The association of nonaccidental trauma with historical factors, examination findings, and diagnostic testing during the initial trauma evaluation

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Nonaccidental trauma (NAT) or child abuse is the deliberate or intentionally inflicted injury of a child and is a form of child maltreatment.[1] One in four children experience some form of maltreatment in their lifetime.[2] Annually, nearly one million children are victims of maltreatment in the United States[1] at a cost of $124 billion.[3] In 2014, 1,580 US children died of abuse or neglect.[1,4]

Children who are victims of recurrent NAT experience significantly higher mortality (25%) compared to victims of a single NAT episode (10%).[5] Up to one third of children diagnosed with NAT had abuse missed on a prior presentation, and a third of those children subsequently suffered additional injuries from abuse.[5–8] It is important to recognize child abuse early to avoid repeated and/or escalated injuries.[1,3,4,9–11]

The purpose of this article is to summarize the existing highest quality evidence on the association of various elements of history, physical examination, and diagnostic tests with a diagnosis of NAT. This summary is intended to inform the eventual development of a clinical practice guideline and highlight potential gaps in current research.

Submitted: November 4, 2016, Revised: January 25, 2017, Accepted: February 17, 2017, Published online: March 23, 2017.

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This study was presented as a poster at the 3rd annual meeting of the Pediatric Trauma Society, November 11–12, 2016, in Nashville, Tennessee.

The views expressed herein are those of the authors and do not reflect the official policy or position the US Army Medical Department, the US Army Office of the Surgeon General, the Department of the Army, the Department of Defense, or the US Government.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

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DOI: 10.1097/TA.0000000000001441

METHODS

The Pediatric Trauma Society (PTS) Guideline Committee identified screening for NAT as a key area for guideline development. A multi-disciplinary working group was created including the Pediatric Trauma Society members and international experts in NAT. Subgroups were developed to summarize and assess the quality of the evidence describing the correlation between NAT and the following: bruising, burns, abusive head trauma (AHT), abdominal injuries, fractures, historical factors, and oral trauma. These groups participated in 16 organized teleconferences.

Each subgroup started to evaluate the literature using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) methodology to rate the level of evidence associated with NAT[12] by answering clinical questions in a patient population (P), intervention (I), comparator (C), and outcome (O) or PICO format.[13] However, following widespread consultation including medical librarians, and a comprehensive search of the literature, the subgroups concluded that there was insufficient evidence to develop GRADE-based guidelines.

The subgroups recognized that there were multiple systematic reviews in the literature, and identified the need for a single work-product, concisely synthesizing the existing high-quality evidence pertaining to the detection of NAT in children. The evidence was reviewed, critically analyzed, and summarized through a rigorous iterative process (Fig. 1). When applicable, validated screening tools to differentiate accidental from nonaccidental injuries were reviewed to further augment the synthesis of data for application by frontline clinicians. Nonaccidental trauma in each study was defined by the criteria set forth by Maguire et al.[14]

RESULTS

Bruising

Importance

Bruising is a normal part of development.[15] However, some bruising has been shown to be associated with risk for fatal and nonfatal abusive injury.[16]

Association

A 2013 systematic review of nonabusive bruises noted distribution over the front of the body and bony prominences

Figure 1. The model of the creation of the working group and process.

(i.e., knees, shins, and forehead), while abusive bruises occurred most commonly on the face, ear, neck, head, truck, buttocks, and arms. Abusive bruises were larger, more often patterned (i.e., rope, pole, belt), and more often associated with petechiae.[17] (Table, Supplemental Digital Content 1, http://links.lww.com/TA/A904). A longitudinal study of children 6 years or younger found bruising patterns to be dependent on age and development.[15]

Bruising may predict further abuse. A case-control study examined previous sentinel injuries (visible or detectable minor injury in a precruising infant that is poorly explained and suspicious for physical abuse) in children who were found to have definite abuse, intermediate concern for abuse, or nonabuse after evaluation by a hospital-based child protection team.[18] Infants with definite abuse had a 4.4 (95% CI, 2.0–9.6) increased odds of previous injury compared to infants with intermediate concern for abuse; and no nonabused infants had a previous sentinel injury. Bruising accounted for 80% of sentinel injuries.

Screening Tools

Bruising predictive of NAT involves the torso, ear, or neck for children 4 years or younger (TEN-4), and in any region for children 4 months or younger. A Bruising Clinical Decision Rule (TEN-4 BCDR) including the age of the child and the location of the bruises was derived on an inpatient population in Intensive Care, with a sensitivity of 97% and a specificity of 84%.[19] (Table, Supplemental Digital Content 1, http://links.lww.com/TA/A904).

Burns

Importance

In a study conducted by the Centers for Disease Control and Prevention, 2.8% of all nonfatal injuries in children ages 0 to 4 years were burns; and of these, 1.3% were identified as intentional. Up to 25% of children admitted to burn centers are victims of abuse.[20]

Association

Most intentional burn injury can be divided into scalds, contact and flame injury, though some rare cases fall outside this classification including microwave/radiation, electrical, and chemical burns.

There have been two comprehensive systematic reviews focused on intentional burn injury (Table, Supplemental Digital Content 2, http://links.lww.com/TA/A905).[21,22] Factors suggestive of abusive burns include a history that is incompatible with the examination, coexisting skeletal injuries[23,24] or other unrelated injuries, previous abuse, or numerous prior "accidental" injuries, domestic violence, a sibling that is blamed for the injury, or a passive and fearful child.[21,25] One study analyzed 5,553 burn victims and found 297 (5.3%) had confirmed abuse after investigation by Child Protective Services or their child abuse team. After multivariate logistic regression, the following characteristics were independently associated with confirmed abuse: younger age, chemical, contact and scald burns, and burns to bilateral feet, buttocks, and perineum (Table, Supplemental Digital Content 2, http://links.lww.com/TA/A905). Indeed, 76.7% of children who were intentionally burned were younger than 2 years, and 94.3% of victims were younger than 5 years.[22] Burns to chest were found to be associated with unintentional injury (Table, Supplemental Digital Content 2, http://links.lww.com/TA/A905).[22]

Scalding represents most (up to 89%) of intentional burn injuries, which can be difficult to distinguish from unintentional scalds.[22] Factors reassuring for unintentional scalds include spill injuries from beverages, involve the upper extremities, face, and/or trunk with irregular demarcation, and asymmetric distributions on upper body (Table 1).[21,25]

Contact burns that are on the palmar surface of the hands, superficial, or with irregular demarcations are more likely accidental in that they indicate the reflex to withdraw immediately. "Branding" burns are described from a hair dryer, cigarettes, a cigarette lighter, or clothes iron. They are deep, third-degree burns, often clustered on the face, back, dorsum of extremities, trunk, genitalia, or buttocks and are more likely intentional.[25]

Screening Tools

An evidence-based triage tool (Table 1) based on a systematic review (Table, Supplemental Digital Content 2, http://links.lww.com/TA/A905) was developed to aid in distinguishing intentional from unintentional scalds.[21] The tool is currently undergoing a prospective validation study. A recent study provides validity for this tool and recommends adding chemical and contact burns to the scald component of the previously derived triage tool.[22]

Intracranial Injuries

Importance

Abusive head trauma (AHT) describes traumatic brain injury and its associated structures in infants and children that results from violent shaking, blunt impact, or a combination of the two.[26,27] Abusive head trauma is the leading cause of morbidity and mortality in children suffering from physical abuse and is a leading cause of traumatic death in infancy.[4,28,29] Abusive head trauma has higher mortality rates, increased hospital lengths of stay, higher median Injury Severity Score (ISS), and incurs higher medical costs compared to unintentional

