



VIEWPOINT

Suspicious childhood injury: Formulation of forensic opinion

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Abstract: Child protection paediatricians have a role as forensic experts in the context of suspicious childhood injury. The task of forensic evaluation of suspicious injury is to reach a conclusion to support legal proceedings. For each injury, one of four conclusions should be reached:

- 1 The injury has been caused by another person and is considered to have been inflicted.
- 2 The injury is adequately explained by the circumstances of the injury event provided (by the carer or other witnesses).
- 3 The injury is self-inflicted – has been caused by the child's own behaviour as a result of normal childhood activity (with no other person actively involved).
- 4 The mechanism or sequence of events leading to the injury remains indeterminate or unclear.

An additional consideration is determining the extent to which an injury incident was foreseeable and therefore preventable, to form an opinion on whether lack of care (neglect) is involved. Opinions reflect a body of knowledge in forensic and medical literature of known mechanisms of injury including biomechanical aspects of tissue injury in trauma scenarios. Limitations in using research documenting injury type and prevalence at different developmental stages is discussed and in particular, the application of such research to support a conclusion that the injury must have been inflicted. Emerging recognition of research documenting injuries that overlap with those found in populations of children thought to have been physically assaulted creates some doubt on previous opinions regarding exclusivity of certain findings in children definitively indicating 'abuse'. Forensic paediatricians should remain objective, limit their opinions to what can be confidently stated and exercise caution where reasonable doubt exists and avoid speculation.

Key words: injury; forensic; medico-legal; opinion; abuse; inflicted.

Paediatricians working in the field of child protection are required to provide forensic opinions about injuries in children where there is some suspicion that they may have been caused by physical assault or abuse (when inflicted by a parent or carer).^{1,2} The opinion may assist police to pursue criminal charges and/or the state statutory child protection agency in their assessment of whether or not the child is in need of protection. While much of the medical literature states that certain injuries can be attributed to assault or abuse, for example cutaneous injury in soft tissues not overlying bones or a spiral fracture of the femur in 3-month-old, in reality, the literature is justifying why some injuries in particular body regions in children at specific developmental levels should raise

Key Points

- 1 Paediatricians working in child protection are required to undertake a medico-legal function in the evaluation of suspicious childhood injury.
- 2 Forensic opinions must remain objective.
- 3 Injuries always reflect the nature and severity of traumatic forces rather than precisely the circumstances of the injury.

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suspicion that the subject child has been physically assaulted or abused. Application of such research to support definitive forensic opinion is often problematic.

This discussion focuses on the assessment and opinion formulation of those injuries that have already been identified as suspicious and as a consequence require a more comprehensive forensic assessment. In infants and young children, a forensic medical opinion depends on injury documented on examination and then considered in the context of the explanation provided by care givers. Traditionally, when an explanation is, in the view of the medical person, inadequate to account for the injury, then, the opinion will most likely be that the injury has resulted from 'abuse' (caused by a parent or carer).

Typical injuries in infants and young children requiring forensic evaluation include soft tissue injury such as bruising, fractures and head injuries. Also, across the developmental age range, forensic opinion on genital injury is commonly requested.

The task of forensic evaluation of suspicious injury is to reach a conclusion in relation to the injury, specifically whether or not the injury is considered to have been inflicted. To this end, for each injury or injury cluster, one of four conclusions should be reached:

- 1 The injury has been caused by another person and is considered to have been inflicted.
- 2 The injury is adequately explained by the circumstances of the injury event provided (by the carer or other witness).

- 3 The injury is self-inflicted – has been caused by the child's own behaviour as a result of normal childhood activity (with no other person actively involved).
- 4 The mechanism or sequence of events leading to the injury remains indeterminate or unclear.

Currently, in both the literature and in written opinions, injury that is concluded to have resulted from (2) and (3) above tends to be referred to as 'accidental'. This is regarded as equivalent to saying that the injury has not resulted from 'abuse'. Medical evidence cannot formulate an opinion on intent of actions of other persons. This is the focus of a police investigation with a judicial officer as the final arbiter. An important additional consideration that must be made when assessing suspicious injuries in infants and children is to what extent the injury incident should have been foreseeable by the parent or carer and therefore preventable. Lack of adequate care or supervision (neglect) might be the predominant opinion in these situations. Occasionally, a finding that is regarded by others as a 'suspicious injury' is incorrect. For example, a Mongolian blue spot may be mistaken for a bruise or lichen sclerosis of the anogenital area considered to be an injury due to sexual molestation.

