Evidence-Based Assessment And Management Of Pediatric Mild Traumatic Brain Injury

Abstract

Closed head injury (CHI) resulting in concussion accounts for half a million emergency department (ED) visits annually. Children aged 0 to 4 years and adolescents aged 15 to 19 years are most likely to sustain a traumatic brain injury. There is a 2:1 male-to-female preponderance of mild traumatic brain injury (MTBI) across all ages. Mild traumatic brain injury often presents with symptoms of concussion such as loss of consciousness (LOC), amnesia, confusion, headache, nausea, and vomiting; these symptoms should be evaluated for other potential etiologies. A pediatric Glasgow Coma Scale (GCS) score of 14 or below is concerning for clinically important traumatic brain injury (TBI), and CT scan is recommended. The American Academy of Pediatrics has recommended observation periods of 24 hours in children with CHI; however, with reliable families in close proximity to a hospital and with a well-appearing child, observation may occur at home.

Case Presentation

It is a busy Saturday afternoon in the ED. You are evaluating a 2-year-old girl who fell off a swing and hit the back of her head on the dirt approximately 3 feet below. She lost consciousness for 20 seconds, cried, and was consoled by her parents. She did not vomit, and her parents say that she...
seems to be back to her usual self. You approach the tearful toddler who has a 3 cm occipital cephalohematoma without step-off, laceration, or abrasion. Her vital signs are as follows: heart rate of 102 beats per minute, blood pressure of 95/57 mm Hg, respiratory rate of 18 breaths per minute, and normal pulse oximetry. Her GCS score is 15. She has no neurologic deficits on examination and cries inconsolably when you approach her. She does not appear to have any other injuries. Upon discussion with her parents, you find that she has no past medical history, her vaccinations are up to date, and she is not taking any medication. What are your next steps in evaluating this patient, and do they include observation or imaging? What does the “crying” mean? Does the patient have a headache or is she just terrified of being in the hospital? Does the time from injury affect your decision to observe her in the ED? In this tearful but otherwise well-appearing child, is exposure to ionizing radiation and potential sedation “worth it”?

**Introduction**

The rate of pediatric CHI is approximately 180 per 100,000 in the United States (US). The Centers for Disease Control and Prevention (CDC) has called TBI a public health problem in children. Traumatic brain injury accounts annually for 3000 deaths, 29,000 hospitalizations, and 473,947 ED visits in the US in children 14 years and younger. Although TBI is the leading cause of death in this population, 75% of pediatric CHIs may be classified as concussions due to MTBI. The diagnosis of MTBI and management of these patients is often challenging. The decision to discharge home, to observe in the ED, or to obtain immediate imaging in the well-appearing child is multifactorial. Ionizing radiation and its risk for potential malignancy in young patients as well as the risks of sedation that might be needed to obtain imaging are concerns that emergency clinicians should consider.

Many clinicians feel uncomfortable with the diagnosis of MTBI and use the term “concussion” interchangeably. Although the definitions of these two terms do overlap, their connotations have different meanings to discharged families, sports coaches, and healthcare providers. A recent study highlighted a general misinterpretation that an injury described as a concussion is less severe than one described as MTBI, which may result in a premature return to activity in a young athlete. In the age of highly competitive youth sports, what discharge recommendations and precautions can we give to families with children who are eager to return to play? Often, the emergency clinician refers to medical clearance by follow up with primary medical doctors (PMDs), sports physicians, or neurologists in the concussed athlete. It is unrealistic to assume that such precautions will be heeded without education of the risks of postconcussive syndrome and second impact syndrome in the ED. Additionally, medical follow up after concussion in the pediatric nonathlete is of equal importance.

This issue of Pediatric Emergency Medicine Practice will discuss the evaluation and management of pediatric patients with MTBI using the best available evidence from the literature. In addition to discussing a variety of recent studies, we will also review management practice guidelines from the American Academy of Pediatrics, the American College of Emergency Physicians, and the Children’s Hospital of Philadelphia. (See Table 1.)