TABLE 1. Triage Tool for Scald Injury Proposed by Maguire et al.[21]

Intentional Scald Must be Excluded	Intentional Scald Should be Considered	Intentional Scald Unlikely
Mechanism: immersion		Spill injury
		Flowing water injury
Agent: hot tap water		Nontap water (beverage)
Pattern: clear upper limits Scald symmetry (extremities)	Uniform scald depth Skin fold sparing Central sparing buttocks	Irregular margin and burn depth Lack stocking distribution
Distribution: Isolated scald buttock/perineum ± lower extremities Isolated scald lower extremities	Glove and stocking distribution 1 limb glove/stocking	Asymmetric involvement lower limbs Head, neck and trunk or face and upper body
Clinical features	Previous burn injury	
Associated unrelated injury	Neglect/faltering growth	
History incompatible with examination findings	History inconsistent with assessed development	
Coexisting fractures		
Historical/social features	Trigger, such as: Soiling/enuresis/	
Passive, introverted, fearful child	Misbehavior	
Previous abuse	Differing historical accounts	
Domestic violence	Lack of parental concern	
Numerous prior accidental injuries	Unrelated adult presenting child	
Sibling blamed for scald	Child known to social services	

trauma.[29,30] Approximately 20% of infants with AHT die from their injury, and many survivors have long-term disabilities.[31] Approximately one in three children who have suffered from AHT have been previously evaluated by health care providers and NAT was not diagnosed at initial presentation and were at risk of reinjury and fatal AHT.[6,11]

Association

In a meta-analysis of 1,945 children younger than 16 years old with intracranial injuries (ICI), the probability of AHT differed based on the number and type of additional clinical features. Retinal hemorrhages and apnea, although infrequently recorded, had strong associations with AHT.[32,33] A systematic review determined that subdural hemorrhage (SDH), cerebral ischemia, retinal hemorrhage, skull fractures with ICI, metaphyseal fractures, long bone fractures, seizures, apnea, and no history of trauma were significantly associated with AHT.[34] Inconsistency in the definition and reporting of variables as well as high statistical heterogeneity were limitations to this review (Table, Supplemental Digital Content 3, http://links.lww.com/TA/A906).

A systematic review to identify neuroradiological features associated with AHT noted SDH to be significantly associated with AHT.[33,35] Meta-analyses of these studies with low level of heterogeneity found SDH following certain patterns to be more highly associated with AHT including interhemispheric hemorrhages (adjusted OR, 8.03; 95% CI, 5.58–11.56) and multiple SDHs (adjusted OR, 6.01; 95% CI, 2.52–14.35).[35] Hypoxic-ischemic injury, cerebral edema, and ICI in the absence of skull fractures were also associated with AHT, while focal parenchymal injury was not predictive (Table, Supplemental Digital Content 3, http://links.lww.com/TA/A906).[35]

Another systematic review described the pattern of retinal hemorrhages and associated retinal features that distinguish AHT from non-AHT (Table, Supplemental Digital Content 3, http://links.lww.com/TA/A906).[33,36] Bilateral and multilayered retinal hemorrhages with extension into the periphery were highly specific for NAT,[36] confirming similar findings of an earlier systematic review.[37] The sensitivity of intraocular hemorrhages for AHT was 75% and specificity was 94%.[37] Intraretinal hemorrhage at the posterior pole was the most common finding associated with AHT and extensive, bilateral and multilayered intraocular hemorrhages were the most specific for AHT.[37]

Screening Tools

The Pittsburgh Infant Brain Injury Score (PIBIS) was developed to assist providers in deciding when well-appearing infants are at risk for traumatic brain injury and should undergo head CT for evaluation of AHT. Well-appearing but high-risk infants included afebrile infants with no history of trauma but presenting with an apparent life-threatening event (ALTE) such as apnea, vomiting, or seizures; soft tissue swelling of the scalp, bruising; or other nonspecific neurologic symptoms.[38,39] The test characteristics for the five-point PIBIS (abnormal dermatologic examination result [soft tissue swelling of the scalp or bruising] [2 points], age 3 months or older [1], head circumference greater than 85th percentile [1], and serum hemoglobin 11.2 g/dL or less [1]) in 862 subjects revealed a sensitivity for abnormal neuroimaging at a score of 2 of 93% (95% CI, 89–96%) and a specificity of 53% (95% CI, 49–57%) (Table 1). A PIBIS score of 2 or higher may alert a provider about the possibility of brain injury in a high-risk infant, but should not be used to make a diagnosis of abuse.[38]

The Predicting Abusive Head Trauma Tool (PredAHT) was derived by a multivariate analysis of individual patient data from six separate comparative studies to determine distinguishing clinical features of AHT from non-AHT (nAHT).[32] This tool was externally validated on a cohort of children younger than 36 months with ICI, confirmed as abusive or nonabusive.[40] Information about six features (retinal hemorrhage, rib and long-bone fractures, apnea, seizures, and head or neck bruising) was collected in 133 nAHT cases and 65 AHT cases; 97% of the children were younger than 24 months. When 3 or more features were present, the estimated probability of AHT was greater than 80% (95% CI, 63.3–91.8). The sensitivity of the tool was 72%, the specificity was 86%, and the area under the curve (AUC) was 0.88.[40]

The Pediatric Brain Injury Research Network (PEDIBIRN) similarly derived and prospectively validated a four-variable rule on a cohort of children younger than 36 months admitted to the pediatric intensive care unit with ICI, confirmed as abusive or nonabusive.[41–43] The variables included acute respiratory compromise before admission; bruising of the torso, ears or neck; bilateral or interhemispheric SDHs or collections; and any skull fracture other than an isolated, unilateral, nondiastatic, linear, and parietal fracture. When 1 or more predictor variables were present, this rule demonstrated a sensitivity of 96%, a specificity of 43% for AHT, prevalence of 0.43 (95% CI, 0.37–0.49), and AUC of 0.78. Notably, the isolated predictive quality of any bruising involving the child's ears, neck, or torso for AHT demonstrated the following test characteristics: sensitivity, 37% (95% CI, 0.29–0.46); specificity, 94% (95% CI, 0.89–0.97); and prevalence, 0.43 (95% CI, 0.37–0.49). These tools may assist in differentiating AHT from nAHT in seriously injured hospitalized children with ICI.

Abdominal Injuries

Importance

The reported incidence of abdominal trauma in NAT ranges from 0.5% to 4%,[44–46] but these injuries account for up to 50% of abusive fatalities.[47] Fewer than 12% of patients with abusive abdominal injury present with abdominal bruising,[47] and the abdominal injury is unlikely to be recognized as abusive.[48] Occult abdominal trauma may be as high as 6% to 8% among abused children without overt signs of injury.[49]

Association

One systematic review to date has compared accidental and abusive abdominal injuries (Table, Supplemental Digital Content 4, http://links.lww.com/TA/A907).[33,47,48,50–54] Victims of NAT 4 years or younger suffer from a higher percentage of hollow viscus injury, particularly duodenal perforation.[50,51,53] One study demonstrated 100% of children who presented with duodenal injuries who were 2 years or younger,[54] and another 100% 4 years or younger,[51] respectively, were related to NAT, and none were related to unintentional mechanisms such as falls. Abused children were more likely to experience duodenal transections than nonabused (35% vs. 17%).[54] Another study noted that the incidence of small bowel injuries were higher in NAT patients compared to accidental falls (35% vs. 2.9%; relative risk [RR], 12.2; 95% CI, 1.7–86.9).[55]

