



# STATE OF THE SCIENCE: SKULL FRACTURE AND INTRACRANIAL INJURY IN CHILDREN BELOW AGE 2

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**CE** Earn Up to 5.5 Hours. See page 592.

## Contribution to Emergency Nursing Practice

- The current literature indicates that children under age 2 are the most susceptible to skull fracture and intracranial injury in the pediatric population. However, specific variables to consider in the assessment of children of this age have not been widely disseminated to the nursing profession or within existing ED triage resources.
- This article contributes state-of-the-science information regarding the patient- and injury-specific variables that have been shown to be predictive of underlying skull fracture and intracranial injury in children below age 2 with suspected minor head injuries.
- Key implications for emergency nursing practice include that, for children below age 2, ED triage nurses should consider age in months, presence and size of any scalp hematoma, region of any scalp hematoma, and age-specific severity of injury mechanism in determining the risk of underlying skull fracture and intracranial injury.

## The Problem

A gap exists in the literature regarding the best practice for ED triage assessment in children below age 2 who have sustained suspected minor head injuries. Head injuries are a

frequent reason for children's ED visits,<sup>1,2</sup> and children below age 2 account for approximately 25% of these visits.<sup>3</sup> Although most children who present to emergency departments for evaluation of head injuries have not sustained underlying skull fractures or intracranial injury (closed head injury [CHI]), identifying those who may have sustained CHIs is important because secondary injuries (eg, increased bleeding or swelling of the brain) are more likely to occur when primary injuries are not identified. Unlike other injuries, CHIs cannot be identified by visual inspection alone. Assessing the risk of an underlying CHI in a child below age 2 who has presented to the emergency department for evaluation of a head injury can be challenging for nurses and medical providers, especially when the child is nonverbal.<sup>4</sup>

Although the definition of what is considered a "minor head injury" varies within the literature, the definition used for this article aligns with the definition used in the Pediatric Emergency Care Advanced Research Network (PECARN) Pediatric Head Injury Study,<sup>1</sup> the largest study of pediatric head injuries found in the literature. Suspected "minor head injury" refers to a head injury that occurred in the past 24 hours in a child with a Glasgow Coma Score (GCS) of 14 to 15, indicating a fully appropriate (15) or just slightly altered (14) mental status on examination. Proper identification of the risk for underlying CHI at the point of triage, which is the point of the initial ED assessment and prioritization, helps to reduce the risk of secondary injury while also aiding in the identification of inflicted injuries in children when the mechanism and injury characteristics do not clinically align.<sup>5</sup>

This article presents the state of the science regarding the patient- and injury-specific variables that have been shown to be predictive of underlying CHI in children below age 2 with suspected minor head injuries. Children whose injuries meet national trauma criteria,<sup>6</sup> regardless of how they arrive to the emergency department and how well they appear, are not included with those considered to have "suspected minor head injuries" because national trauma criteria independently delineate the necessity of specialized immediate care for patients who have sustained certain types of injuries known to carry high risks of loss of life or limb.

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## Methods

The literature was reviewed for relevant articles that addressed head-injury assessment in children below age 2. Databases used included PUBMED, CINAHL, The Cochrane Library, Web of Science, and Google Scholar. Primary key-word searches included *pediatric* or *children* or *infants*, *head injury*, *assessment*, *triage*, *emergency department*, and *nursing*. Limits were placed to narrow the search from 2014 to 2018 for the majority of the sources. However, selected seminal articles were also included to capture the derivation and validation studies of several clinical decision rules for pediatric head injuries,<sup>1,7-10</sup> as well as the US national trauma criteria<sup>6</sup> that were last updated in 2012. Also, a few unique articles focused on the biomechanics of infant falls or characteristics of infant skulls were also included because of a lack of more recent literature on the topic.

## Background

Several validated clinical decision rules<sup>1,7,8,10,11</sup> exist to help medical providers assess pediatric patients with a history of blunt head trauma, but the decision rules vary considerably in their terminology, the ages of their patients, the outcomes of interest, and the overall aims. Most of the decision rules are focused on guiding the neuroimaging decision and identifying injuries that require life-saving or surgical intervention. None of the current clinical decision rules are designed to aid the ED triage nurse in age-specific assessments and triage-acuity decisions for children below age 2.<sup>4</sup> The data regarding the specific variables to consider in the assessment of these children have not been widely disseminated to the nursing profession.<sup>4</sup> This is a problem because ED triage nurses are typically the first health care professionals to assess patients who present to emergency departments for evaluation, and they are tasked with acuity decisions that help to determine the initial prioritization of care.

