgren [52], and Kleinman [59].

Cranial and lower limb combinations

In combination with head trauma from SBS, abusive head trauma from non-SBS is the leading cause of death in children ≤1 year [47]. Cranial fractures of all types are seen both in NAI and non-abusive traumas. As such, there are no specific cranial fracture types that are diagnostic of NAI. Case studies documenting abusive trauma in the crania of children have recorded linear, multiple, complex, depressed, bilateral, and fractures that cross sutural lines [44, 53]. For a thorough discussion on mechanisms and more discussion on the aforementioned fracture types see chapter 2 of Bilo et al. [22].

In their 2012 meta-analysis of 24 studies, Piteau et al. [47] were able to make statically significant connections between abusive head trauma and multiple injury loci. The study showed that each of the subdural hemorrhages, cerebral ischemia and skull fractures, in conjunction with intracranial injury, retinal hemorrhages, long bone, rib, and metaphyseal fractures, were individually significantly associated with abusive head trauma. Interestingly, the meta-analysis also demonstrated that isolated skull fractures were significantly associated with non-abusive head trauma. This assertion supports the position taken by several workers that bilateral or multiple skull fractures are indicative of abuse (see for example Lancon et al. [43], Kleinman and Marks [54], Dwek [55]).

In healthy infants, the extreme cartilaginous nature of the infant cranium requires a significant amount of direct trauma to produce cranial fractures. Despite the presence of several large studies and meta-analysis there is still significant heterogeneity among workers as to the types and localities of skeletal cranial trauma statistically associated with NAI [22, 37, 47]. As such children under 18 months presenting with cranial fractures generated by inadequate explanations should be thoroughly examined for intra-cranial and postcranial injury [56]. A more detailed and systematic description of cranial injuries including fracture type and location is needed so that future studies can more thoroughly analyze these variables for statistical significance [66].

In the absence of cranial traumata, postcranial injuries have been cited as indicators of NAI by several workers; see for example Maguire et al. [37], and Pandya et al. [57, 58]. In their 2013 meta-analysis Maguire and colleagues' report that in children ≤18 months old fractures of the femur and humerus were the second and third most predictive fractures of abuse, retaining a higher positive predictive value (PPV) (50.1 and 43.8 %, respectively) for abuse than cranial fractures (20 %). Due to a paucity of appropriate studies focusing on the fibula and tibia no positive predictive data could be generated for these bones. However, a retrospective study by Pandya et al. [57] of five hundred child abuse cases determined that for children ≤18 months old, fractures of the tibia/fibula were 12.8 times more likely to be found in cases of NAI. For this age group, tibial and fibular fractures were second only to rib fractures in their association with NAI.

Pandya et al. [58] generated data on the significance of fracture location for the femora and humerus. For children ≤18 months old proximal and diaphyseal fractures of the humerus were overwhelmingly associated with abuse (83 and 86 %, respectively) [58]. For similarly aged cohorts, fractures of the femoral diaphysis and distal femur were associated with NAI (Odds ratio and 95 % CI of 0.4 and 2.3, respectively). Kleinman [59] conducted a 10 year retrospective study in which he demonstrated that classic metaphyseal lesions were encountered in 50 % of infants at high risk for abuse (i.e., suspected). Although there is a paucity of studies on fracture types, some workers have associated fracture types with NAI in non-ambulatory children; see for example, Haney et al. [60] for a discussion on transverse fractures of the femur. Although there are few systematic studies on fracture type, the mechanisms of fracture production are at present well known. As such, spiral fractures, transverse fractures, and oblique fractures in the limbs of non-ambulatory children should initiate careful postcranial analysis [42].

Thoracic combinations

The thorax includes the ribs, sternum, vertebral column, clavicle, and scapula. The following discussion will focus

at length on the ribs as they are the region where the most substantial evidence for NAI is focused. For more in depth discussion by body element the reader is encouraged to see Abel [34].

In the clavicle and scapula, only fractures to the lateral portion of the bones (acromial process of the scapula) have been shown to be suggestive of NAI in children under 2 years old [54, 55, 61]. Fractures to the sternum are rare in young children and as such there is a paucity of studies tying them to NAI. When present, they do suggest direct trauma, however, sternal injuries alone are not indicative of NAI [62].