Combined hollow viscus and solid organ injury was more common in NAT.[47,53] Children with intra-abdominal injury (IAI) due to NAT were younger (2.5–3.7 years)[53] compared to nonabused children (7.6–10.3 years).[47,50] Nonaccidental trauma victims were significantly more likely to die of their IAI (53%) than those accidentally injured (21%) (p = 0.014).[47] Nonaccidental trauma was found to more frequently have a delay in presentation than accidental injury and have a higher associated injury severity (Abbreviated Injury Scale [AIS] ≥ 2) compared to low-velocity injuries (falls <10 feet, bicycle crashes, and household trauma).[47,53]

Most evidence suggests that solid organ injuries occur equally between NAT and accidentally injured patients.[47,48,50,53] However, one recent study suggested solid organ injuries were more likely to occur in unintentional falls (65% vs. 89%; RR, 0.73; 95% CI, 0.59–0.91).[55] Nonaccidental trauma pancreatic injury was noted to be present in 1% of all pancreatic fatalities, and each of whom had multiple additional injuries.[52] Pancreatic injuries in NAT are often associated with hollow viscus injuries, and may present late as a pancreatic pseudocyst.[48] Pancreatic injuries were more common among young NAT victims compared to fall casualties (25.4% vs. 5.7%; RR, 4.44; 95% CI, 1.08–18.22).[55]

Screening Tools

Studies are hampered by the lack of consistent application of a criterion standard to test screening elements (i.e., CT scan was not used 100% when analyzing history, physical, and laboratory test results).[48] One study found that abdominal tenderness, distension, bruising, and abnormal bowel sounds had a likelihood ratio (LR) of 5 or higher for abusive abdominal injury.[56] Another study noted that only distension (p = 0.03) and bruising (p = 0.003) were significantly associated with abdominal injury.[57] Most children presented with no definitive history[48,49] or history of a fall.[47]

Low systolic blood pressure, abdominal tenderness, femur fracture, aspartate transaminase (AST) greater than 200 U/L or alanine transaminase (ALT) greater than 125 U/L, an initial hematocrit of less than 30%, and hematuria greater than 5 RBCs/high power field were important predictors of IAI in children sustaining *generalized* blunt torso trauma. Pediatric blunt trauma patients with any one of these findings should be considered at significant risk for IAI. Patients with none of these risk factors were at low risk for IAI.[45]

In NAT, a negative test result (liver function tests, amylase, and lipase) is of limited value; however, a positive test result warrants consideration of abdominal CT, especially if amylase and lipase increase over time or there are physical examination findings as previously noted.[45,46,49,52,56] One prospective, multicenter, observational study of all children younger than 60 months referred for subspecialty evaluation of possible physical abuse determined the sensitivity and specificity of routine transaminase testing in young children who underwent consultation for physical abuse. The AUC for transaminases (AST or ALT) as a test for identified abdominal injury was 0.85 (95% CI, 0.78–0.91). A cutoff of 80 IU/L for either AST or ALT identified 41 of 53 abdominal injuries, with 218 false-positives among 1,219 children without IAI (sensitivity: 77%; specificity: 82%). Transaminase levels were elevated in 14 of 17 patients with occult IAI, i.e., without external injury (no evidence of bruising).[56]

Computed tomographic scan remains the criterion standard for screening of both accidental and NAT in children. Children with abusive abdominal trauma have a high likelihood of associated injuries prompting a thorough evaluation of the child for additional injuries (Table, Supplemental Digital Content 4, http://links.lww.com/TA/A907).[47,48,50,53,55]

Fractures

Importance

Skeletal injuries represent the second most common injury sustained by physically abused children.[58] Understanding the history, development of the child, and the response to injury by the child and caretakers were critical when differentiating NAT from accidental injuries (Table, Supplemental Digital Content 5, http://links.lww.com/TA/A908). Children with multiple skeletal injuries of unclear etiology or without histories of trauma but who present to care because of a child's change in behavior were more likely to be victims of NAT.[59] A diagnosis of abuse was made in approximately 20% to 25% of fracture cases in children 12 months or younger and in 6% to 7% in children 12 to 23 months old.[60,61] Up to 20% of abuse-related skeletal injuries were not identified initially.[8]

Association

Children 24 months or younger remain at highest risk for abusive skeletal injuries.[62,63] Skull fractures were among the most challenging to classify with regard to risk of abuse. A systematic review of children with skull fractures aged 0 to 48 months noted a positive predictive value (PPV) of a skull fracture for suspected or confirmed abuse of 20.1 (95% CI, 13.3–26.9).[28,33,64] Linear parietal fractures are the most common in both unintentional and abusive injury. Unlike fractures in other areas of the body, younger age (i.e.; age 18 months or younger) was not associated with NAT.[64]

Rib fractures have the highest specificity for NAT at upward of 70%.[63–65] These fractures may be found anywhere along the rib arc although most commonly and equally occurring anteriorly or posteriorly. The classic metaphyseal lesion (bucket-handle, chip, or corner fractures) is also highly suspicious for NAT among those aged 12 months or younger.[66] This type of fracture is typically seen in the distal femur or proximal tibia.[65,66]

Overall, the probabilities of femur fractures being the result of NAT are 16.7% to 35% in children 12 months or younger and 1.5% to 6% in children 12 months or older.[67] In a systematic review of femur fractures, the presence of additional injuries and reported suspicious history were the factors most predictive of NAT, while the type or position of the fracture was not predictive.[67] Once children are walking alone, they can sustain a torsion fracture of the femur, analogous to the “toddler fracture” of the tibia (a spiral break in the tibia, which occurs after a child twists their leg during a fall).[68]

Proximal and mid-shaft humeral fractures have a likelihood of NAT, but a distal humeral fracture (supracondylar) can be accidental in the ambulating child.[64,65] Importantly, humeral fractures have a PPV for abuse of 43.8 (95% CI, 27.6–59.9) in 0 to 18 months versus PPV of 1.8% (95% CI, 0–3.9) in 18 to 48 months.[33] Both femoral and humeral fractures are often underinvestigated by medical personnel in tertiary centers.[69] Tibia/fibula and radius/ulna fractures should be considered for possible NAT with the exception of distal buckle fractures or “toddler fractures” in ambulating children with histories of falls.[62–64] Skeletal injuries of the hands, feet, and pelvis are rare; however, they may be identified as occult injuries from the skeletal survey.[70] Spinal fractures are summarized in Supplemental Digital Content 5 (Table, Supplemental Digital Content 5, http://links.lww.com/TA/A908).

Screening Tools

The American Academy of Pediatrics has criteria that indicate a full (21-image) skeletal survey should be performed in all children younger than 2 years of age with suspected abuse.[71] A standard protocol has been published including age, history, and injury type using the UCLA RAND consensus methodology to help clinicians correctly identify those children with occult skeletal trauma in which further screening should be used.[63] This protocol removed any socioeconomic factors and delineates when skeletal surveys are mandatory.[71] Further research regarding the use of this type of protocol is needed to validate its use; 24% of children with suspected NAT had positive skeletal surveys, with a mean of 2.5 fractures per child (range, 0–9). The ages of positive cases ranged from 2 weeks to 36 months (82%12 months or younger).[72] Prevalence of occult fractures was equivalent between those aged 12 to 23 months (18.9%) and 0 to 11 months (22.7%). Up to 10% of children with fractures undergoing skeletal survey had additional fractures that were either acute or healing of their hands, feet, or pelvis.[70] Oblique views of the ribs considerably enhance detection of rib fractures. Follow-up skeletal surveys improve the rate of fracture detection in suspected cases of NAT;[73] however, there is considerable controversy as to which images can be omitted on repeat follow-up skeletal surveys (i.e., some argue excluding the pelvis, lateral spine, hands, and skull is appropriate).[74]

Historical Factors

Importance

Victims of NAT may not be able to effectively communicate the history of an injury owing to their developmental stage. History is often obtained from caregivers or witnesses and helps differentiate unintentional trauma from NAT.