**Critical Appraisal Of The Literature**

The literature review was launched with Ovid MEDLINE® and PubMed searches for articles on mild traumatic brain injury from 1950-2011. Keywords included: mild traumatic brain injury, traumatic brain injury, concussion, postconcussive syndrome, second impact syndrome, and closed head injury. These articles were limited to all infants and all children ages 0 to 18 years. This search yielded 4392 articles. Eighty-four of these articles are included as the basis for the discussion in this publication, with the oldest published in 1992. They comprise a growing body of literature of clinical trials, multicenter observational studies, and meta-analyses that have resulted in multiple practice guidelines for pediatric MTBI and concussion. In 2010, the American Academy of Pediatrics published an in-depth report on sports-related concussion in children.
The Mild Traumatic Brain Injury Committee of the American Congress of Rehabilitation Medicine has defined MTBI as a “traumatically induced physiological disruption of brain function, as manifested by a least 1 of the following:

1. Any period of loss of consciousness;
2. Any loss of memory for events immediately before or after the accident;
3. Any alteration in mental state at the time of the accident (eg feeling dazed, disoriented or confused); and
4. Focal neurological deficit(s) that may or may not be transient, but where the severity of the injury does not exceed the following:

- Posttraumatic amnesia not greater than 24 hours;
- After 30 minutes, an initial GCS score of 13 to 15; and
- Loss of consciousness of approximately 30 minutes or less.\(^8\)

The Children’s Hospital of Philadelphia Practice Guidelines further define pediatric MTBI in children with a GCS score of 14 to 15 at the initial examination without focal neurologic deficits.\(^7\) The American Academy of Neurology Concussion states that concussion is a “trauma-induced alteration in mental status that may or may not involve a loss of consciousness” and is attributable to mild-to-severe symptoms associated with TBI.\(^9\) There is overlap in

<table>
<thead>
<tr>
<th>Table 1. Practice Parameters For Mild Traumatic Brain Injury</th>
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<td>Organization</td>
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<td>American Academy of Pediatrics(^5)</td>
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<td>American College of Emergency Physicians(^6)</td>
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Abbreviations: CHI, closed head injury; CT, computed tomography; ED, emergency department; LOC, loss of consciousness; MRI, magnetic resonance imaging; MTBI, mild traumatic brain injury; TBI, traumatic brain injury.
these definitions and recent literature uses MTBI and concussion interchangeably.

Arguably, we are contributing to potential under-management by assigning a diagnosis of concussion due to symptomatology without a specific diagnosis of TBI severity. In a recent study, parents who did not equate MTBI and concussion regarded the latter as considerably “better” than MTBI. In a prospective cohort of 434 pediatric patients with TBI, Dematteo found that out of the 32% diagnosed with concussion, only 37% had a GCS score of 13 to 15. Pediatric patients with moderate to severe TBI are also diagnosed with concussion. Clinicians caring for pediatric patients and their families must come to a consensus on terminology related to pediatric CHI. In light of this argument, the remainder of our discussion will refer to MTBI as the injury pathology with concussion referring to symptomatology.

Closed head injury resulting in concussion is a very common pediatric complaint, accounting for half a million ED visits annually. Children aged 0 to 4 years and adolescents aged 15 to 19 years are most likely to sustain a TBI. There is a 2:1 male-to-female preponderance of MTBI across all ages. Boys aged 0 to 4 years have the highest rates of TBI-related ED visits, hospitalizations, and deaths.

The CDC reports that falls are the leading cause (50%) of TBI among children aged 0 to 14 years. Collisions with moving or stationary objects (including motor vehicle collisions) are the second leading cause of TBI in children (25%). Nonaccidental trauma (NAT) is responsible for 2.9% of reported TBIs and is important to consider in the differential diagnosis in all children with head injury, especially in those 2 years and younger.

Thirty million American children participate in athletic programs each year, and sports-related TBI occurs frequently. Each year, EDs in the US treat an estimated 135,000 sports- and recreation-related TBIs among children ages 5 to 18.