Fractures to the ribs in absence of all other fractures are considered to be highly indicative of child abuse, this is especially true for children under 2 years of age [25, 63–65]. A key study in this regard was the 6 year retrospective study by Barnsness et al. [63], which identified the PPV of rib fractures in children $\leq$3 years old as indicators of abuse to be as high as 95 %. Moreover, the Barnsness study also found that in 29 % of cases (out of 78), rib fractures were the only indication of NAI. In several studies of NAI in children, fractures to the ribs have been commonly found in multiple ribs and in combination with other cranial and postcranial fractures (see for example Barnsness et al. [63], Cadzow and Armstrong [66], Tun et al. [67], Love et al. [68]). As such careful systematic examination of the ribs may provide evidence for multiple instances of abuse. In their large pediatric trauma study, Pandya et al. [57] confirmed that combinations of rib fractures and accompanying limb fractures were highly indicative of abuse in children <18 months old.

The most common mechanism of injury associated with non-accidental rib fractures is the anterior–posterior compression previously discussed with SBS. As Abel [34] points out, rib fractures due to NAI may occur anywhere on the rib, however, posterior and midshaft fractures are the most common in cases of abuse [63, 69]. Fractures on the posterior aspect of the rib are more common in this scenario because this is the location where mechanical forces are highest, and where the joint made by the rib tubercle and the transverse process of the vertebrae acts as a lever when force is applied, leading to fracture [22, 68].

Documentation of fracture types (e.g., transverse, oblique, etc.) and locations (e.g., anterior, posterior) is important in the determination of NAI versus accidental injury. In their 2011 study, Yang et al. [70] analyzed 42 non-traumatic cases showing fractures caused by cardiopulmonary resuscitation (CPR). The study that focused on adults, demonstrated that fractures caused by the anterior–posterior compressions of CPR were overwhelmingly buckle fractures (90 %) with 28 % located along the costochondral junction. In general, rib fractures in children under 3 years old are rare; this is partly due to the extremely flexible nature of the child thoracic region [66]. In fact, the 1984 work by Feldman and Brewer found no evidence for rib fractures in over 50 infant patients that underwent CPR [69]. However, the presence of buckle fractures is difficult to observe via radiographic analysis, the most typical analysis performed on infant victims of abuse [37, 55]. While the Yang et al. [70] study is not specific to infants, it suggests that rib fracture type and location is an important consideration in the determination of NAI versus accidental trauma in general, a notion supported by Love et al. [68]. Love et al. [68] propose a novel classification system for rib fractures to be utilized in the forensic anthropological analysis of infant cases. This proposed schema separates individual ribs into the following: four sections, posterior, posterolateral, anterolateral, and anterior, and utilizes four possible types of fractures such as buckle transverse, oblique, and sternal end plate. Following the example set by Kleinman et al. [71] for long bones, the classification scheme will provide future analysts with increased fracture identification capabilities and clarify the relationship of specific rib fracture types and localities with abuse.

Analysis of physical abuse

Because the majority of victims of abuse are alive when they present, radiological investigations of abuse including radionuclide imaging, radiographic skeletal survey, MRI, and CT are the most commonly performed types of analysis [56, 72, 73]. According to the American College of Radiology appropriateness criteria, all children $\leq$24 months of age with suspected abuse should undergo at minimum an X-ray skeletal survey. However, several workers demonstrated that a single skeletal survey may miss as many as 37 % of fractures generated by NAI [37–39, 55]. The most current recommendations generated by these authors for radiological analysis includes multiple skeletal surveys separated by 11–14 days, oblique views of the thoracic region, and close views of individual elements [37]. In addition to macro and microscopic analysis, forensic anthropological analysis should also include radiographs and bone density measurement (when appropriate).

Fatal neglect

The majority of children who died of fatal child maltreatment in the US in 2011, 71 %, died from neglect exclusively or in combination with other forms of maltreatment [2, 16, 74]. In their recent paper, Welch and Bonner [75] define two general categories of neglect: *deprivation-of-needs neglect* or the caregiver's inability to provide for the

child's basic needs (e.g., food, water, shelter, medical care, clothing, and education) and *supervisory neglect* or a failure of a caretaker to provide adequate supervision and safety for the child's developmental age. Out of 372 cases of fatal neglect, 26 (7.8 %) of the cases occurred because the victim was denied of clothing, shelter, food or was abandoned without these essential needs, while 9.7 % were due to medical neglect [75]. Because of the rarity of fatal starvation cases, fatal neglect research resulting from *deprivation-of-needs* is almost nonexistent and is based on retrospective case studies and forensic case reports.