Association

In a multivariate analysis of the stated reason for the visit, the two best predictors of NAT were (1) injury inconsistent with the history and (2) if the patient was referred to the clinician for suspected child abuse.[75]

In efforts to reduce disparities in child abuse evaluation, one group used a single historical event (unwitnessed event leading to ICI) to determine which infants received a skeletal survey.[76] They found that screening increased and disparities in evaluations diminished; however, it did not lead to a significant increase in the diagnosis of NAT.

Screening Tools

There are no identified screening tools regarding historical factors in NAT. Elements of the history that are commonly attributed to an increased risk of NAT are summarized in Table 2; however, the sensitivity and specificity of each element are unknown.[77,78]

Oral Injuries

Importance

Facial and intraoral trauma has been described in up to 49% of infants and 38% of toddlers with NAT.[79] Furthermore, these numbers likely under-represent the true incidence of inflicted oral abuse because a documented oral examination is often lacking in the evaluation of an injured child.

Association

The correlation of oral injuries and abuse have been well documented, but a systemic review concluded that NAT cannot

TABLE 2. Test Characteristics of Prediction Tools for Nonaccidental Trauma

Overall Group	Prediction Tool	Aim	Patient Population	Test Characteristics	Level of Evidence
Hymel et al. (2014),[41]	4-variable AHT clinical prediction rule (PEDIBIRN) Variables: Acute respiratory compromise before admission; bruising of the torso, ears, or neck; bilateral or interhemispheric subdural hemorrhages or collections; and any skull fractures other than an isolated, unilateral, nondiastatic, linear, parietal fracture	To validate the screening performance for AHT of a previously derived 4-variable prediction rule	No. of subjects: 124 AHT cases, 167 non-AHT cases Age range: children <3 years of age Subject characteristics: Hospitalized patients in the pediatric intensive care unit with intracranial injury on CT or MRI, confirmed as AHT or nAHT (nAHT) Confirmation of Abuse: A priori definitional criteria for AHT*	When ≥ 1 feature were present: sensitivity: 0.96 (95% CI, 0.90–0.99); specificity, 0.43 (95% CI, 0.35–0.50); AUC, 0.78	Level II
Cowley et al. (2015),[40]	Predicting Abusive Head Trauma Tool (PredAHT) Variables: Retinal hemorrhage, rib and long-bone fractures, apnea, seizures, and head or neck bruising	To validate the previously developed PredAHT tool to provide a prediction of the probability of AHT in children aged <36 months presenting with an intracranial injury.	No. of subjects: 133 non-AHT cases and 65 AHT cases Age range, children <36 months Subject characteristics: Hospitalized patients with intracranial injury, confirmed as AHT or nAHT Confirmation of abuse: abuse ranking 1–2**	When ≥ 3 features were present in children <3 years with intracranial injury: Sensitivity, 72.3% (95% CI, 60.4–81.7); Specificity, 85.7% (95% CI, 78.8–90.7); AUC, 0.88	Level II
Berger et al. (2016),[38]	Pittsburgh Infant Brain Injury Score (PIBIS) Variables: Abnormal dermatologic examination results (2 points), age ≥ 3 months (1 point), head circumference >85th percentile (1 point), and serum hemoglobin <11.2 (1 point)	To validate the previously developed PIBIS, a clinical prediction rule to assist physicians decide which high-risk infants should undergo CT of the head	No. of subjects: 214 cases (abnormal neuroimaging at enrollment or during follow-up—traumatic and nontraumatic) and 826 controls (normal neuroimaging, or no imaging at enrollment and follow-up); age range, infants <365 days. Subject Characteristics: well-appearing infants with temp <38.3°C, no history of trauma, and a symptom associated with having a brain abnormality (vomiting, apnea)	Test characteristics of identification of abnormal neuroimaging at a score of 2: sensitivity, 93% (89–96); specificity, 53% (49–57); NPV of a score <2 for detection of abnormal neuroimaging was 96% (93.6–97.9)	Level III

*One or more of these criteria: 1. Primary caregiver admission of abusive acts. 2. Witnessed abusive acts. 3. Specific primary caregiver denial of any head trauma, although the perambulatory child in his or her care became acutely, clearly, and persistently ill with clinical signs linked to traumatic cranial injuries visible on CT or MRI. 4. Primary caregiver account of the child's head injury event was clearly historically inconsistent with repetition over time. 5. Primary caregiver account of the child's head injury event was developmentally inconsistent with child's known or expected gross motor skills. 6. Two or more categories of extracranial injuries considered moderately or highly suspicious for abuse.

**Nonaccidental trauma was defined in each report by meeting one of the following criteria as proposed by Maguire, et al.:[14] 1. Abuse confirmed at case conference, family, civil or criminal court proceedings or admitted by perpetrator or witnessed. 2. Abuse confirmed by stated criteria where diagnosis was based upon additional features and did not rely on the variable of interest, and included multidisciplinary assessment. 3. Abuse defined by stated criteria. 4. Abuse stated as occurring, but no supporting detail given as to how it was determined. 5. Abuse stated simply as "suspected".

be diagnosed based solely on a torn labial frenum.[79,80] In mobile children (median age, 19 months), a small study of 21 patients found that a frenum injury is less suggestive of abuse than previously thought.[81] Given that up to 50% of *school-age children* will sustain accidental dental injuries, including frena tears, there is inherent difficulty in distinguishing accidental from inflicted oral injuries.[82]

Screening Tools

There are no identified screening tools regarding oral injuries in NAT.

DISCUSSION

Nonaccidental trauma is a leading cause of childhood traumatic injury and death[5] and has an increased incidence of high ISS, craniotomy, exploratory laparotomy, prolonged intensive care unit and hospital length of stay, and mortality compared to unintentional trauma.[83] Evidence for identifying injuries associated with NAT varies widely, as even the highest quality systematic reviews do not reach Level I criteria because there are no randomized control trials nor prospective trials with large effect size, and no negative criteria (Supplemental Digital Contents).[12] The need exists for prospectively developed screening tools for the identification of NAT. These must then be validated prospectively and must undergo implementation evaluations in accordance with the development of a clinical decision rule for use in trauma.[84]

Clinical practice guidelines and/or clinical decision support are effective tools to facilitate the application of evidence during direct patient care in the clinical environment. In countries where child abuse screening in emergency departments is mandatory, such as the Netherlands, clinicians often use checklists of historical risk factors for abuse to help identify children who might benefit from additional screening. Most of the instruments are highly sensitive but do not effectively guide clinical evaluation. A systematic review of 50 years of published studies evaluating screening tools found a lack of a criterion standard for determination of abuse and poor quality of the studies.[85] Child abuse instruments identified patients only when they had clinical symptoms with low sensitivity and only moderate specificity.

