Pediatric Radiology (2021) 51:861–865
https://doi.org/10.1007/s00247-020-04915-7

CHILD ABUSE IMAGING

What's in a name? Sentinel injuries in abused infants

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Received: 1 June 2020 / Revised: 28 August 2020 / Accepted: 12 November 2020 / Published online: 12 May 2021

Abstract
Infants are at greatest risk of severe and fatal physical abuse yet they sometimes present for medical care multiple times with abusive injuries prior to being diagnosed with abuse and having protective actions taken. Efforts to identify these infants in a timely manner are critical to prevent repeated, escalating abuse and subsequent harm. Increasing the identification and evaluation of sentinel injuries has been highlighted as a strategy for improving timely detection of abuse in infants. Sentinel injuries are visible, minor, poorly explained injuries in young infants that raise concern for abuse. These injuries include cutaneous injuries such as bruising, subconjunctival hemorrhages and intra-oral injuries. Sentinel injuries can signal concurrent clinically occult but more serious injuries or precede more significant trauma from abuse. As such, sentinel injuries offer an opportunity to intervene and protect infants from further harm. A thorough physical exam is critical for detecting sentinel injuries. Imaging with skeletal survey and, when appropriate, neuroimaging are key components of the medical evaluation of sentinel injuries in these high-risk infants.

Keywords Bruising · Child abuse · Children · Infant · Radiography · Sentinel injuries · Skeletal survey

Introduction

Infants carry the highest risk of maltreatment, including fatal maltreatment [1]. Delays in diagnosis can contribute to the high morbidity and mortality associated with abuse in infants. Infants sometimes present to care multiple times prior to abuse recognition and initiation of child protection efforts, putting the child at risk of repeated injury [2–4]. Approximately 25–31% of victims of abusive head trauma are missed on initial presentation to medical care, more than 25% suffer reinjury, and 41% suffer medical complications as sequelae of missed abuse [3, 4]. Efforts to identify physical abuse early and protect this vulnerable population from further injury are essential. Identification and prompt thorough evaluation of sentinel injuries has been identified as a strategy for increasing early detection of abuse in infants. Sentinel injuries are minor detectable and poorly explained injuries that can alert a clinician to physical abuse. Consider the following illustrative cases, which are informed by actual cases but whose details have been changed to maintain anonymity.

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Illustrative cases

Joey was 1 month of age when he presented to medical care with an upper respiratory infection. During his care, an unexplained truncal bruise was noted. No history of trauma was provided. A report was filed to child protective services out of concern for abuse, but Joey remained in his home with his parents. Imaging and laboratory screening evaluation for

additional injuries was negative at the time of initial presentation, and a follow-up skeletal survey obtained 2 weeks later was also negative. Two months later, Joey presented with seizures and was diagnosed with neurologically devastating injuries from abusive head trauma.

Jane was 2 months of age when she presented with a torn frenulum. A skeletal survey was obtained at presentation and revealed multiple rib fractures. A report was filed to child protective services out of concern for abuse.

Defining sentinel injuries

The "canary in the coal mine" is an expression used to describe an early sign of a poor outcome. Until well into the 1900s, miners would descend into the dangerous coal mines with canaries. As a "sentinel species," canaries are more sensitive to carbon monoxide exposure than humans. If a canary became symptomatic, miners were warned of a potential toxic exposure and could escape to safety [5].

The term "sentinel" in "sentinel injury" is similar to its use in "sentinel species" in that it is intended to signify an alert or warning. Sentinel injuries have been defined as "a visible or detectable minor injury in a pre-cruising infant that is poorly explained and therefore suspicious for physical abuse" [6]. Others have included injuries in infants younger than 12 months of age who are cruising but who have implausible explanations [7]. These injuries can also alert providers to additional concurrent clinically occult abusive injuries or herald more severe abuse in the future. In the illustrative cases here, the initial bruise and the torn frenulum would be considered sentinel injuries. In the first case, the identification of poorly explained bruising in a non-ambulatory infant was an early warning sign of the more severe abuse that followed. In the second case, the torn frenulum was the only visible sign of trauma, but further evaluation identified additional more serious injuries.

Types of sentinel injuries

Sentinel injuries can come in different forms. These include but are not limited to: cutaneous injuries such a bruising [8–14], subconjunctival hemorrhages [15] and intra-oral injuries [16].

Bruising and other cutaneous injuries

Minor cutaneous injuries that can alert physicians to physical abuse include bruises, abrasions and, potentially, minor burns that are poorly explained. Bruising is the most commonly identified type of sentinel injury [7].