## Results

Many children below age 2 who present to emergency departments for the evaluation of suspected minor head injuries are clinically asymptomatic, yet some of these children have sustained underlying CHIs.<sup>4,8,12</sup> Nationwide, approximately half of the children below age 2 who present to emergency departments for evaluation of head injuries receive neuroimaging (eg, computed tomography [CT] scans), of whom

approximately 10% have some degree of documented underlying CHI.<sup>13</sup> Only approximately 1% of children below age 2 who have sustained head injuries will have underlying CHIs requiring life-saving intervention; this increases to 4% for children of any age with altered mental status and/or known skull fractures.<sup>1</sup>

## TRIAGE ACCURACY

A study by Griffin et al<sup>4</sup> collected acuity-level information for 200 head-injured children aged 0 to 17 in a southeastern children's emergency department. Of the 100 children who sustained CHIs, only 42 (42%) had been assigned acuity levels considered "accurate," indicating at least an emergency severity index (ESI) 2 or "urgent" risk status, and most of the children who were considered clinically asymptomatic (20 of 35 children: 57%) were below age 2.<sup>4</sup> These data support the assertion that nurses who triage children need age-specific, evidence-based data at the point of care to help guide their assessments, risk stratification, and acuity decisions for head injuries, especially for children below age 2.

## Etiology of Head Injuries in Children Below Age 2

### FALLS

Falls are the most common mechanism of head injuries for children assessed in emergency departments<sup>13,14</sup> and are responsible for up to 80% of head injuries in children below age 2.<sup>14,15</sup> Many children of this age group "fall" because they are actually dropped by caregivers. Other common falls in children below age 2 include falling out of unsecured car seats, falling off beds, falling off sofas, and falling out of shopping carts.<sup>4,16</sup> Some falls are unwitnessed, which may contribute to delays in seeking care. The [Table](#) provides the average heights of some of the most common falls in children below age 2.

### ABUSIVE HEAD TRAUMA

Children below age 2 are at high risk for inflicted injury.<sup>17</sup> Up to two thirds of children who are victims of abusive head trauma are below 12 months of age,<sup>16,18</sup> with the peak age being below 3 months of age. Many of these children are brought to emergency departments with false histories of having fallen.<sup>16,18</sup>

TABLE  
Average height of common falls in children below age 2

Fall surface	Approximate height in inches/feet	Approximate height in meters
Sofa	18 to 20 inches (1.5 feet)	0.5 meter
Bed	18 to 36 inches (1.5 feet to 3 feet)	0.5 to 1 meter
Changing table	36 to 43 inches (3 feet to 3.5 feet)	0.5 to 1 meter
Counter	36 inches (3 feet)	1 meter
Shopping cart	36 to 42 inches (3 feet to 3.5 feet)	0.5 to 1 meter
Caregiver's arms	4 to 5 feet, depending on height of the adult	1.2 meters to 1.5 meters

Most cases of severe or fatal abusive head trauma involve diffuse brain injury vs focal injury.<sup>18,19</sup> It is important to note that if abuse did not include blunt impact, the injury may or may not be visible to the naked eye or on radiography. A retrospective study of data for 1,143 children below age 2 from 20 US Child Abuse Teams found that 19.7% (141 of 714) had sustained occult head injuries (visible on radiography) as part of their suspected abuse.<sup>20</sup> Subdural hematoma was the injury most commonly found in these cases (82 of 141), consistent with the findings of the study by Case et al, which concluded that subdural hematoma (regardless of whether it was visible on radiography) was the most common autopsy finding in 90% to 98% of the cases of abusive head trauma in this age group.<sup>19</sup> In summary, not all children who are victims of abusive head trauma will present with externally visible injuries. For those who do present with visible injuries, evidence-based triage assessment by nurses who are aware of developmentally appropriate injuries in children below age 2 can aid in the early identification of the abuse.