In 1999, Powell et al evaluated data of over 23,000 reported sports injuries from the National Athletic Trainer Association (NATA) injury surveillance program of high school sports and identified 1217 MTBIs. Out of the 10 popular high school sports evaluated, football accounted for the majority of reported MTBIs (63.4%), followed by wrestling (10.5%). (See Table 2.)

It has been shown that under-reporting of youth concussions in organized play occurs often, and epidemiologic data of such injuries is difficult to accurately describe. The NATA injury surveillance program describes a reportable MTBI as an injury identified by a certified athletic trainer requiring the cessation of a player’s participation for evaluation and observation before returning to play. However, in competitive youth sports, coaches and players may be hesitant to report injuries for fear of absence from play. In a case series of 592 children by Browne et al, severe concussive head injuries are 6 times more likely to have resulted from organized sports than simple play. Additionally, the incidence of serious head injury is higher in young athletes than in adults. High school athletes sustaining concussion as compared to college athletes had longer memory dysfunction and scored lower on neuropsychological evaluations. Second impact syndrome is a serious concern in this active population.

The neurobiochemical mechanisms of MTBI manifestations are related to biochemical derangements marked by reactive oxygen species mediated damage, energy metabolism depression, and alteration of gene expression potentially leading to a variation of N-acetylaspartate (NAA) concentration. N-acetylaspartate is found in high concentrations in the brain, is visible by proton magnetic resonance (MR) spectroscopy, and is decreased in situations of TBI. Studies evaluating the usage of proton MR spectroscopy to mark concussion resolution are underway. Persisting learning impairments following MTBI are attributed to enhancements of gamma-amnobutyric acid (GABA)-mediated inhibition that suppresses a type of synaptic plasticity. Animal models have been employed to gather such data to relate to pediatric MTBI.

**Differential Diagnosis**

The differential diagnosis of MTBI is clinically focused on more ominous sequelae of CHI such as moderate or severe TBI. Since MTBI often presents with symptoms of concussion such as LOC, amnesia, confusion, headache, nausea, and vomiting, these symptoms should be evaluated for other potential etiologies. See Table 3 for the differential diagnosis for MTBI and strategies to rule these out.

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### Table 2. Incidence Of Reported Mild Traumatic Brain Injury In High School Sports

<table>
<thead>
<tr>
<th>Sport</th>
<th>% Total Reported MTBIs</th>
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<tbody>
<tr>
<td>Football</td>
<td>63.4%</td>
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<tr>
<td>Wrestling</td>
<td>10.5%</td>
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<tr>
<td>Girls’ soccer</td>
<td>6.2%</td>
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<tr>
<td>Boys’ soccer</td>
<td>5.7%</td>
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<tr>
<td>Girls’ basketball</td>
<td>5.2%</td>
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<tr>
<td>Boys’ basketball</td>
<td>4.2%</td>
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<tr>
<td>Softball</td>
<td>2.1%</td>
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<tr>
<td>Baseball</td>
<td>1.2%</td>
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<tr>
<td>Field hockey</td>
<td>1.1%</td>
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<tr>
<td>Volleyball</td>
<td>0.5%</td>
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</table>
Prehospital Care

The prehospital care of pediatric CHI does not necessarily start with emergency medical services (EMS). Many school nurses, gym teachers, and athletic trainers are educated to identify concussive symptoms. A position statement by NATA recommended that institutions that sponsor athletic activities establish emergency response plans including written emergency plans and the education/training of school personnel that coordinate care with local EMS. The American Academy of Pediatrics (AAP) Committee on School Health guidelines state a need for school leaders to establish emergency response plans as well as maintain school personnel including nurses and athletic trainers educated in emergency response training and emergency care.

Prehospital care is focused on stabilization and identification of potentially serious injury. Pediatric patients who have sustained an MTBI are generally awake and maintaining their airway upon EMS arrival. Standard initial assessment of airway, breathing, circulation, and disability (ABCD) should be completed regardless of seemingly well appearance. Children with CHI and symptoms of concussion are at risk of having life-threatening injuries such as intracranial hemorrhage (ICH), cervical spine fractures, or facial fractures contributing to airway obstruction. The appropriate evaluation with immobilization during transport is necessary if cervical spine or other relevant injuries are suspected. This may be more challenging in younger patients as demonstrated in a study by Collopy evaluating EMS interventions in children with head, neck, and face injuries. The authors found that C-collar placement was less commonly implemented for children younger than 5. The National Emergency Medical Services Education Standards provides paramedics with guidelines and protocols including the evaluation of pediatric CHI and related considerations.

