Fractures in physical child abuse

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Abstract
Fractures are regularly reported in young children who have suffered from physical abuse or neglect. Clinicians need to be aware of the epidemiology and the causes of fractures in children and have an understanding of the indicators that suggest that a fracture may have arisen from child abuse. They should be able to identify which children should be investigated to exclude child abuse and the optimal radiological investigation techniques that are currently recommended.

This review identifies some of the features that can be used to differentiate abusive fractures from the greater numbers of childhood fractures that are sustained from accidental trauma. Current investigation strategies and diagnostic dilemmas are discussed.

Keywords child abuse; fractures; radiology

Introduction
Fractures have been reported in up to one-third of children who have been investigated for physical abuse. They can result from intentional injury or arise from neglect when a child has not been adequately supervised or has been left in hazardous circumstances. Clinicians need to be aware of the epidemiology and the causes of fractures in children and have an understanding of the indicators that suggest that a fracture may have arisen from child abuse. They should be able to identify which children should be investigated to exclude child abuse and the optimal radiological investigation techniques that are currently recommended.

Differentiating abusive fractures from the greater numbers of childhood fractures that are sustained from un-witnessed accidental trauma can be challenging. A small number of children sustain fractures due to medical conditions that predispose to bone fragility – for example, osteogenesis imperfecta, osteopenia of prematurity and rarer metabolic disorders. These are generally diagnosed de novo in babies or infants.

Studies show that up to one-third of children will sustain a fracture before their 16th birthday. Accidental fractures are most common in school-age children and generally result from significant traumatic events such as falls or motor vehicle related incidents. These can be recalled in detail by older children who sustain the injury or by carers of younger children who have witnessed the event.

The epidemiology of abusive fractures
There is a strong inverse relationship between the age of the child and the prevalence of abusive fractures. Infants and toddlers are most prone to fractures in physical child abuse, in contrast to accidental fractures, which are most commonly seen in children over the age of 5 years.

Most abusive fractures present as occult injuries that are detected during an investigation for suspected child abuse or when a child has had an x-ray for other clinical reasons. Abusive fractures have been reported in every bone or group of bones within the skeletal system. They are characteristically multiple and may have been sustained over a period of time, in which case they show different stages of healing on radiological imaging. The type of fractures incurred will depend upon the force, the direction of strain and the type of insult that the child is exposed to.

Radiological investigations to identify occult fractures in children
Radiological techniques have advanced since Kempe first described the ‘battered baby’ who typically had multiple fractures identified on a ‘babygram’ – a single image of the whole baby on one x-ray. Current recommendations for a skeletal survey include a 19 image series of x-rays of the skeleton to give clear visualisation of each bone within the skeleton.

Studies show that the greatest yield of occult fractures is apparent in skeletal surveys performed on children under the age of 2 years old where physical abuse is suspected. Children with abusive thermal injuries have also been shown to sustain a significant number of skeletal injuries. It is, therefore, recommended that every child under the age of 2 years where physical child abuse is suspected should have skeletal imaging to exclude occult fractures. Older children should be assessed on an individual basis and skeletal surveys requested accordingly.

Acute fractures in babies can be difficult to visualise on plain x-ray films. This applies in particular to rib and metaphyseal fractures. The recognition of rib fractures is greatly improved when oblique views of the chest are added to the initial imaging sequence or when a radionuclide bone scan is performed. Metaphyseal fractures can be seen more easily on coned views of the affected joint. A repeat skeletal survey at 10–14 days after the initial radiological investigation will also add extra information about fractures. Once a fracture shows signs of healing it becomes more easily visualised on an x-ray. Repeat images may, therefore, help to identify additional fractures, clarify ambiguous findings or give further information regarding the age of a fracture.

Ageing fractures
Paediatricians and radiologist are often called upon to give evidence in child protection cases heard in the Family or Criminal Court. Expert witnesses are frequently asked to give their opinion about the age of a fracture. Fractures go through a recognised sequence of histopathological changes when healing. These give characteristic appearances on x-ray. The changes start with subperiosteal new bone formation and progress to loss of fracture.
line definition, soft and hard callus formation and finally bone remodelling. The healing process is a continuum and there is overlap in the time frames and intensity of these changes. It has been suggested that young children have faster bone healing times that older children and it is possible that different bones heal at different rates. This, however, has not been scientifically verified in the literature to date.13

Radiologists use their clinical experience to assess the healing stages of a fracture as seen on an x-ray. Charts to guide this assessment have been drawn up in text books and are widely used. However, there is little to validate their accuracy within the published literature and any work that has been done looks at the stages of healing in bones that have been immobilised as part of their treatment, which is clearly not the case when estimating the age of an occult fracture. Experienced radiologists are able to give broad estimates of the age of a fracture based on the radiological appearance and can confidently state that a fracture is old or recent, which is helpful in determining whether a child may have been injured on a number of occasions.13

Rib fractures
Rib fractures have the greatest positive predictive value for child abuse in infants or toddlers. In the absence of violent trauma, the probability of abuse in a young child who has rib fractures is 71% rising to 92% if pathological fractures are excluded.14 Abusive rib fractures are frequently multiple and may occur at any point along the rib, posterior rib fractures are commonly reported in abuse and anterior rib fractures have been associated with abusive intra-abdominal injury.15,16 Rib fractures have been reported after child birth of a large-for-dates baby,17 after physiotherapy18 and in osteopenia of prematurity. A recent review of the scientific literature showed that unlike adult rib fractures, they rarely occur after cardiopulmonary resuscitation when performed on a hard surface, either by trained medical personnel or lay persons.19 The incidence is estimated at 0.3%. When they do occur, the fractures are anterior and may be multiple. Studies that looked at this relied upon x-rays post-cardiopulmonary resuscitation; the children did not receive further follow-up films or oblique chest x-rays.