Failure to thrive is a clinical diagnosis made in the living child who is not adequately gaining weight or growing and is generally characterized by persistently falling below the third or fifth percentile on standard child growth charts [74, 76]. Malnutrition is the main factor involved in growth failure and depending upon the duration and severity of the malnutrition two types of malnutrition insults can be identified- *wasting* and *stunting*. Linear growth will continue for some time after the cessation of weight gain and may continue with continued weight loss. However, fatal starvation is considered extremely rare and the most severe form of abuse [20] and may be difficult to prove even after autopsy [18, 76, 77]. Knight and Collins [18] found that the age range of infants in malnutrition/starvation and dehydration cases was 6–18 months and that the primary caregiver at the time of death was usually the mother. Starvation is more commonly observed in younger infants/toddlers as older children can generally feed themselves if there is no underlying physical and/or mental disability.

In fatal neglect cases it is imperative that complete medical and family histories be evaluated. In many of the cases starvation is difficult to assess due to a possible underlying medical condition, as many times there is also evidence of medical neglect where the parent has also neglected to continue with recommended well-baby visits, and thus, there is no medical history of the child's development. Knight and Collins [18] and Collins [78] found the following findings to be present in starved infants: cachexia or wasting, dehydration, decreased subcutaneous and visceral fat, muscle atrophy, osteopenia/osteoporosis, osteomalacia, rickets, thin, dry, wrinkled skin, brittle hair, decreased organ weights, sunken eyes and cheeks, depressed fontanels, protruding ribs, vertebrae and iliac crests, empty GI tract, secondary infections, and poor hygiene. Mehta and coworkers [79] recommend that malnutrition in an individual child should be diagnosed via anthropometric parameters and their cutoffs. Thus, the WHO [1], Gomez et al. [80], and Waterlow [81] classification systems that have been developed to assess protein-energy malnutrition (PEM) in developing countries are useful standards to aid in medicolegal death investigations [82].

New approaches

For cases that involve juvenile remains in an advanced state of decomposition or skeletonization, assessing malnutrition or fatal neglect is even more challenging. It is crucial that family histories, review of living conditions, and witness interviews be thoroughly conducted. Skeletal indicators that would be diagnostic of malnutrition/starvation would include discrepancies between different hard tissue aging standards. For example, aging based on different long bones, dental development and measurement of the *pars basilaris* in the base of the skull could suggest a nutritional deficit. Dental development and the *pars basilaris* are less affected by environmental stressors such as nutrition, and thus, would more closely reflect actual chronological age of the infant than long bone lengths that can be significantly impacted by environmental factors. In addition, the distal segments of the extremities (e.g., the tibia) have been found to be the first elements to be affected (e.g., stunted) during severe environmental stressors such as starvation [83]. These discrepancies in combination with other metabolic insufficiencies, such as rickets resulting from severe vitamin D deficiency, vitamin C deficiency resulting in scurvy, and lines of arrested growth (Harris Lines), would also indicate a high specificity of fatal starvation [84]. However, caution should be exercised, and careful consideration of the limitations of the evidence considered when making interpretations of fatal neglect from the juvenile skeleton. In children, low intakes of vitamin D can lead to reduced bone acquisition and inadequate protein and caloric intake can lead to growth retardation and decreased formation of cortical bone [85]. As Knight and Collins [18] have noted osteopenia/osteoporosis was a common finding in starvation deaths, bone densitometry is a useful tool that can be used in a medicolegal context.

Bone densitometry became a widespread tool in the evaluation on adult bone health after its commercial introduction in 1987 [86]. Pediatric use of dual energy X-ray absorptiometry (DXA) has increased as well with the development of normative data for pediatric patients [87] and it is the most widely available technique for measurement of bone status in children [88]. Bone mineral density (BMD) and bone mineral content (BMC) has been found to be directly associated with chronological age [89, 90]. In healthy Spanish children, BMD was shown to increase progressively with age from birth until 4 years of age with boys and girls having similar BMD values [89]. In another Spanish pediatric study of healthy children aged 3–21 years of age, the same pattern was observed with BMD values increasing progressively with age, however, the most significant increases were detected in the first 3 years of life and again in late puberty [90]. BMD has been determined to have a strong association with age, weight, and length/height, and the pattern of BMD increases were found to be similar to height growth velocities [89].