Emergency Department Evaluation

History

Kelly et al described 3 issues to be addressed in the management of the concussed patient: (1) the appropriate management of the injured athlete at the time of injury to identify potential neurosurgical emergencies (epidural, subdural, and intracerebral hemorrhages), (2) the prevention of catastrophic outcome related to acute brain swelling, and (3) the avoidance of cumulative brain injury related to repeated concussions. In evaluating a patient with concussive symptoms, the clinician should address and exclude these issues in order to diagnose MTBI.

The ED evaluation of the pediatric patient with CHI and suspected MTBI relies on historical description as well as physical findings to lend to our clinical assessment. Much of our evidence-based data comes from studies by the Pediatric Emergency Care Applied Research Network (PECARN) as well as a large meta-analysis by Dunning in 2004 describing the findings of 16 papers to assess factors in the presentation of ICH in children with CHI. Dunning went on to publish the children’s head injury algorithm for the prediction of important clinical events (CHALICE). This study examined 14 clinical variables, which are listed in Table 4. Importantly, the CHALICE study did not exclude patients with moderate or severe head injury; hence, the algorithm is most valuable for its negative predictive value. Additionally, the Canadian CATCH study developed decision rules to evaluate the use of head CT in minor CHI, though these rules have yet to be validated.

In 2009, PECARN derived and validated clinical prediction rules for children at very low risk of clinically important TBI. They defined clinically important TBI as “death from TBI, neurosurgery, intubation for more than 24 hours due to TBI, or hospital admission of 2 nights or more associated with TBI on CT.” The study evaluated over 40,000 children presenting to the ED within 24 hours of CHI and with a GCS score of 14 to 15. It assessed the following potential predictors: severity of injury mechanism, history of LOC, duration of LOC, headache, severity of headache, vomiting and number of times, acting abnormally according to parent,
Table 4. CHALICE Clinical Variables

<table>
<thead>
<tr>
<th>LOC &gt; 5 minutes</th>
<th>Amnesia &gt; 5 minutes</th>
<th>Drowsiness</th>
<th>Vomiting &gt; 2 times</th>
<th>Suspicion of NAT</th>
<th>Seizure</th>
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<tbody>
<tr>
<td>GCS score &lt; 14, or &lt; 15 if under 1 year old</td>
<td>Suspicion of penetrating or depressed skull injury or tense fontanelle</td>
<td>Signs of basilar skull fracture</td>
<td>Neurologic deficit</td>
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<tr>
<td>Cephalohematoma or laceration &gt; 5 cm in children &lt; 1 year old</td>
<td>High-speed accident</td>
<td>Fall &gt; 3 meters</td>
<td>High-speed injury from projectile</td>
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Abbreviations: GCS, Glasgow Coma Scale; LOC, loss of consciousness; NAT, nonaccidental trauma.
et al evaluated children younger than 2 years of age and found that increasing height of fall had a higher incidence of ICH or skull fracture but also noted that 7% of the children who fell less than 3 feet also had these injuries. Severe mechanism of injury places the child at higher risk for all types of TBI. Similarly, mild mechanism of injury does not rule out the possibility of ICH.

### Loss Of Consciousness
Most clinicians are concerned by a history of LOC and its duration. It has been reported that traumatic brain injury occurs more commonly in children with a history of LOC than those without. The CHALICE rules recommend CT imaging in children with LOC greater than 5 minutes.