### Significance of Fall Characteristics

As falls represent the most common mechanism of head injuries in children, several studies have sought specifically to examine falls to determine which falls pose higher risks for sustaining underlying CHI in infants and young children.<sup>16,21,22</sup> Overall, the literature related to fall heights and surfaces indicates that falls—including being dropped by caregivers—are responsible for 70% to 80% of CHIs in children below age 2,<sup>5,14,22</sup> many of whom have few, if any, symptoms of injury other than scalp hematoma.<sup>5,22</sup> Studies also indicate that age in months, especially for

children below 12 months of age, is a major factor to consider when predicting risk of underlying CHI due to falls.<sup>4,18,21,23</sup> Although the literature is limited regarding specific fall surfaces, several studies have found that hard fall surfaces, such as concrete, are associated with a higher risk of CHI in children below age 2.<sup>16,21,24</sup>

Assessing the severity of the injury mechanism can be particularly challenging when a child has been injured as the result of a fall because the risk of CHI varies in relation to the child's height and the height of the fall, both of which are usually reported as estimates by caregivers. Children below age 2 typically lack the developmental ability to provide detailed histories of the falls and their symptoms following the fall. Some of these children have fallen from heights considered to be severe mechanisms of injury for this age group. However, this fact can be easily missed if the history and details of the fall are vague. In children below age 2, falls from more than 3 feet, such as falls from caregivers' arms and falls from shopping carts, are "severe" mechanisms of injury based on the PECARN criteria and represent the most common severe mechanism of injury in this age group.<sup>1,25</sup> This fact can be easily missed at the point of triage.

### Severity of the Injury Mechanism

Head injuries in children that require medical or surgical intervention are most often caused by severe injury mechanisms such as certain motor vehicle crashes (MVCs), bicycle accidents, and assaults including child abuse.<sup>5</sup> Many of the children injured in high-speed MVCs and other severe mechanisms are brought to emergency departments by emergency medical services from accident scenes and receive expedited care because they meet national trauma criteria.

For those who do not meet national trauma criteria, there are other resources—such as the Pediatric Emergency Care Advanced Research Network (PECARN) Head Injury Algorithm<sup>1</sup>—which define mild, moderate, and severe mechanisms of injury based on the risk of underlying skull fracture and/or intracranial injury, but this information is not present in existing ED triage nurse resources.

### Anatomical and Physiological Differences

In comparison with older children, children below age 2 have a higher risk for sustaining underlying CHIs secondary to minor head trauma owing to several anatomical and physiological differences.<sup>5,13,15,26</sup> The heads of children below age 2 are proportionately larger than the rest of their bodies; their neck muscles are weaker; and their motor abilities are underdeveloped, all of which contribute to a higher incidence of skull fracture in the first year of life when compared with older children.<sup>15,26</sup> As a result, their heads are more likely to hit surfaces when they fall, and their ability to change positions during falls or brace the falls is limited. The younger the child, the higher the risk of underlying CHI.<sup>1,4,8,15</sup>

The risk for CHI also varies based on the skull region injured, regardless of the child's age. For example, the frontal region has the lowest incidence of CHI compared with other regions in children age 0 to 17.<sup>1</sup> The temporal and parietal regions are often combined (known as the “temporal-parietal region” for identification purposes) because of their close proximity compared with other regions of the skull. The temporal-parietal region is in closer proximity to the middle meningeal artery, which is the major artery that perfuses the brain. The temporal region, in particular, includes an area near the ear that is the thinnest area of the skull<sup>17</sup> and is more likely to contribute to a higher incidence of fracture with blunt-force impact (such as by a baseball that hits a child's head). Thus, for patients of all ages, an injury to the temporal-parietal region is more likely to result in significant intracranial bleeding than an injury to another region.

Infants, generally considered to be children younger than 12 months of age, are at particularly high risk for certain hematomas and diffuse brain injury and swelling due to loose connections among the soft tissues of their heads.<sup>26</sup> Their softer and more pliable skulls—compared with those of older children and adults—also put infants at higher risk of depressed skull fractures.<sup>5,26</sup> Depressed skull fractures are more severe than linear and nondisplaced fractures because the bone displacement

can cause secondary trauma in the form of brain-tissue or vessel injury.

### SKULL FRACTURE VS INTRACRANIAL INJURY

Although the presence of skull fracture is a known predictor of an intracranial or brain injury,<sup>18</sup> skull fractures and intracranial injuries may also occur independently of one another. Signs of a possible underlying skull fracture that can be seen objectively by caregivers or health care providers include lacerations and hematomas of the scalp. In children below age 2, a scalp hematoma is often the only clinical sign of an underlying skull fracture.<sup>18</sup> The larger the hematoma, the higher the risk of an underlying skull fracture.<sup>1,2,18</sup>

### Signs and Symptoms

Children below age 2 who have sustained underlying CHIs are often clinically asymptomatic; they do not have any obvious altered mental status or other clinical signs or symptoms of injury other than—in some cases—hematomas.<sup>3-5,18</sup>

Classic symptoms of underlying CHIs in adults and older children (such as increased sleepiness, vomiting, and behavioral changes) can be normal assessment findings in children below age 2, based on developmental age.<sup>4,27</sup>

Obtunded or truly lethargic children below age 2 should be relatively easily identified by triage nurses owing to minimal responsiveness to stimulation and/or pain. However, subtle alterations in mental status may be more challenging to identify in infants and young children.