In a study of malnourished children, Alp et al. [91] ascertained that BMD was significantly lower in malnourished children and that bone mineralization was severely affected by the severity of malnutrition. They recommended measures of BMD in malnourished children to assess the severity of osteopenia and in follow up visits to monitor the response to therapies. DXA of the lumbar spine and hip has been listed as highly appropriate for pediatric use for those at risk of osteoporosis by The American College of Radiology [56]. Therefore, DXA used in conjunction with other skeletal indicators can be a useful tool in the examination of possible cases of fatal starvation in decomposed or skeletonized remains [20].

Risk factors

In 1980, Schmitt [92] brought attention to the fatal risk of sending and infant who presented with poorly-explained injuries home without intervention. The severity of the injury is also a primary determinant in the classification of an injury as non-accidental or inflicted, which is established on whether the injury is more severe than the history given by the caretakers would deem. Confounding the issue is that the severity of the injury is also a determinant of whether the infant or child will be brought for medical care by the caretakers in the first place. Missed (misdiagnosed injury) and missing (undiscovered) injuries account for the large disparity between case fatality rate databases [10].

Certain parent and child characteristics and household compositions have been shown to be risk factors that can contribute to a child's death. For example, children living with an adult with no biologic affinity to the child are at 8 % greater risk of death [75]. In these households the unrelated adult was identified as the perpetrator in 84 % of the cases and of these 74 % were reported to be the mother's boyfriend [16]. One study that investigated risk factors for maltreatment in 644 families found different risk patterns predicted the occurrence of physical, sexual abuse, and neglect. Maternal youth and sociopathy was a strong predictor in all types of abuse and the risk factor increased from 3 % with no risk factors present to 24 % if 4 or more risk factors were present [7]. Substance abuse showed the strongest association with both physical abuse and neglect, while depression was strongly associated with physical abuse [7]. Brown and colleagues determined that low maternal involvement, early separation from the mother, and perinatal problems, were risk factors for physical abuse, while poverty and large family size were strongly associated with neglect [7]. Social and demographic variables were shown to be of limited predictive value for child maltreatment, but substance abuse and depression were observed to be strongly associated with physical abuse and surprisingly OCD and antisocial behavior was ascertained to be associated with neglect [7]. Younger parents are slightly more likely to maltreat their children, but the mother's age is inversely related to severe maltreatment. A low level of education also plays a role, but it is only associated with fathers. Also, a larger number of children in the household will increase the chance of abuse as will poor familial support. On a global scale, low socioeconomic status was a good predictor of neglect, which is similar to national data. Boys were more commonly the victims of physical abuse, while girls were most often victims of infanticide, sexual abuse, prostitution, and educational and nutritional neglect [1].

Key points

1. Fatal maltreatment and neglect investigations are multidisciplinary in nature and require the orchestration of various agencies involved in the examination and investigation.
2. For medicolegal investigations of fatal maltreatment, thorough radiological assessment and examination with dissection is recommended for the proper documentation of any injuries. In addition, a family history and a caretaker account of the sustained injuries will allow the investigator to assess if the account of the injuries is in fact an adequate explanation for the injuries that are present.
3. For suspected fatal neglect due to nutritional deprivation, medical histories/evaluations (e.g., well-baby visits) to assess the level of wasting and stunting are recommended when possible. If the remains are skeletonized or decomposed a combination of skeletal, dental, and new modalities such as DXA scans can be utilized to assess malnutrition or starvation.
4. For any case involving the death of a child, careful scene documentation including overall living conditions, family and medical histories should be collected.

References

1. World Health Organization World Report on Violence and Health. Child abuse and neglect by parents and other caregivers. 2002. http://www.who.int/violence_injury_prevention/violence/global_campaign/en/chap3.pdf. 13 Dec 2013.
2. US Department of Health and Human Services, Administration for Children and Families, Administration on Children, Youth and Families, Children's Bureau. Child maltreatment 2011. 2012. http://www.acf.hhs.gov/programs/cb/research-data-technology/statistics-research/child-maltreatment. 31 Dec 2013.
3. United States Government Accountability Office. Child maltreatment: strengthening national data on child fatalities could aid