The literature therefore currently suggests that a more productive way forward is by developing injury-specific tools (e.g., for bruising, fractures, head injury, etc.). Existing injury-specific tools are either aimed at a very specific population (age younger than 1 year presenting with a fracture[86] or children4 years or younger admitted to pediatric intensive care with trauma and bruising.[87] However, the advances made in developing screening tools, such as those previously discussed to identify potential cases of AHT, or determine which children with intracranial injury may have been abused, hold considerable promise, particularly if they could be incorporated into the electronic medical record. When the caregiver history does not provide a clear mechanism, explain the severity or fit with regard to the timing of a child's findings, clinicians must have a low threshold for considering abuse (Table 2). Preschool-age children (younger than 4 years) are an especially vulnerable population. There is a lack of "eyes on the child," the concept that once the patient has entered school or society, they are much more visible to the outside world and injuries are much more identifiable. Apparently, innocuous injuries such as bruising or minor oral injuries (including torn labial frenum), especially in premobile children, may provide the opportunity to identify and intervene with a child before the abuse escalates. Table 3 summarizes key take home points to differentiate accidental from NAT.

Bruising patterns suggestive of NAT depend on motor developmental stage of the child. The prevalence of bruising in healthy nonabused *infants* is low. Specifically, the TEN-4 screening criteria is highly suggestive of NAT when compared to unintentional bruising patterns: bruising in children younger than 4 years on trunk, ears, neck; or any bruising in infants younger than 4 months is NAT until proven otherwise. The TEN-4 was highly specific for AHT in the PEDIBIRN prediction tool when it was the sole predictor variable. The traumatologist can use this simple tool to prompt further screening for NAT, including AHT in particular. Patterned bruising, associated petechiae, larger size, bruising to cheeks, and buttocks are also concerning for NAT.

Burns and scalds to buttocks, perineum, bilateral lower limbs, or unilateral limbs are highly associated with NAT. Other risk factors include any burn in children younger than 5 years, multiple contact burns, or clearly demarcated edges of the burn. Although deep burns to the hands are associated with NAT, those that are more superficial and with irregular demarcations are more likely unintentional. "Branding" burns occur in NAT and may be from household objects leaving distinctive patterns.

Abusive head trauma is associated with SDH, hypoxic-ischemic injury, diffuse axonal injury, metaphyseal fractures, rib fractures, retinal hemorrhages, apnea, and seizures. Screening tools such as the PIBIS are highly sensitive and may aid the surgeon in determining the need for a head CT. Clinical prediction tools such as PEDIBIRN and PredAHT are highly sensitive and specific, respectively, for AHT (Tables 1 and 3).

Duodenal injuries in children 4 years or younger are highly suspicious for NAT.[48,51,54] Physical examination findings including abdominal bruising and distension are highly associated with IAI, but lack of bruising does not exclude IAI in NAT. Of note, when considering NAT, a lower elevation of AST/ALT compared to generalized blunt abdominal trauma

TABLE 3. Elements of the History that are Commonly Attributed to an Increased Risk of Inflicted Injury[77,78]

Element
• An unreasonable delay in care
• An unexplained or poorly explained history of events
• An implausible history based on:
o Type of injury
o Mechanism of injury
o Age of the child
o Developmental capabilities of the child
• A history that changes over time by a single caretaker
• A discrepancy in history by multiple caretakers
• An inappropriate response to the event by caretaker or child
• A report of harm to the child
• An unlikely or unusual injury for the age of the child

should prompt consideration of CT, even in the setting of a normal abdominal examination result.[56]

Fractures among nonambulating children, including no clear correlating history, fractures of the proximal and mid-shaft humerus, femur fractures in nonambulatory children, rib fractures without associated major trauma, and occult fractures in children younger than 2 years are all suggestive of NAT. The American Academy of Pediatrics recommends a skeletal survey of the entire bony skeleton in cases of suspected NAT.[71] Up to 24% of patients with suspected NAT will have findings of occult skeletal fractures.[72]

The individual components of the history have not been rigorously studied and are not fully understood. The recent development of a performance assessment tool for documentation of history taking in physical abuse may elucidate the sensitivity and specificity of the historical details related to abusive injury.[88] A systematic review of professional interventions for health care providers to improve child protection in emergency departments identified reminder systems and checklists that included historical elements of the presenting complaint that were believed to be important to the recognition of abuse.[89] Additionally, a modified Delphi process with an expert panel of child abuse pediatricians identified highly recommended elements for child abuse evaluations (Table, Supplemental Digital Content 6, http://links.lww.com/TA/A909).[90]

Finally, intra-oral injury in *non-ambulatory children* is highly suspicious (but not diagnostic) for NAT. Thus, children with intra-oral injuries that have not been independently witnessed should always be evaluated for NAT; and conversely, children with suspicion for NAT should have a carefully documented oral examination. Children with intra-oral injuries may be at risk for further and potentially more significant abuse in the future.[10,16]

CONCLUSIONS

The original intent of the work group was to create a screening tool for the traumatologist to meaningfully screen for NAT in children. As previously noted, this could not be achieved based on the lack of available high-quality data. Nevertheless, a pattern of injuries based on a careful review of the literature that should prompt the traumatologist to consider NAT when evaluating injured children emerged. These data should inform the development of local guidelines and be used to drive further research in this field. Any injury in nonambulatory child, specific patterns of bruising (TEN-4), characteristic

TABLE 4. A Summary of Features Associated with NAT) and Recommendations Based on Specific Findings Including Bruising, Burns, Intracranial Injury, Abdominal Injury, Skeletal Injuries, Historical Factors, and Oral Injuries

Category	Features Associated with NAT, Compared to Nonabused Children	Summary Recommendations
Bruising	TEN-4 clinical prediction rule: bruising in children <4 years on trunk, ears, neck; or any bruising in infants <4 months[19] Patterned, petechiae, large size, cheeks, ear, neck, head, truck, buttocks, arms[17] Less likely from abuse: Front of body, bony prominences; however, “expected” bruising depends on developmental age/disability of the child[17]	TEN-4 bruising 97% sensitive, 84% specific for NAT ➔ child abuse workup “When you don't cruise, you don't bruise.”
Burns	Independent associations with confirmed abuse—age (2.1 vs. 5.0 years); chemical burn; contact burn; scald burn; feet; buttocks; perineum[22] Less likely from abuse: beverages, spill injuries with irregular margins, burns to chest and head (spills)[21]	Up to 25% children admitted to burn centers have been abused[20] Most intentional burn injury is from scalds to buttocks, perineum, bilateral lower limbs, feet, unilateral limbs, multiple contact burns, or clearly demarcated edges ➔ child abuse workup.[21] Any burn in age <5 years ➔ child abuse workup.[22]
Intracranial injury	Subdural hemorrhage, hypoxic-ischemic injury, diffuse axonal injury, metaphyseal fractures, rib fractures, retinal hemorrhages, apnea, seizures	PEDIBIRN clinical prediction rule, 96% sensitive, 43% specific for AHT 1+ feature* in child <3 years ➔ child abuse workup[41–43] PredAHT clinical prediction rule, 72% sensitive, 86% specific for AHT 3+ features** in child <3 years ➔ child abuse workup[32]
Abdominal injury	Children with NAT and abdominal injury have a higher ISS, higher mortality, and often need an operation. It is important to note that intra-abdominal injury may be found without bruising but in the presence of elevated LFTs.	Hollow viscus injury, particularly duodenal injury, in children <4 years, combined hollow viscus + solid organ injury ➔ child abuse workup[48]
Skeletal injury	Fractures in children <3 years and/or nonambulating child Fractures proximal and mid-shaft humerus, femur fractures + nonambulating child Rib fractures in absence of major trauma	Fracture patterns inconsistent with degree of mobility and child age ➔ child abuse work up[65] Skeletal survey to screen for occult fractures is indicated for any child <2 years with suspected NAT[71]
Oral injury	Frena injury + nonambulating child	Lip injury is extremely common in accidental trauma and does not justify a child abuse workup[79]
Historical factors	Delay in care, inconsistent or implausible history, a history that changes or is developmentally incompatible, a report or concern for harm to the child, domestic violence	Children who present with a change in behavior + skeletal injuries, subdural hemorrhage with suspicious history, injury inconsistent with history, and delay in seeking care ➔ child abuse workup

*Acute respiratory compromise before admission; bruising of the torso, ears, or neck; bilateral or interhemispheric subdural hemorrhages or collections; and any skull fractures other than an isolated, unilateral, nondiastatic, linear, and parietal fracture.