Long bone fractures
The most common femoral fracture is a mid-shaft fracture in both intentional and non-intentional injury6,20–23 with the exception of children under 15 months of age who are not yet walking where a spiral fracture of the femur is more commonly seen in physical abuse.24 This is strongly related to the developmental level of the child. It is difficult for a child who is not yet walking or pulling to stand to sustain a spiral fracture from a ‘simple’ accident. Once a child is walking, however, a spiral fracture of this nature can result from a fall that involves a twisting mechanism.

Spiral fractures to the shaft of the humerus are seen significantly more often in physical abuse than in non-abuse1,6,25,26 whilst supra-condylar humeral fractures,27 or greenstick fractures of the ulnar are most commonly sustained in an accidental fall onto the outstretched hand.

Tibial, radial and ulnar fractures are reported in abuse more commonly than after an accident in infants.1,6,28

Skull fractures
Skull fractures in infants are prevalent in both abuse and non-abuse. The profile of fracture types is similar for abuse and non-abuse and the most common fracture type from either cause is a linear fracture.1,6,29,30 It should be noted that significant intracranial injury can be seen in child abuse without evidence of a skull fracture where the presumed mechanism of injury is shaking.

Metaphyseal fractures
Metaphyseal fractures have been widely held as one of the strongest radiological indicators of physical abuse since Caffey’s description of the ‘battered baby’ in 1957. Metaphyseal fractures are reported as either corner or bucket-handle fractures, which is dependent upon the angle at which the x-ray film is taken. They are small fractures and difficult to visualise, especially in their acute phase when they can be confused with normal variants and, therefore, need careful investigation with serial x-rays and specialised radiological views of the area.

Metaphyseal fractures are more commonly reported in child abuse than non-abuse but published scientific evidence in this field is limited.6 Studies that compare radiological findings with post-mortem studies show that metaphyseal fractures are under-diagnosed radiologically.31–34 These fractures are classically found in infants and toddlers and they occur most commonly in the femur and tibia. Metaphyseal fractures, however, are not exclusive to child abuse, they have also been reported in positional talipes correction, physiotherapy and following child birth.35–37

Fractures of the axial skeleton
Fracture dislocation of vertebrae and compression injury of the vertebral bodies have also been reported in child abuse.38–40 These injuries occur with and without injury to the spinal cord. Because of the risk of long-term kyphoscoliosis41,42 and neurological morbidity, the skeletal survey should be carefully examined to exclude these fractures. Magnetic resonance imaging, to exclude spinal cord injury, is recommended whenever a spinal fracture is suspected. A number of case reports involved children with co-existing non-accidental head injury and one case report included a child who sustained a compression fracture when the perpetrator admitted slamming the child onto a hard surface in a seated position.

Pelvic fractures have been reported in association with child sexual abuse.43,44 Care is needed when visualising the pubic rami especially when gonads are shielded.

In contrast to most other abusive fractures, mandibular fractures are seen in older children from blows to the jaw.45 A 6-month-old infant is described with bilateral fractured mandible and multiple tiny fractures around the teeth sockets where the father admitted a direct blow to her lower jaw.46

Recommended investigation strategy
Fractures need to be excluded in any infant toddler or baby where physical child abuse is suspected or where a pattern of
fractures suggests abuse. The child needs a detailed assessment and investigation and a thorough exclusion of non-intentional or pathological causes for bony injury.47 This should be undertaken as part of a thorough general assessment of the child. Table 1 outlines priority areas that should be addressed in the context of bony injury.

Table 1

Priority areas that should be addressed in the context of bony injury

Which children should be investigated for occult fractures?
- All children under the age of 2 years where physical abuse is suspected
- All children where an occult fracture has been identified during the course of clinical assessment
- Any child whatever the age where an abusive bony injury is suspected

What investigation should be performed?
- Skeletal survey according to BPSR guidelines
  N.B. Skeletal survey should include oblique views of the ribs
- Radio-nuclide scan or repeat skeletal imaging 10–14 days after the first investigation will help to identify further fractures, clarify ambiguous findings and help with decisions about the age of a fracture within a broad timeframe
- Neuro-imaging (CT/MRI) should be considered as part of skeletal survey in any child under 1 year to exclude intracerebral injury

What historical information is needed about the fracture?
- Explanation of how the fracture was sustained
  - Is explanation consistent with the pattern of injury seen?
  - All children where physical abuse is suspected
  - Radio-nuclide scan or repeat skeletal imaging 10–14 days after the first investigation will help to identify further fractures, clarify ambiguous findings and help with decisions about the age of a fracture within a broad timeframe
  - Neuro-imaging (CT/MRI) should be considered as part of skeletal survey in any child under 1 year to exclude intracerebral injury

What information is needed from the examination?
- What is the full extent of bony injury?
- Are there any other associated injuries?
- Are there any clinical features of a medical condition that causes bone fragility?
- A thorough general examination to include (eye and ophthalmological assessment of retina

Supplementary questions to highlight risk factors for pathological bone disease
- Any bone disease within the family?
- Any deafness or hearing problems?
- Past history of fractures in the child or relatives?
- History of prematurity?

Indicators of abusive fractures that warrant further investigation
- Multiple fractures
- Fractures at different stages of healing
- Occult fractures
- Fractures in pre-mobile infants, especially spiral fractures of long bones
- Rib fractures
- Metaphyseal fractures

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