Often, a history of LOC post head injury occurs in isolation of other signs and symptoms. In a single-center study by Palchak, 142 children presented with isolated LOC or amnesia, and none of them had clinically important TBI. Of note, 9.4% of those with LOC or amnesia in addition to other symptoms (i.e., not isolated LOC or amnesia) after CHI did have findings on CT. In PECARN’s abstract of secondary analysis of isolated LOC following blunt head injury, it was reported that the risk of TBI is very small; 4 of 790 children with isolated LOC had positive CT findings with only 1 requiring intervention. The authors concluded that LOC should not drive the decision to obtain imaging when it occurs in isolation.

### Vomiting
The large meta-analysis by Dunning found that vomiting was not a predictor of ICH. In fact, this analysis showed that even repeated vomiting over a limited period of time may not be more significant than a single emesis. The limitations of this analysis included the lack of documentation of duration for observation of vomiting. Dunning et al later published the prospective CHALICE rules that recommend CT in children with CHI and history of vomiting 3 or more times.

In an abstract presented by PECARN, preliminary data suggested that 1.7% of children with isolated vomiting had TBI on CT, while 0.2% required intervention. In this study, the risk of TBI did not seem to increase with increased number of vomiting episodes. In a large study of adults and children by Nee et al in 1999, there was an increased relative risk of skull fracture in patients with head injury and vomiting. However, this study also demonstrated that a single episode of vomiting was as significant as multiple episodes. These studies challenge our concern for the number of episodes of emesis.

### History Of Seizure
Posttraumatic seizures occur in less than 10% of pediatric head injuries, most commonly with severe TBI, but can occur after minor CHI. In a study by Holmes et al, 52 children who sustained blunt head trauma and posttraumatic seizure with a negative head CT in the ED were evaluated for neurologic sequelae, and none had neurologic deterioration or required neurosurgical intervention. Of note, 7 children of the 20 who were hospitalized received phenytoin, and it is unclear if this had an effect. The authors support that such a population may be safely considered for discharge from the ED, though the study was limited by its small sample size. The CHALICE rules recommend CT imaging in children without history of epilepsy who sustain a seizure after CHI.

### Past Medical History
It is important to elicit a thorough past medical history in patients presenting to the ED with a history of minor head trauma. Seizure disorders, history of syncope, or stroke could be the underlying cause of trauma due to fall. A history of previous head injury or symptoms of concussion should heighten the emergency clinician’s concern for TBI sequelae such as second impact syndrome.

Patients with congenital or acquired bleeding disorders are at increased risk of ICH after minor head injuries. However, it is important to note that most of these patients will be symptomatic if ICH is present. A secondary analysis of the PECARN study by Lee compared head CT results after CHI in 230 children with bleeding disorders and almost 15,000 children without. They found that head CTs were obtained in this population twice as often, though there was not a higher incidence of positive findings. This study confirms that children with bleeding disorders sustaining head injury with ICH are generally symptomatic.

### Medications
A history of medication use and abuse contributes to potential secondary causes for head injury and symptoms of concussion such as with fall after acute alcohol intoxication. Additionally, anticoagulant use (warfarin for example) furthers the likelihood of ICH in MTBI. A 2011 study from the Journal of Trauma highlights a relationship between high INR (international normalized ratio) (with a suggested cutoff value of 2.43) and likelihood of ICH, with a negative predictive value of 97%.

### Physical Examination
Important physical findings in the patient with suspected MTBI include: vital signs assessment, GCS score and neurologic examination, presence of cephalohematoma or skull abnormality, and evaluation of other injuries that may prove to be distractors from TBI or may suggest NAT.
Cephalohematoma
An abstract of a secondary analysis by PECARN concluded that there is a low risk (0.5%) of clinically important TBI in children less than 2 years of age with isolated scalp hematomas. However, it was noted that the likelihood of TBI on CT was higher in those children less than 3 months (20%, with 1.9% requiring intervention) and those with large temporal-parietal cephalohematomas.45 The CHALICE rules recommend CT in patients less than 1 year of age with the presence of a bruise, swelling, or laceration > 5 cm after CHI.28 The CATCH rules attribute a “medium risk” of TBI on CT (though not as likely to necessitate neurologic intervention) in children with large, boggy cephalohematomas after CHI.29 Simon et al refers to frontal cephalohematomas as potentially obscuring palpable skull fractures.46