in prevention (GAO-11-599). 2011. http://www.gao.gov/new.items/d11599.pdf. 31 Dec 2013.
4. US Department of Health and Human Services Administration for Children and Families Administration on Children, Youth and Families Children's Bureau. Child abuse and neglect fatalities 2011: statistics and interventions. http://www.childwelfare.gov/pubs/factsheets/fatality.pdf. 31 Dec 2013.
5. Ross AH, Abel S, Radisch D. Pattern of injury in child fatalities resulting from child abuse. Forensic Sci Int. 2009;188:99–102.
6. Adamson P. Innocenti report card 11. UNICEF. http://www.unicef-irc.org/publications/pdf/rc11_eng.pdf. 3 Jan 2014.
7. Brown J, Cohen P, Johnson J, Salzinger S. A longitudinal analysis of risk factors for child maltreatment: findings of a 17-year prospective study of officially recorded and self-reported child abuse and neglect. Child Abuse Negl. 1998;22:1065–78.
8. McGee RA, Wolfe DA, Yuen SA, Wilson SK, Carnochan J. The measurement of maltreatment: a comparison of approaches. Child Abuse Negl. 1995;2:233–49.
9. Belsky J, Vondra J. Lessons from child abuse: the determinants of parenting. In: Cicchetti D, Carlson V, editors. Current research and theoretical advances in child maltreatment. Cambridge: University Press; 1989. p. 153–202.
10. Chadwick DL, Castillo EM, Kuelbs C, Cox SA, Lindsay SP. Missed and missing cases of abusive injuries: the magnitude and the measurement of the problem. Child Abuse Negl. 2010;34:943–50.
11. Flaherty EG. Does the wording of the mandate to report suspected child abuse serve as another barrier to child abuse reporting? Child Abuse Negl. 2006;30:341–3.
12. Ragan KL. Fatal child maltreatment: the challenges of identifying the causes and incidence of deaths from abuse and neglect. In: Ross AH, Abel S, editors. The juvenile skeleton in forensic abuse investigations. New York: Humana Press; 2011. p. 7–17.
13. Kempe CH, Silverman FN, Steele BF, Droegemueller W, Silver HK. The battered child syndrome. J Am Med Assoc. 1962;181:17–24.
14. Jason J, Andereck N. Fatal child abuse in Georgia: the epidemiology of severe physical child abuse. Child Abuse Negl. 1983;7:1–9.
15. Palusci V, Covington T. Child maltreatment deaths in the U.S. national child death review case reporting system. Child Abuse Neglect. 2013. doi:10.1016/j.chiabu.2013.08.014.
16. Damashek A, Nelson MM, Bonner BL. Fatal child maltreatment: characteristics of deaths from physical abuse versus neglect. Child Abuse Negl. 2013;37:735–44.
17. Asser S, Swan R. Child fatalities from religion-motivated medical neglect. Pediatrics. 1998;101:621–5.
18. Knight LD, Collins KA. A 25-year retrospective review of deaths due to pediatric neglect. Am J Forensic Med Pathol. 2005;26:221–8.
19. Palusci V, Wirtz S, Covington T. Using capture-recapture methods to better ascertain the incidence of fatal child maltreatment. Child Abuse Negl. 2010;34:396–402.
20. Ross AH. Fatal starvation/malnutrition: medicolegal investigation from the juvenile skeleton. In: Ross AH, Abel S, editors. The juvenile skeleton in forensic abuse investigations. New York: Humana Press; 2011. p. 151–65.
21. Ubelaker DH, Montaperto KM. Biomechanical and remodeling factors in the interpretation of fractures in juveniles. In: Ross AH, Abel S, editors. The juvenile skeleton in forensic abuse investigations. New York: Humana Press; 2011. p. 33–48.
22. Bilo RAC, Robben SGF, Van Rijn RR. General aspects of fractures in child abuse. In: Mattei P, editor. The fundamentals of pediatric surgery. New York: Springer; 2011. p. 1–13.
23. Cramer KE, Green NE. Child abuse. In: Green NE, Swiontkowski MF, editors. Skeletal trauma in children, vol. 3. 3rd ed. Philadelphia: Saunders; 2003. p. 587–605.