For each category of injury (such as bruise, fracture, thermal) there exists a variable level of knowledge in the forensic and general medical literature of mechanisms of causation. For example, much is known about the biomechanical aspects of tissue injury, which refers to the tissue response to the range of forces associated with various types of injurious events.^{3,4} This information assists the forensic paediatrician in the identification of patterns of injury that are known to have resulted from physical assault as opposed to those that occur in the normal daily activities of children at various developmental stages.⁵⁻⁷

In many cases, a forensic opinion cannot categorically state the precise cause of a suspicious injury. Sometimes, however, categorical opinions, including how an injury was caused and whether or not it was inflicted by another person, are possible. The particular patterned bruising that results from multiple impacts from a broom handle and the distinctive pattern of slap marks to a child's face are two such examples where categorical opinion about inflicted injury is possible from the appearance of the injury.

With most injury, however, while the appearance or nature of the injury might indicate the biomechanics involved in its production, for example, an external injury resulted from blunt trauma or a spiral long bone fracture was caused by torsional forces, the appearance of the injury does not allow a more specific conclusion regarding causative circumstances to be drawn. In such situations, it has become common for child protection/forensic paediatricians to refer to research studies which have documented a biomechanically similar or equivalent injury type and its prevalence at different developmental stages of a child and then formulate an opinion as to whether or not the suspicious injury that has been assessed has been inflicted.⁸ For example, some may provide an opinion based on research indicating that in a population of 12-month-old infants a facial bruise is rare, to conclude that an unexplained bruise on the face of a 12-month-old infant must have been inflicted.⁹ Such opinion formulation is not well based and is further discussed below.

Cutaneous Injury

The most frequent suspicious injury identified and evaluated in children is bruising. A bruise is defined as a haemorrhage beneath or within the skin.¹⁰ Bruises are caused by trauma, most commonly blunt impact, but also by excessive pressure from restraint, occasionally suction trauma (most often seen in sexual assault) or biting.¹⁰ If a bruise is patterned, it can be stated that it has been caused by forceful impact applied at or near a right angle to the skin surface by a patterned object (for example a belt buckle).¹⁰ A flexible cord or round stick will cause linear tram-track bruising with two parallel lines in close proximity. In this scenario, the bruising has resulted from small blood vessel disruption along the edges of the impacting object, with sparing in the centre. A patterned bruise can also arise if a blow is delivered through overlying clothing or material that is patterned.¹⁰

Most bruises found in children are not patterned and are often ill-defined.⁸ The opinion therefore is limited to what can be stated about the likely mechanism. In infants, sometimes clusters of small discoid bruises in close proximity to each other are seen. While such bruises are suggestive of significant fingertip pressure from forceful gripping or squeezing, such a causative opinion is rarely able to be definitive. The location and prevalence of bruising occurring as a result of normal activities, self-inflicted bruising, has been documented in the medical literature for infants over their developmental range.⁸ This population-based data reliably forms the basis for the identification of suspicious bruising in infants but its value is not as straightforward when individual infants and young children are assessed in regard to whether or not a suspicious bruise has been inflicted. Other factors, including the explanation provided, a police evaluation, witness accounts must be sought and taken into consideration. It is important that the formulation of a forensic medical opinion is not influenced by the presence of adverse psychosocial circumstances and risk factors for abuse. Such considerations must be made in the overall management of child protection cases but not in the forensic medical opinion. Similarly, prior child protection history should be excluded from opinion formulation related to currently present injury.

Fractures

There is a body of knowledge on fractures in children that purportedly identifies features to assist the forensic paediatrician in determining whether a fracture is likely to have been inflicted as opposed to having occurred 'accidentally'. This research includes population studies of childhood injuries, case series and studies comparing characteristics of 'accidental versus substantiated cases of abuse'.^{5,6,11}

The studies, however, fail to be clear in relation to how the conclusion has been drawn that a fracture has either resulted from an 'accident' or resulted from 'abuse'. What is well understood however is the biomechanical forces involved in fracture causation, which can be summarised as follows:

- 1 Levering, bending or direct impact forces to long bones cause greenstick, horizontal and oblique fractures of long bones.
- 2 Torsional forces cause spiral fractures of long bones.

- 3 Chest encirclement and chest compression cause posterior (paravertebral) rib fractures, between the head and tubercle of the rib.¹²
- 4 Torsional and traction forces (pulling and twisting actions) cause distal metaphyseal fractures at the end of long bones (adjacent to the growth plate) in infants.¹³ The term classic metaphyseal fracture was used by Kleinman to describe these fractures that histologically occur through the primary spongiosa in the subepiphyseal region of the metaphysis.¹⁴
- 5 Direct blows or impact (the head hitting a firm to hard surface) causing skull fractures.