**Retinal hemorrhage, rib and long-bone fractures, apnea, seizures, and head or neck bruising.

burns (sharply demarcated scalds or contact burns) or fractures, ICI (especially with associated fractures, retinal hemorrhage, apnea, and suspicious history), abdominal (especially duodenal injuries in patients 4 years or younger) or intra-oral injuries as defined in Table 4, or injuries inconsistent with the history offered or the child's developmental stage, must prompt a full child protection evaluation.

AUTHORSHIP

M.A.E., K.F., M.A., and S.M. each contributed to the literature search, study design, data collection, data analysis, data interpretation, writing, and critical revision of the manuscript. G.T., M.A.B., S.J.D., K.F., and J.M.C. each contributed to the literature search, data collection, data analysis, data interpretation, and writing of the manuscript. R.B. contributed to study design, writing, and critical revision of the manuscript.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Centers for Disease Control and Prevention. Child maltreatment: fact-sheet. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, Division of Violence Prevention; 2016. Available at: http://www.cdc.gov/ncipc/factsheets/cmfacts.htm. [Updated April 25, 2016; Accessed May 15, 2016].
2. Finkelhor D, Turner HA, Shattuck A, Hamby SL. Violence, crime, and abuse exposure in a national sample of children and youth: an update. *JAMA Pediatr*. 2013;167(7):614–621.
3. Centers for Disease Control and Prevention. *Child Abuse and Neglect Prevention*. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, Division of Violence Prevention; 2016 Available at: http://www.cdc.gov/violenceprevention/childmaltreatment/. [Updated April 5, 2016; Accessed May 15, 2016].
4. U.S. Department of Health & Human Services Administration for Children and Families, Administration on Children, Youth and Families, Children's Bureau. *Child Maltreatment 2014*. Washington, DC: Children's Bureau Administration for Children, Youth, and Families; 2016. Available at: http://www.acf.hhs.gov/programs/cb/research-data-technology/statistics-research/child-maltreatment. Accessed January 20, 2017.
5. Deans KJ, Thackeray J, Askegard-Giesmann JR, Earley E, Groner JI, Minneci PC. Mortality increases with recurrent episodes of nonaccidental trauma in children. *J Trauma Acute Care Surg*. 2013;75(1):161–165.
6. Jenny C, Hymel KP, Ritzen A, Reinert SE, Hay TC. Analysis of missed cases of abusive head trauma. *JAMA*. 1999;281(7):621–626.
7. Thorpe EL, Zuckerbraun NS, Wolford JE, Berger RP. Missed opportunities to diagnose child physical abuse. *Pediatr Emerg Care*. 2014;30(11):771–776.
8. Ravichandiran N, Schuh S, Bejuk M, Al-Harthy N, Shouldice M, Au H, Boutis K. Delayed identification of pediatric abuse-related fractures. *Pediatrics*. 2010;125(1):60–66.
9. Child Welfare Information Gateway. Mandatory Reporters of Child Abuse and Neglect. Children's Bureau/ACYF/ACF/HHS, 2016 Pages 1–61. Available at: https://www.childwelfare.gov/pubPDFs/manda.pdf#page=1&view=Introduction. Accessed May 15, 2016.
10. Thackeray JD. Frena tears and abusive head injury: a cautionary tale. *Pediatr Emerg Care*. 2007;23(10):735–737.
11. Oral R, Yagmur F, Nashelsky M, Turkmen M, Kirby P. Fatal abusive head trauma cases: consequence of medical staff missing milder forms of physical abuse. *Pediatr Emerg Care*. 2008;24(12):816–821.
12. Sauaia A, Moore EE, Crebs JL, Maier RV, Hoyt DB, Shackford SR. Evidence level of individual studies: a proposed framework for surgical research. *J Trauma Acute Care Surg*. 2012;72(6):1484–1490.
13. *Gin-McMaster Guideline Development Checklist (GDC)*. Hamilton, Ontario: McMaster University; 2016. Available at https://cebgrade.mcmaster.ca/guidecheck.html. Accessed October 4, 2016.
14. Maguire S, Pickerd N, Farewell D, Mann M, Tempest V, Kemp AM. Which clinical features distinguish inflicted from non-inflicted brain injury? A systematic review. *Arch Dis Child*. 2009;94(11):860–867.
15. Kemp AM, Dunstan F, Nuttall D, Hamilton M, Collins P, Maguire S. Patterns of bruising in preschool children—a longitudinal study. *Arch Dis Child*. 2015;100(5):426–431.
16. Sheets LK, Leach ME, Koszewski IJ, Lessmeier AM, Nugent M, Simpson P. Sentinel injuries in infants evaluated for child physical abuse. *Pediatrics*. 2013;131(4):701–707.
17. Maguire S, Mann M. Systematic reviews of bruising in relation to child abuse—what have we learnt: an overview of review updates. *Evid Based Child Health*. 2013;8(2):255–263.
18. Pierce MC, Kaczor K, Acker D, Carle M, Webb T, Brenzel AJ. Bruising missed as a prognostic indicator of future fatal and near-fatal physical child abuse. 2008 Available at: http://www.abstracts2view.com/pasall/view.php?nu=PAS08L1_3204. Accessed April 2, 2016.
19. Pierce MC, Kaczor K, Aldridge S, O'Flynn J, Lorenz DJ. Bruising characteristics discriminating physical child abuse from accidental trauma. *Pediatrics*. 2010;125(1):67–74.
20. Centers for Disease Control and Prevention. *Injury Prevention & Control: Data & Statistics (WISQARSTM)*. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2016 Available at: https://www.cdc.gov/injury/wisqars/. [Updated May 14, 2016; cited 2016 October 14].
21. Maguire S, Moynihan S, Mann M, Potokar T, Kemp AM. A systematic review of the features that indicate intentional scalds in children. *Burns*. 2008;34(8):1072–1081.
22. Hodgman EI, Pastorek RA, Saeman MR, Cripps MW, Bernstein IH, Wolf SE, Kowalske KJ, Arnoldo BD, Phelan HA. The Parkland Burn Center experience with 297 cases of child abuse from 1974 to 2010. *Burns*. 2016;42(5):1121–1127.
23. Degraw M, Hicks RA, Lindberg D. Incidence of fractures among children with burns with concern regarding abuse. *Pediatrics*. 2010;125(2):e295–e299.
24. Hicks RA, Stolfi A. Skeletal surveys in children with burns caused by child abuse. *Pediatr Emerg Care*. 2007;23(5):308–313.
25. Peck MD, Priolo-Kapel D. Child abuse by burning: a review of the literature and an algorithm for medical investigations. *J Trauma*. 2002;53(5):1013–1022.
26. Christian CW, Block RCommittee on Child Abuse, Neglect; American Academy of Pediatrics. Abusive head trauma in infants and children. *Pediatrics*. 2009;123(5):1409–1411.
27. Parks SE, Annest JL, Hill HA, Karch DL. *Pediatric Abusive Head Trauma: Recommended Definitions for Public Health Surveillance and Research*. Atlanta, GA: Centers for Disease Control and Prevention; 2012.
28. Billmire ME, Myers PA. Serious head injury in infants: accident or abuse? *Pediatrics*. 1985;75(2):340–342.
29. Keenan HT, Runyan DK, Marshall SW, Nocera MA, Merten DF, Sinal SH. A population-based study of inflicted traumatic brain injury in young children. *JAMA*. 2003;290(5):621–626.
30. Libby AM, Sills MR, Thurston NK, Orton HD. Costs of childhood physical abuse: comparing inflicted and unintentional traumatic brain injuries. *Pediatrics*. 2003;112(1 Pt 1):58–65.
31. Makaroff KL, Putnam FW. Outcomes of infants and children with inflicted traumatic brain injury. *Dev Med Child Neurol*. 2003;45(7):497–502.
32. Maguire SA, Kemp AM, Lumb RC, Farewell DM. Estimating the probability of abusive head trauma: a pooled analysis. *Pediatrics*. 2011;128(3):e550–e564.
33. Maguire S. Reviews Cardiff, Wales: Core Info—Cardiff Child Protection Systematic Reviews; 2016 Available at: http://www.core-info.cardiff.ac.uk/reviews. [Updated 2015; cited 2016 December 26].
34. Piteau SJ, Ward MG, Barrowman NJ, Plint AC. Clinical and radiographic characteristics associated with abusive and nonabusive head trauma: a systematic review. *Pediatrics*. 2012;130(2):315–323.
35. Kemp AM, Jaspan T, Griffiths J, Stoodley N, Mann MK, Tempest V, Maguire SA. Neuroimaging: what neuroradiological features distinguish abusive from non-abusive head trauma? A systematic review. *Arch Dis Child*. 2011;96(12):1103–1112.
36. Maguire SA, Watts PO, Shaw AD, Holden S, Taylor RH, Watkins WJ, Mann MK, Tempest V, Kemp AM. Retinal haemorrhages and related findings in abusive and non-abusive head trauma: a systematic review. *Eye (Lond)*. 2013;27(1):28–36.