Bruising is rare in pre-cruising infants. Studies in the outpatient and emergency settings have highlighted that ≤2% of infants 0–8 months of age have bruising [12, 14, 17]. In a study of children presenting to well-child visits, only 2.2% of pre-cruising infants had bruising, compared to 17.8% and 51.9% of cruising and walking infants, respectively [14].

Infants presenting with bruising are at risk for concurrent injuries including fractures and traumatic brain injuries that might not be apparent on physical examination. Infants <6 months of age with bruising are at particularly high risk of having concurrent injuries identified on skeletal survey or neuroimaging. In a study of infants <6 months who presented with apparently isolated bruising and were referred for evaluation by a subspecialty child protection team, half of the infants had additional serious injuries identified on skeletal survey or neuroimaging [10]. Among those infants in the study who underwent skeletal surveys, the imaging revealed new injuries (i.e. not found on a prior study or physical exam) in 24.8% (34/137) [10]. Among infants in the study who underwent neuroimaging, new injuries were identified in 30.1% (40/133) [10]. A separate study not limited to the subset of infants referred to a child protection team similarly found that approximately 1 in 5 skeletal surveys in infants <6 months presenting with bruising identified an occult fracture [18]. When the denominator was conservatively expanded to include those infants who did not undergo skeletal surveys, approximately 1 in 10 infants <6 months presenting with bruising had an occult fracture identified [18].

Notably, infants with bruising might not present with traumatic complaints. A prospective study of infants with bruising identified in emergency departments noted that 90% had medical chief complaints, with only 8% presenting with a chief complaint related to trauma [12]. Thorough skin examinations of all infants regardless of chief complaint are warranted to ensure detection and appropriate evaluation of these subtle findings.

Subconjunctival hemorrhages

Subconjunctival hemorrhages have been reported in abused infants and children. Abuse should be considered as a potential etiology of non-birth-related subconjunctival hemorrhages in infants [15, 19]. The precise risk of abuse and yield of skeletal survey and neuroimaging among well-appearing infants presenting with an isolated subconjunctival hemorrhage on physical examination are not known.

The differential diagnosis for subconjunctival hemorrhages reported in the literature includes trauma, Valsalva and vomiting, infection including pertussis, as well as oncologic and hematologic causes [15]. Traumatic etiologies include blunt trauma and asphyxia such as with thoracic compression,

as well as birth trauma. Although vomiting has been reported as a cause of subconjunctival hemorrhages in older children and adults, it has been suggested that infants are not able to generate enough force from Valsalva to cause subconjunctival hemorrhages [15]. A study of 100 infants with vomiting secondary to hypertrophic pyloric stenosis identified subconjunctival hemorrhages in only 2% [20]. Similarly, while subconjunctival hemorrhages have been described in children and adults following paroxysmal coughing such as from pertussis, the prevalence of subconjunctival hemorrhages specifically in infants with paroxysmal coughing has not been reported. Thus when presented with an infant with subconjunctival hemorrhages, inquiring about vomiting and coughing as part of a thorough history is reasonable; however, an evaluation for abuse remains warranted.

Current literature on subconjunctival hemorrhages and risk of abuse is largely limited to case series. Many children in these reported cases had bruising in addition to subconjunctival hemorrhages. In 2005, Spitzer and colleagues [19] described three abused infants who presented with subconjunctival hemorrhages, two of whom had concurrent bruising. In 2013, DeRidder and colleagues [15] described 14 abused children, 9 of whom were <1 year of age, with subconjunctival hemorrhage who underwent child protection team evaluations. Among these children, the majority (11/14) had concurrent bruising. Interestingly, a study of unexplained bruising in 48 infants <6 months identified subconjunctival hemorrhages in 14.6% (7/48) of the infants and in 26.9% (7/26) of the subset of these infants subsequently diagnosed with abuse [9]. While limited to small numbers, the presence of concurrent bruising and subconjunctival hemorrhages in multiple infants highlights trauma as an important cause of subconjunctival hemorrhages in infancy.

The prevalence of abuse among young children with subconjunctival hemorrhages has been estimated using the Pediatric Health Information System (PHIS), but these results should be interpreted within the context of the limitations of the data source. PHIS is an administrative database of children's hospitals that includes billing data associated with emergency department, observational or inpatient stays. Because diagnosis codes are compiled at the end of a clinical encounter, investigators cannot discern presenting injuries. A study using PHIS identified 1,600 children <24 months of age (median age 7 months) with a diagnosis code for subconjunctival hemorrhages [21]. Of these, 14.3% underwent skeletal survey and 19.7% underwent neuroimaging. While the imaging findings cannot be reported from this database, ultimately 8.6% received a diagnosis code for abuse. Because some of the infants in the study could have presented with multiple obvious injuries in addition to the subconjunctival hemorrhages, it is difficult to generalize these results to an infant with an incidentally identified subconjunctival hemorrhages on physical exam. In addition, the sensitivity of billing codes for identifying children who could have had subconjunctival hemorrhage documented in the medical record on physical exam is not known. Some children with subconjunctival hemorrhage might therefore not have been captured with this search strategy. Larger studies are warranted to understand the yield of skeletal surveys and neuroimaging among infants presenting with isolated subconjunctival hemorrhage on physical exam.