24. Kellogg ND. Evaluation of suspected child physical abuse. Pediatrics. 2007;119:1232–41.
25. Kemp AM, Dunstan F, Harrison S, Morris S, Mann M, Rolfe K, Datta S, Thomas DP, Sibert JR, Maguire S. Patterns of skeletal fractures in child abuse: systematic review. BMJ. 2008;337:1–8.
26. Falcone RA, Makoroff K. Child abuse. In: Mattei P, editor. The fundamentals of pediatric surgery. New York: Springer; 2011. p. 169–73.
27. Clarke NMP, Shelton FRM, Taylor CC, Khan T, Needhirajan S. Incidence of fractures in children under the age of 24 months in relation to non-accidental injury. Injury. 2012;43:762–5.
28. Gill DF. Identifying child abuse. Clin Rev. 2012;22:29–36.
29. King J, Diefendorf D, Apthorp J, Negrete VF, Carlson M. Analysis of 429 fractures in 189 battered children. J Pediatr Orthop. 1988;8:585–9.
30. Leventhal J, Thomas S, Rosenfield N, Markowitz R. Fractures in young children. Distinguishing child abuse from unintentional injuries. Am J Dis Child. 1993;147:87–92.
31. Rang M, Wenger D. Children are not just small adults. In: Rang M, Wenger D, Pring ME, editors. Rang's childrens fractures. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2005. p. 1–10.
32. Humphries AL. Basic juvenile skeletal anatomy and growth and development. In: Ross AH, Abel S, editors. The juvenile skeleton in forensic abuse investigations. New York: Humana Press; 2011. p. 19–31.
33. Galloway A. Broken bones: anthropological analysis of blunt force trauma. Springfield: C.C. Thomas; 1999.
34. Abel S. Non-accidental skeletal trauma. In: Ross AH, Abel S, editors. The juvenile skeleton in forensic abuse investigations. New York: Humana Press; 2011. p. 61–77.
35. Kleinman PK. Diagnostic imaging in infant abuse. Am J Roentgenol. 1990;155:703–12.
36. Carty H. Non-accidental injury: a review of the radiology. Eur Radiol. 1997;7:1365–76.
37. Maguire S, Cowley L, Mann M, Kemp A. What does the recent literature add to the identification and investigation of fractures in child abuse: an overview of review updates 2005–2013. Evidence-Based Child Health: A Cochrane Rev J. 2013;8:2044–57.
38. Harlan SR, Nixon GW, Campbell KA, Hansen K, Prince JS. Follow-up skeletal surveys for nonaccidental trauma: can a more limited survey be performed? Pediatr Radiol. 2009;39:962–8.
39. Karmazyn B, Lewis ME, Jennings SG, Hibbard RA, Hicks RA. The prevalence of uncommon fractures on skeletal surveys performed to evaluate for suspected abuse in 930 children: should practice guidelines change? Am J Roentgenol. 2011;197:w159–63.
40. Glencross B, Stuart-Macadam P. Childhood trauma in the archaeological record. Int J Osteoarchaol. 2000;10:198–209.
41. Swischuk L, Hernandez JA. Frequently missed fractures in children (value of comparative views). Emerg Radiol. 2004;11:22–8.
42. Caffey J. The whiplash shaken infant syndrome: manual shaking by the extremities with whiplash-induced intracranial and intraocular bleedings, linked with residual permanent brain damage and mental retardation. Pediatrics. 1974;54:395–403.
43. Lancon JA, Haines DE, Parent AD. Anatomy of the shaken baby syndrome. New Anat. 1998;253:13–8.
44. Hymel KP, Spivak BS. The biomechanics of physical injury. In: Reece RM, Ludwig S, editors. Child abuse: medical diagnosis and management. 2nd ed. Hagerstown, MD: Lippincott Williams and Wilkins; 2001. p. 1–22.
45. Gerber P, Coffman K. Nonaccidental head trauma in infants. Childs Nerv Syst. 2007;23:499–507.
46. Hymel KP, Makoroff KL, Laskey AL, Conaway MR, Blackman JA. Mechanisms, clinical presentations, injuries and outcomes from inflicted versus non-inflicted head trauma during infancy: results of a prospective multicentered, comparative study. Pediatrics. 2007;119:922–9.