37. Bhardwaj G, Chowdhury V, Jacobs MB, Moran KT, Martin FJ, Coroneo MT. A systematic review of the diagnostic accuracy of ocular signs in pediatric abusive head trauma. *Ophthalmology.* 2010;117(5):983–992 e17.
38. Berger RP, Fromkin J, Herman B, Pierce MC, Saladino RA, Flom L, Tyler-Kabara EC, McGinn T, Richichi R, Kochanek PM. Validation of the Pittsburgh Infant Brain Injury Score for Abusive Head Trauma. *Pediatrics*. 2016;138(1).
39. National Institutes of Health. Infantile apnea and home monitoring. *National Institutes of Health Consensus Development Conference Consensus Statement*. 1986;6(6):1–10.
40. Cowley LE, Morris CB, Maguire SA, Farewell DM, Kemp AM. Validation of a prediction tool for abusive head trauma. *Pediatrics*. 2015;136(2): 290–298.
41. Hymel KP, Armijo-Garcia V, Foster R, Frazier TN, Stoiko M, Christie LM, Harper NS, Weeks K, Carroll CL, Hyden P, et al. Validation of a clinical prediction rule for pediatric abusive head trauma. *Pediatrics*. 2014;134(6): e1537–e1544.
42. Hymel KP, Herman BE, Narang SK, Graf JM, Frazier TN, Stoiko M, Christie LM, Harper NS, Carroll CL, Boos SC, et al. Potential impact of a validated screening tool for pediatric abusive head trauma. *J Pediatr*. 2015;167(6): 1375–1381 e1.
43. Hymel KP, Willson DF, Boos SC, Pullin DA, Homa K, Lorenz DJ, Herman BE, Graf JM, Isaac R, Armijo-Garcia V, et al. Derivation of a clinical prediction rule for pediatric abusive head trauma. *Pediatr Crit Care Med*. 2013;14(2): 210–220.
44. Cooper A, Floyd T, Barlow B, Niemirska M, Ludwig S, Seidl T, O'Neill J, Templeton J, Ziegler M, Ross A, et al. Major blunt abdominal trauma due to child abuse. *J Trauma*. 1988;28(10):1483–1487.
45. Holmes JF, Sokolove PE, Brant WE, Palchak MJ, Vance CW, Owings JT, Kuppermann N. Identification of children with intra-abdominal injuries after blunt trauma. *Ann Emerg Med*. 2002;39(5):500–509.
46. Holmes JF, Sokolove PE, Land C, Kuppermann N. Identification of intra-abdominal injuries in children hospitalized following blunt torso trauma. *Acad Emerg Med*. 1999;6(8):799–806.
47. Ledbetter DJ, Hatch EI Jr, Feldman KW, Fligner CL, Tapper D. Diagnostic and surgical implications of child abuse. *Arch Surg*. 1988;123(9): 1101–1105.
48. Maguire SA, Upadhyaya M, Evans A, Mann MK, Haroon MM, Tempest V, Lumb RC, Kemp AM. A systematic review of abusive visceral injuries in childhood—their range and recognition. *Child Abuse Negl*. 2013;37(7): 430–445.
49. Coant PN, Kornberg AE, Brody AS, Edwards-Holmes K. Markers for occult liver injury in cases of physical abuse in children. *Pediatrics*. 1992;89(2):274–278.
50. Barnes PM, Norton CM, Dunstan FD, Kemp AM, Yates DW, Sibert JR. Abdominal injury due to child abuse. *Lancet*. 2005;366(9481):234–235.
51. Gaines BA, Shultz BS, Morrison K, Ford HR. Duodenal injuries in children: beware of child abuse. *J Pediatr Surg*. 2004;39(4):600–602.
52. Jacombs AS, Wines M, Holland A, Ross FI, Shun A, Cass DT. Pancreatic trauma in children. *J Pediatr Surg*. 2004;39(1):96–99.
53. Wood J, Rubin DM, Nance ML, Christian CW. Distinguishing inflicted versus accidental abdominal injuries in young children. *J Trauma*. 2005;59(5):1203–1208.
54. Sowrey L, Lawson KA, Garcia-Filion P, Notrica D, Tuggle D, Eubanks JW 3rd, Maxson RT, Recicar J, Megison SM, Garcia NM. Duodenal injuries in the very young: child abuse? *J Trauma Acute Care Surg*. 2013;74(1):136–141; discussion 41–2.
55. Carter KW, Moulton SL. Pediatric abdominal injury patterns caused by "falls": a comparison between nonaccidental and accidental trauma. *J Pediatr Surg*. 2016;51(2):326–328.
56. Lindberg D, Makoroff K, Harper N, Laskey A, Bechtel K, Deye K, Shapiro RULTRA Investigators. Utility of hepatic transaminases to recognize abuse in children. *Pediatrics*. 2009;124(2):509–516.
57. Hilmes MA, Hernanz-Schulman M, Greeley CS, Piercey LM, Yu C, Kan JH. CT identification of abdominal injuries in abused pre-school-age children. *Pediatr Radiol*. 2011;41(5):643–651.
58. McMahon P, Grossman W, Gaffney M, Stanitski C. Soft-tissue injury as an indication of child abuse. *J Bone Joint Surg Am*. 1995;77(8):1179–1183.
59. Leventhal JM, Thomas SA, Rosenfield NS, Markowitz RI. Fractures in young children. Distinguishing child abuse from unintentional injuries. *Am J Dis Child*. 1993;147(1):87–92.
60. Leventhal JM, Martin KD, Asnes AG. Incidence of fractures attributable to abuse in young hospitalized children: results from analysis of a United States database. *Pediatrics*. 2008;122(3):599–604.
61. Leventhal JM, Martin KD, Asnes AG. Fractures and traumatic brain injuries: abuse versus accidents in a US database of hospitalized children. *Pediatrics*. 2010;126(1):e104–e115.
62. Maguire S. Which injuries may indicate child abuse? *Arch Dis Child Educ Pract Ed*. 2010;95(6):170–177.
63. Wood JN, Fakeye O, Feudtner C, Mondestin V, Localio R, Rubin DM. Development of guidelines for skeletal survey in young children with fractures. *Pediatrics*. 2014;134(1):45–53.
64. Pandya NK, Baldwin K, Wolfgruber H, Christian CW, Drummond DS, Hosalkar HS. Child abuse and orthopaedic injury patterns: analysis at a level I pediatric trauma center. *J Pediatr Orthop*. 2009;29(6):618–625.
65. Maguire S, Cowley L, Mann M, Kemp A. What does the recent literature add to identification and investigation of fractures in child abuse: an overview of review updates from 2005-2013. *Evidenced Based Child Health: A Cochrane Review Journal: Wiley Online Publisher*. 2013:2044–2057.
66. Kleinman PK, Perez-Rossello JM, Newton AW, Feldman HA, Kleinman PL. Prevalence of the classic metaphyseal lesion in infants at low versus high risk for abuse. *AJR Am J Roentgenol*. 2011;197(4):1005–1008.
67. Wood JN, Fakeye O, Mondestin V, Rubin DM, Localio R, Feudtner C. Prevalence of abuse among young children with femur fractures: a systematic review. *BMC Pediatr*. 2014;14:169.
68. Schwend RM, Werth C, Johnston A. Femur shaft fractures in toddlers and young children: rarely from child abuse. *J Pediatr Orthop*. 2000;20(4): 475–481.
69. Shelmerdine SC, Das R, Ingram MD, Negus S. Who are we missing? Too few skeletal surveys for children with humeral and femoral fractures. *Clin Radiol*. 2014;69(12):e512–e516.
70. Lindberg DM, Harper NS, Laskey AL, Berger RPExSTRA Investigators. Prevalence of abusive fractures of the hands, feet, spine, or pelvis on skeletal survey: perhaps "uncommon" is more common than suggested. *Pediatr Emerg Care*. 2013;29(1):26–29.
71. Section on Radiology, American Academy of Pediatrics. Diagnostic imaging of child abuse. *Pediatrics*. 2009;123(5):1430–1435.
72. Day F, Clegg S, McPhillips M, Mok J. A retrospective case series of skeletal surveys in children with suspected non-accidental injury. *J Clin Forensic Med*. 2006;13(2):55–59.
73. Zimmerman S, Makoroff K, Care M, Thomas A, Shapiro R. Utility of follow-up skeletal surveys in suspected child physical abuse evaluations. *Child Abuse Negl*. 2005;29(10):1075–1083.
74. 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(9):962–968.
75. Flaherty EG, Sege RD, Griffith J, Price LL, Wasserman R, Slora E, Dhepyasuwan N, Harris D, Norton D, Angelilli ML, et al. From suspicion of physical child abuse to reporting: primary care clinician decision-making. *Pediatrics*. 2008;122(3):611–619.
76. Rangel EL, Cook BS, Bennett BL, Shebesta K, Ying J, Falcone RA. Eliminating disparity in evaluation for abuse in infants with head injury: use of a screening guideline. *J Pediatr Surg*. 2009;44(6):1229–1234; discussion 34–5.
77. Bechtel K, Stoessel K, Leventhal JM, Ogle E, Teague B, Lavietes S, Banyas B, Allen K, Dziura J, Duncan C. Characteristics that distinguish accidental from abusive injury in hospitalized young children with head trauma. *Pediatrics*. 2004;114(1):165–168.
78. Christian CW. Committee on Child, Abuse Neglect, American Academy of Pediatrics. The evaluation of suspected child physical abuse. *Pediatrics*. 2015;135(5):e1337–e1354.
79. Maguire S, Hunter B, Hunter L, Sibert JR, Mann M, Kemp AM. Welsh Child Protection Systematic Review Group. Diagnosing abuse: a systematic review of torn frenum and other intra-oral injuries. *Arch Dis Child*. 2007;92(12): 1113–1117.
80. Welbury R. Torn labial frenum in isolation not pathognomonic of physical abuse. *Evid Based Dent*. 2007;8(3):71.