### VOMITING, ISOLATED LOSSES OF CONSCIOUSNESS, AND OTHER NEUROLOGIC SYMPTOMS

Although the results of previous studies are fairly consistent in showing that a loss of consciousness (LOC) and repeated vomiting are predictors of underlying CHI in children above age 2, data are mixed on their significance in children below age 2. Authors of the PECARN study, along with other secondary analyses,<sup>3,28</sup> have also challenged classic head injury assumptions such as the importance of vomiting and LOC in children below age 2. Data from the PECARN study also revealed that “3 or more episodes of vomiting” is a predictor for clinically important traumatic brain injury for children aged 2 to 17, yet did not report vomiting as a predictor at all in children below age 2.<sup>1</sup> One possible explanation for this is that an isolated episode of vomiting may be considered

a “normal” response to a head injury, occurring approximately 14% of the time.<sup>5</sup> Although vomiting could be a sign of increased intracranial pressure, and a history of vomiting after head trauma does represent an increased risk of intracranial injury to some degree, especially when accompanied by other symptoms,<sup>3,28</sup> it can also be difficult to differentiate from the normal spitting-up of some infants, unless it is projectile vomiting.

Some studies have also questioned the significance of an isolated LOC, typically defined as a LOC of less than 5 seconds following the injury, in children below age 2.<sup>4,29</sup> A secondary analysis of 40,693 children aged 0 to 17 with head injuries showed that an isolated LOC following blunt head trauma does not represent a significant risk factor for clinically important traumatic brain injury in children below age 2.<sup>29</sup> Whether this is because a brief LOC can be more difficult to identify in children below age 2, or because LOC does not occur as frequently in this age group, is unclear. However, as with vomiting, a history of LOC in conjunction with other symptoms was more concerning.<sup>29</sup> A limitation of the study is that the outcome measured was clinically important traumatic brain injuries (ciTBIs), which were only the most severe, life-threatening injuries. This contrasts with the circumstances most triage nurses are confronted with; triage nurses are challenged with identifying patients at moderate to high risk for any underlying CHI, not only the patients at risk for the most severe, life-threatening injuries. Other neurologic symptoms—such as headache, altered mental status, and amnesia—can be subtle, overlooked, or impossible to assess fully in children below age 2 by both caregivers and medical professionals. However, it is estimated that 3% to 10% of children below age 2 with suspected minor head injuries have sustained underlying CHIs.<sup>5</sup> Even linear skull fractures, which are the simplest, nondisplaced skull fractures, result in underlying intracranial injuries in approximately 15% to 30% of cases.<sup>5</sup>

### Implications for Nursing Practice

Determining the risk of CHI in children below age 2 requires that the triage nurse be able to assess the severity of the injury mechanism accurately, including familiarity with the scalp hematoma characteristics that place children of this age group at greater risk of CHI. As falls and being dropped are the most common mechanisms of injury for children below age 2, information at the point of triage regarding common fall heights for this age group (such as from a caregiver’s arms, bed, sofa, counter, or shopping cart) could be helpful in assessing the severity of the injury

mechanism accurately. The ED triage nurse should be aware that the definition of severe mechanism of injury is different for children age 2 vs children above age 2, specifically in regard to fall height. Having information at the point of care regarding the risks associated with the child’s age in months; hematoma presence, size, and location; and age-specific severity of injury would help ED triage nurses in their assessment and acuity decisions.

### Conclusion

Pediatric patients can be challenging to triage because of often atypical or subtle presentations for high-risk situations.<sup>4</sup> CHIs represent one of these high-risk situations. Based on the literature reviewed, variables that suggest a higher risk of underlying CHI in children below age 2 who have sustained head injuries include younger age (with 2 to 3 months of age and below considered the highest-risk age group); injuries to a nonfrontal area of the scalp (with the temporal-parietal region of the scalp representing the highest risk); the presence of any scalp hematoma; the size of any hematoma (with large or “boggy” hematomas representing the highest risk for underlying CHI); and a severe mechanism of injury (which includes a fall from over 3 feet for this age).<sup>1</sup>

### Author Disclosures

Conflicts of interest: none to report.

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