Rib fractures that are not found in the posterior location (such as anterior and lateral) can be caused by other mechanisms including direct blow or impact to the chest wall.¹⁵ Anterior and lateral rib fractures can occur in conjunction with paravertebral rib fractures, the fractures resulting from chest encirclement and chest compression. It is considered that chest compressions performed as part of cardiopulmonary resuscitation with an infant lying flat on his back will not cause paravertebral rib fractures because the spine is fixed on a flat surface and the backward levering of the posterior parts of the ribs is minimal compared with what occurs when the child is held suspended around the ribs and then experiences chest encirclement and compression.¹²

There are some features of skull fractures that indicate the level of force involved in the injury event. The location of the fracture is not helpful in evaluating an individual case. Children who injury themselves through developmental activities or are dropped by care givers from short distances (less than 1.5 metres) experience relatively low impact forces. They do occasionally sustain skull fractures that are most often simple linear parietal fractures, not depressed and not crossing suture lines. Depressed, stellate or diastatic fractures (a fracture line with greater than usual separation of the bony fragments) suggest greater forces were involved than what is derived from a short distance fall; however, each individual circumstance needs to be carefully and objectively considered.

Head Injury

The most complicated and contentious injuries found in the field of child protection are head injuries.^{16–18} The most common indication of head injury in young infants that requires forensic evaluation is a subdural haemorrhage. The brain is more susceptible to acceleration/deceleration (rotational) forces than translational (linear) forces. Acceleration/deceleration forces are generated from violent movement of the head on the neck. Such forces can be generated from flexion/extension of the neck as a consequence of head impact or from free, violent movement of the head on the neck as would occur with uncontrolled shaking.¹⁶ The issue of whether shaking alone can cause intracranial injuries (including subdural haemorrhages) remains contentious.^{19,20}

Traumatic subdural haemorrhages result from direct impact to the skull and acceleration/deceleration forces. Direct impact subdural haematomas accumulate under the impact or fracture site. They are usually small and may be associated with subarachnoid haemorrhage or adjacent brain contusion. Subdural haemorrhage from primarily acceleration–deceleration forces is

usually thin and film-like, being found over one or both cerebral hemispheres. They may extend into the posterior and sometimes the anterior inter-hemispheric fissure (the space between the two cerebral hemispheres). Subdural bleeding is considered to be the result of the stretching and then tearing of the bridging veins that traverse between the surface of the brain and the intra-dural sinuses. The stretching and tearing is the result of the differential movement between the dura and the brain when the head is subjected to high angular acceleration/deceleration forces.²¹ Other sources of subdural blood are considered possible (for example the intradural sinuses), but their contribution is not clear.^{22,23}

Another indicator of high acceleration/deceleration forces is the presence of primary, traumatic diffuse axonal injury (DAI). This abnormality may be seen on magnetic resonance (MR) imaging, specifically the diffusion weighted images and the Apparent Diffusion Coefficient map, and occurs because of, or secondary to, shearing forces.²⁴ Definitively, traumatic DAI is a histopathological diagnosis and its presence is not able to be stated categorically solely from neuro-radiological examinations. Importantly, it is not possible using imaging techniques to differentiate between the primary injury to the brain from angular acceleration forces and secondary changes derived from hypoxic ischaemic and vascular occlusive changes.²⁵

Retinal haemorrhages are seen in infants in conjunction with intracranial injuries such as subdural haemorrhages.²⁶ It is considered that children who have subdural haemorrhages and retinal haemorrhages have suffered acceleration/deceleration forces to their heads. The presence of retinal haemorrhage indicates the type of forces (acceleration/deceleration) and their magnitude rather than whether or not the genesis of the head injury has been a physical assault.^{27,28} Retinal haemorrhages associated with lower acceleration/deceleration forces tend to be limited to fewer retinal layers and to the posterior pole of the globe. Higher acceleration/deceleration forces result in more extensive retinal haemorrhage, both in terms of the number of retinal layers involved and how far towards the ora serrata the haemorrhages extend. The exact mechanism of retinal haemorrhages remains disputed.^{29,30}

Timing of these types of head injuries is challenging and usually imprecise.^{31,32} It is usually based on the appearance of intracranial and intracerebral blood as it degrades. However, the timing of radiological changes reflecting blood product degradation is not precise and variable. The possibility of unrecognised earlier trauma such as previous unreported head injury or at the time of or prior to delivery can complicate cases where intracranial abnormalities are only found by forensic medical evaluation.^{33,34} Computed tomography of the brain is able to distinguish between recent and older subdural haematomas.²⁵ MR imaging is able to provide an estimate of the age of an older subdural haematoma according to the degree of degradation of the haemoglobin within the haemorrhage.²⁵ Serial MR scans are often necessary to improve the accuracy of age estimation of subdural haematomas.