81. Kidd AJ, Beattie TF, Campbell-Hewson G. Frenal injury in children is not pathognomic of non-accidental injury. *Emerg Med J*. 2010;27(1):52.
82. Andreasen JO. Challenges in clinical dental traumatology. *Endod Dent Traumatol*. 1985;1(2):45–55.
83. Roaten JB, Partrick DA, Nydam TL, Bensard DD, Hendrickson RJ, Sirotnak AP, Karrer FM. Nonaccidental trauma is a major cause of morbidity and mortality among patients at a regional level 1 pediatric trauma center. *J Pediatr Surg*. 2006;41(12):2013–2015.
84. Stiell IG, Wells GA. Methodologic standards for the development of clinical decision rules in emergency medicine. *Ann Emerg Med*. 1999;33(4):437–447.
85. Bailhache M, Leroy V, Pillet P, Salmi LR. Is early detection of abused children possible?: a systematic review of the diagnostic accuracy of the identification of abused children. *BMC Pediatr*. 2013;13:202.
86. Higginbotham N, Lawson KA, Gettig K, Roth J, Hopper E, Higginbotham E, George TM, Maxson T, Edwards G, Garcia NM. Utility of a child abuse screening guideline in an urban pediatric emergency department. *J Trauma Acute Care Surg*. 2014;76(3):871–877.
87. Laskey AL, Stump TE, Hicks RA, Smith JL. Yield of skeletal surveys in children ≤ 18 months of age presenting with isolated skull fractures. *J Pediatr*. 2013;162(1):86–89.
88. Burrell T, Moffatt M, Toy S, Nielsen-Parker M, Anderst J. Preliminary development of a performance assessment tool for documentation of history taking in child physical abuse. *Pediatr Emerg Care*. 2016;32(10):675–681.
89. Newton AS, Zou B, Hamm MP, Curran J, Gupta S, Dumonceaux C, Lewis M. Improving child protection in the emergency department: a systematic review of professional interventions for health care providers. *Acad Emerg Med*. 2010;17(2):117–125.
90. Campbell KA, Olson LM, Keenan HT. Critical elements in the medical evaluation of suspected child physical abuse. *Pediatrics*. 2015;136(1): 35–43.
91. Dunstan FD, Guildea ZE, Kontos K, Kemp AM, Sibert JR. A scoring system for bruise patterns: a tool for identifying abuse. *Arch Dis Child*. 2002;86(5): 330–333.
92. Kemp AM, Maguire SA, Nuttall D, Collins P, Dunstan F. Bruising in children who are assessed for suspected physical abuse. *Arch Dis Child*. 2014;99(2): 108–113.
93. Kemper AR, Wallace DK, Quinn GE. Systematic review of digital imaging screening strategies for retinopathy of prematurity. *Pediatrics*. 2008;122(4): 825–830.
94. Woodman J, Pitt M, Wentz R, Taylor B, Hodes D, Gilbert RE. Performance of screening tests for child physical abuse in accident and emergency departments. *Health Technol Assess*. 2008;12(33):iii, xi-xiii 1–95.
95. Sittig JS, Uiterwaal CS, Moons KG, Russel IM, Nievelstein RA, Nieuwenhuis EE, van de Putte EM. Value of systematic detection of physical child abuse at emergency rooms: a cross-sectional diagnostic accuracy study. *BMJ Open*. 2016;6(3):e010788.