Frena tears and other intra-oral injuries

Oral injuries have also been reported as sentinel injuries in infants later diagnosed with more serious abusive injuries. Among infants hospitalized with injuries and diagnosed with abuse, caregivers reported prior intra-oral injuries in 3% [7]. Oral injuries described in abused children include trauma to the lips, oral mucosa, gingiva and tongue [22].

Of specific concern in infants, particularly pre-mobile infants, is frena tears which can be caused by forceful insertion of objects into an infant's mouth or blunt trauma to the face. Frena tears can be easily missed, and a thorough oral examination is warranted for identification. Frena injuries in young infants warrant consideration and evaluation for abuse with consideration of the plausibility of the history provided and developmental abilities of the infant. Thackeray [23] reported three cases of infants who initially presented with frena tears and subsequently presented with severe abusive head trauma. The precise prevalence of abuse among infants presenting with isolated frena tears is not known. A 2007 systematic review highlighted a paucity of evidence specifically regarding isolated torn labial frena and abuse [16]. A more recent study using PHIS data reported that among infants <6 months with hospital-based encounters and a diagnosis of oropharyngeal injuries, 17.0% were diagnosed as abused [21]. Whether the infants in this study presented with isolated oropharyngeal injuries or numerous injuries and traumatic symptoms is not known.

Prevalence of sentinel injuries in abused vs. non-abused infants

Sentinel injuries are more commonly reported as prior injuries in infants diagnosed with abuse compared to non-abused infants. A 2013 study of hospitalized injured infants compared the prevalence of a prior sentinel injury among children diagnosed with abuse and infants not diagnosed with abuse. Among 200 infants diagnosed with abuse, 27.5% had a prior sentinel injury [7]. Most sentinel injuries (71%) in abused infants occurred in children younger than 3 months [7]. The majority of sentinel injures (80%) in abused infants were bruises. Eleven percent were intra-oral injuries. None of the

101 infants in the non-abused control group had prior sentinel injuries. A reported history of a sentinel injury could therefore elevate the clinical concern for abuse. When evaluating for abuse, clinicians should ask caregivers about prior injuries such as bruising.

Imaging evaluation of sentinel injuries

Imaging to identify occult injuries not suspected on physical exam is a key component of the evaluation of sentinel injuries. The American Academy of Pediatrics recommends a skeletal survey for all children younger than 2 years for whom there is concern for abuse [24, 25]. In addition to children <2 years with injuries from suspected abuse, skeletal surveys are specifically recommended in non-ambulatory infants with bruising or other skin injuries or oral injuries [24]. As such, a skeletal survey is an appropriate part of the evaluation of an infant with a sentinel injury.

The American Academy of Pediatrics 2015 clinical report noted that infants undergoing abuse evaluations, including asymptomatic infants, benefit from neuroimaging because of the potential morbidity associated with abusive head trauma [24]. The 2015 report also included neuroimaging in infants with "suspicious bruising" among the testing to be considered as part of the evaluation of physical abuse. Thus, neuroimaging should be considered in the evaluation of an infant with a sentinel injury even in the absence of neurologic symptoms or other injuries. Neuroimaging must be performed in infants with findings suggestive of abusive head trauma. Additional research is needed to clarify the yield of neuroimaging in asymptomatic infants presenting with different types of sentinel injuries to further refine imaging recommendations in this population.

Conclusion

Sentinel injuries are minor detectable injuries that can alert a clinician to a young infant who has concurrent additional injuries not identifiable on physical examination or who is at risk of experiencing escalating physical abuse. Multiple studies have highlighted the association between bruising and clinically occult injury identification and abuse. Thus, an evaluation for occult injuries including performance of a skeletal survey and neuroimaging should be performed in infants with concerning bruising. A thorough evaluation including skeletal survey is also appropriate in infants with other types of sentinel injuries. Neuroimaging should also be considered in the evaluation of these infants. Additional studies are needed to further quantify the prevalence of clinically occult injuries on skeletal survey and the prevalence of abuse among infants presenting with subconjunctival hemorrhages and intra-oral injuries.

Compliance with ethical standards

Conflicts of interest The Children's Hospital of Philadelphia has received payment for Dr. Henry's and Dr. Wood's expert testimony following subpoenas in cases of suspected child abuse.

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