47. Piteau SJ, Ward MGK, Barrowman NJ, Plint AC. Clinical and radiographic characteristics associated with abusive and non-abusive head trauma: a systematic review. Pediatrics. 2012;130:315–23.
48. Battered child syndrome: investigating child abuse and homicide. US Department of Justice. 2002. https://www.ncjrs.gov/pdffiles1/ojjdp/161406.pdf. 3 Jan 2014.
49. Piteau SJ, Ward MG, Barrowman NJ, Plint AC. Supreme court of the United States. 2007. http://www.supremecourt.gov/opinions/11pdf/10-1115.pdf. 3 Jan 2014.
50. Findley KA, Barnes PD, Moran DA, Squier W. Shaken baby syndrome, abusive head trauma, and actual innocence: getting it right. Hous J Health Law Policy. 2012;12:209–312.
51. Tuerkheimer D. The next innocence project: shaken baby syndrome and the criminal courts. Wash Univ Law Rev. 2009;87:1–58.
52. Moreno JA, Holmgren B. Dissent into confusion: the Supreme Court, denialism, and the false "scientific" controversy over shaken baby syndrome. Utah Law Rev. 2013;2013:153–217.
53. Hobbs CJ. Skull fracture and the diagnosis of abuse. Arch Dis Child. 1984;59:246–52.
54. Kleinman PK, Marks SC. A regional approach to the classic metaphyseal lesion in abused infants: the distal femur. Am J Roentgenol. 1998;170:43–7.
55. Dwek J. Radiographic approach to child abuse. Clin Orthop Relat Res. 2011;469:776–89.
56. American College of Radiology. ACR appropriateness criteria 2009. www.acr.org/Secondary-MainMenuCategones/quality_safety/app_criteria/pdf/ExpertPanelonPediatriclmaging/Suspected Physical-AbuseChildDoc9.aspx. 3 Jan 2014.
57. Pandya NK, Baldwin K, Wolfgruber H, Christian CW, Drummond DS, Hosalkar HS. Child abuse and orthopaedic injury patterns: analysis at a level 1 pediatric trauma center. J Pediatr Orthop. 2009;28:618–25.
58. Pandya NK, Baldwin K, Kamath AF, Wenger DR, Hosalkar HS. Unexplained fractures: child abuse or bone disease. A systematic review. Clin Orthop Relat Res. 2011;469:805–12.
59. Kleinman PK. Prevalence of the classic metaphyseal lesion in infants versus high risk for abuse. Am J Roentgenol. 2011;197:1005–8.
60. Haney SB, Boas SC, Kutz TJ, Starling SP. Transverse fracture of the distal femoral metadiaphysis: a plausible accidental mechanism. Pediatr Emerg Care. 2009;25:841–4.
61. Merten DF, Radkowski MA, Leonidas JC. The abused child: a radiological reappraisal. Radiology. 1983;146:377–81.
62. Hechter S, Huyer D, Manson D. Sternal fractures as a manifestation of abusive injury in children. Pediatr Radiol. 2002;32:902–6.
63. Barsness KA, Cha E, Bensard DD, Calkins CM, Patrick DA, Strain JD. The positive predictive value of rib fractures as an indicator of nonaccidental trauma in children. J Trauma. 2003;54:1107–10.
64. Kraft JK. Imaging of non-accidental injury. Orthop Trauma. 2012;25:109–18.
65. Mulpuri K, Sloboogean BL, Tredwell SJ. The epidemiology of nonaccidental trauma in children. Clin Orthop Relat Res. 2011;469:759–67.
66. Cadzow SP, Armstrong KL. Rib fractures in infants: red alert! J Paediatr Child Health. 2000;36:322–6.
67. Tun K, Choudhary AK, Methratta S, Boal DK. Radiological features of non-accidental injury. J Radiol Nurs. 2012;32:3–9.
68. Love JC, Derrick SM, Wiersema JM, Pinto DC, Greele C, Donaruma-Kwoh M, Bista B. Novel classification system of rib fractures observed in infants. J Forensic Sci. 2013;58:330–5.
69. Feldman K, Brewer D. Child abuse: cardiopulmonary resuscitation and rib fractures. Pediatrics. 1984;73:339–42.
70. Yang K, Lynch M, O'Donnell C. "Buckle" rib fracture: an artifact following cardiopulmonary resuscitation detected on postmortem CT. Leg Med. 2011;13:233–9.
71. Kleinman PK, Marks SC, Blackbourne B. The metaphyseal lesion in abused infants: a radiologic–histopathologic study. Am J Roentgenol. 1986;8:585–9.