Genital Injury

Forensic paediatricians are frequently asked, 'Has this child has been sexually assaulted?' The opinion in such a context (an

allegation of historical sexual assault) cannot conclude that sexual assault occurred but may be able to provide some information that is relevant to broader legal issues. Medical evidence is based on the identification of injuries to the anogenital region, interpreted from a biomechanical perspective. Determining whether sexual assault has or is likely to have occurred rests with investigating police officers.

Establishing the presence of a genital injury by a forensic paediatrician may be useful as corroboration of other evidence gathered by the police, particularly the child's statement. The presence of an injury (genital or otherwise) makes complaints of sexual assault more likely to be prosecuted than when no injury is identified, independent of the child's allegations.³⁵ Most physical examinations of the genital area in children who have alleged some form of sexual molestation are normal with no signs of injury being found.^{36,37} The likelihood that physical signs of recent or older injury will be present depends on factors such as the age of the child, the nature of the alleged assault (injury is more likely with penetration of the genitals/anus), the frequency of the assaults and time lapsed until medical examination is undertaken as minor injury will heal quickly. An explanation for the lack of physical findings frequently needs to be made to counsel, judicial officers and juries during the provision of expert evidence.

In cases when penetration occurs inside the labia in the vestibule, the hymen will not show evidence of penetrating trauma and the only injury to the hymen might be signs of bruising or abrasion on its external surface. Alternatively, abrasions or friability may be seen inside the labia minora (in the vestibule) or at the posterior forchette reflecting frictional trauma or bruising may be evident in the vulval region derived from compressive forces. The most common positive sign of blunt penetrating sexual trauma is a transection of the hymen in the posterior location.³⁸ When such hymenal injury is seen, the medical examiner is able to state that it has been caused by blunt penetrating trauma but cannot say what exactly the penetrating object was. For example, a finger, penis, pencil or another object can all equally cause such an injury. The presence of additional genital injuries and evidence of tissue healing provides some information that is useful in providing an opinion as to whether the injury has been caused as reported by the complainant or whether credible alternative explanations need to be actively considered. It is important to recognise that sexual assault is not the sole cause of blunt penetrating injury to hymens in young children. Case reports exist where hymenal injuries have occurred in scenarios involving female children self-inflicting blunt penetrating injury by falling onto a protuberant object in the bath (author's experience).

Expressing Expert Opinion

Terminology is important in communicating a forensic opinion and its limitations. It is best to avoid the term 'consistent with' if the precise cause or mechanism is known. The term 'consistent with' provides a way of communicating whether the injury could be caused as has been alleged but also implies that alternative explanations may equally account for the findings. To enable forensic opinions to be clearly understood, it is more appropriate to state the injury could be accounted for as alleged

but also provide further comment in relation to other alternative explanations that may also need to be considered. Weighting each of the various possible causes, using terms such as 'unlikely' or 'most probably' is a useful way to communicate the opinion, both in the forensic report and also as evidence in court. If categorical statements are able to be made regarding injury mechanisms, such statements should be preferentially used.

In conclusion, in cases where children are evaluated because of suspicious injury, in only a small number will it be possible to conclude the exact cause of the trauma. When the biomechanics of an injury is known, this informs the forensic paediatrician of the trauma mechanism. However, this information will not be available with the majority of injuries and, therefore, the forensic opinion regarding cause must remain open to the range of credible possibilities. If an opinion regarding injury causation is based on the limited research documenting population-based injury prevalence and pattern, this must be clearly stated in the opinion. Such opinions should be supported by the lack of a tenable explanation in an infant or child not developmentally capable of causing the injury to themselves through normal activity. As research proceeds with the documentation of incidents of trauma in children that have been independently witnessed and have not involved other persons, there is an increasing realisation of the overlap between these injuries and those identified in populations of children in whom physical assault has been suspected. Therefore, doubt has justifiably been cast on the previously stated pathognomonic link between some injuries or injury patterns and 'abuse'. For example, so-called 'classical metaphyseal fractures' have been identified in children who have not been abused,³⁹ posterior rib fractures have occurred in situations other than physical assault¹² and patterns of head injury previously thought to have been always inflicted have been found in children secondary to high force falls.^{25,40}

Injuries always reflect the nature and severity of traumatic forces rather than precisely the circumstances of the injury. It is important to state that the physical characteristics of injuries do not allow determination of the intent of the actions of other persons who may have been involved. It is imperative that forensic paediatricians remain objective, limit their opinions to what can be confidently stated and exercise caution where reasonable doubt exists, avoiding speculation.^{41,42} Given that at the time of writing a medico-legal opinion it is not known which legal jurisdiction may use the opinion, it should always be expressed objectively and be constructed for high-level criminal jurisdiction trials.

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