72. Defilippi C, Santoro B, Pautasso P. Bony lesions from non-accidental trauma. In: Martino F, editor. Imaging of pediatric bone and joint trauma. Milan: Springer; 2011. p. 187–202.
73. Duffy SO, Squires J, Fromkin JB, Berger RP. Use of skeletal surveys to evaluate for physical abuse: analysis of 703 consecutive skeletal surveys. Pediatrics. 2011;127:e47–52.
74. Cardoso H, Magalhães T. Evidence of neglect from immature human skeletal remains: an auxological approach from teeth and bones. In: Ross AH, Abel S, editors. The juvenile skeleton in forensic abuse investigations. New York: Humana Press; 2011. p. 125–50.
75. Welch G, Bonner B. Fatal child neglect: characteristics, causation, and strategies for prevention. Child Abuse Negl. 2013;37:745–52.
76. Berkowitz CD. Fatal child neglect. Adv Pediatr. 2001;48:331–61.
77. Kellogg ND, Lukefahr JL. Criminally prosecuted cases of child starvation. Pediatrics. 2005;116:1309–16.
78. Collins KA. Intentional starvation/malnutrition and dehydration in children. In: Griest K, editor. Pediatric homicide. Medical investigation. Boca Raton: CRC Press; 2010. p. 169–85.
79. Mehta NM, Corkins MR, Lyman B, Malone A, Goday PS, Carney L, Monczka JL, Plogsted SW, Schwenk WF. Defining pediatric malnutrition: a paradigm shift toward etiology-related definitions. J Parent Enter Nutr. 2013;37:460–81.
80. Gomez F, Galvan RR, Cravioto J, Frenk S. Malnutrition in infancy and childhood with special reference to kwashiorkor. Adv Pediatr. 1955;7:131–69.
81. Waterlow JC. Classification and definition of protein-caloric malnutrition. Br Med J. 1972;2:566–9.
82. Madea B. Death as the result of starvation. Diagnostic criteria. In: Tsokos M, editor. Forensic pathology reviews, vol. 2. Totowa, NJ: Humana Press; 2005. p. 3–26.
83. Fleagle JG, Samonds KW, Hegsted DM. Physical growth of cebus monkeys, *Cebus albifrons*, during protein or caloric deficiency. Am J Clin Nutr. 1975;28:246–53.
84. Piercecchi-Marti MD, Louis-Borrione C, Bartoli C, Sanvoisin A, Panuel M, Pelissier-Alicot L, Leonetti G. Malnutrition, a rare form of child abuse: diagnostic criteria. J Forensic Sci. 2006;51:670–3.
85. Sawyer AJ, Bachrach LK. Rationale for bone densitometry in childhood and adolescence. In: Sawyer AJ, Bachrach LK, Fung EB, editors. Bone densitometry in growing patients. Guidelines for clinical practice. Totowa: Humana Press; 2007. p. 1–13.
86. Binkowitz LA, Henwood MJ. Pediatric DXA: technique and interpretation. Pediatr Radiol. 2007;37:21–31.
87. Crabtree NJ, Leonard MB, Zemel BS. Dual-energy X-ray absorptiometry. In: Sawyer AJ, Bachrach LK, Fung EB, editors. Bone densitometry in growing patients. Guidelines for clinical practice. Totowa: Humana Press; 2007. p. 41–57.
88. Ward KA, Mughal Z, Adams JE. Tools for measuring bone in children and adolescents. In: Sawyer AJ, Bachrach LK, Fung EB, editors. Bone densitometry in growing patients. Guidelines for clinical practice. Totowa: Humana Press; 2007. p. 15–40.
89. Yeste D, del Rio M, Carrascosa G. Densidad mineral ósea en lactantes y niños (0–4 años) a nivel de columna lumbar. Patrones de normalidad. Anales Españoles de. Pediatria. 1998;49:248–52.
90. del Rio L, Carrascosa F, Pons M, Yeste G, Domenech FM. Bone mineral density of the lumbar spine in white mediterranean Spanish children and adolescents: changes related to age, sex and puberty. Pediatr Res. 1994;35:362–6.

91. Alp H, Orbak Z, Kermen T, Uslu H. Bone mineral density in malnourished children without rachitic manifestations. Pediatr Int. 2006;48:128–31.

92. Schmitt BD. The child with nonaccidental trauma. In: Kempe CH, Heller RE, editors. The battered child. 4th ed. Chicago: University of Chicago Press; 1980. p. 128–46.