Suggestion Of Skull Fracture
Skull fracture is often difficult to assess for on clinical examination. Large cephalohematomas can easily obscure any step off that would suggest cranial abnormality as in displaced skull fracture. Meanwhile, linear non-displaced fractures would be difficult to ascertain upon palpation. The CHALICE rules defined signs of basilar skull fracture to include blood or cerebrospinal fluid (CSF) from ear or nose, periorbital ecchymosis, Battle sign, hemotympanum, facial crepitus, or serious facial injury.28 A cerebrospinal fluid leak as a manifestation of rhinorrhea or otorrhea suggests basilar skull fracture and can be confirmed with a beta-2-transferrin assay when there is clinical suspicion. In a large meta-analysis, it was reported that the presence of skull fracture increases the risk of intracranial injury by 4 times.25 PECARN’s 2009 Lancet study as well as the CHALICE rules found that children with signs of skull fracture have a higher risk of clinically important TBI and should be imaged.28,30 The CATCH rules report that children with suspected open or displaced skull fracture have a high likelihood of the need for neurologic intervention; therefore, these patients require CT imaging.29 Patients with signs of basilar skull fracture are attributed a medium risk.

Glasgow Coma Scale Score
Recent literature indicates that children with CHI and a GCS score < 14 have a risk of more than 20% of TBI on head CT, justifying the risk of radiation associated with obtaining a head CT scan.28,47 Initially, the American Congress of Rehabilitation Medicine’s definition of MTBI included a GCS score of ≥ 13, which is supported by adult studies. However, the 2003 Children’s Hospital of Philadelphia pediatric MTBI practice guidelines rejected incorporating a GCS score of ≤ 13 into the MTBI algorithm as a large review had shown that 33.8% of patients with a GCS score of 13 had an intracranial lesion and 10.8% required emergency surgery.48 Dietrich et al reminds us that a normal GCS score is not a reliable indicator of the absence of TBI.49 Notably, the CATCH rules recommended CT scanning in any child with a GCS score < 15 2 hours after the injury, and the CHALICE rules recommend imaging in children less than 1 year with a GCS score < 15 or 1 year and older with a GCS score < 14.28,29

Diagnostic Studies

Laboratory Testing
There is little support for laboratory testing in identifying MTBI. However, studies investigating biochemical “brain biomarkers” are underway. An ideal brain biomarker would be measurable in the serum after TBI and correlate with brain injury. Current biomarkers being studied include: S100B, D-dimer, myelin basic protein, and neuronal specific enolase. These biomarkers will be discussed in the Cutting Edge section of this review.

Specific evaluation with routine laboratory tests such as CBC or electrolytes is not useful in MTBI but rather more useful in evaluating for differential diagnosis such as bleeding disorders or seizure or the presence of other traumatic injuries.

Imaging

Head Computed Tomography
Currently, as many as 50% of children assessed for head trauma in North American EDs undergo head CT scanning.50 It remains the best test to evaluate for traumatic intracranial pathology in the acute setting as it is obtained in minutes, rarely requires sedation, and is accurate for ICH and skull fracture. Notably, with strict adherence to the CHALICE rules, the recommended head CT rate is increased. In the implementation study of the CHALICE rules, application of the guideline resulted in an extra 21 (4.6%) scans as compared to pre-existing guidelines.51 Similarly, an Australian study implementing the CHALICE rules found that its application doubled the proportion of scans.52 Several large studies have sought to create guidelines for the decision to obtain a head CT after pediatric CHI, and these are summarized in Table 5.

It is important to consider that children are 10 times more radiosensitive than adults and that CT imaging carries a risk of subsequent malignancy extrapolated as 1 fatal cancer per 1000 to 5000 pediatric head CT examinations.53,54 This malignancy risk is extrapolated from data on Japan’s atomic bomb survivors; for this reason, it is not universally accepted by radiologists. Regardless, using radiation amounts “as low as reasonably achievable” (ALARA) is desired; emergency clinicians in nonpediatric hospitals must consider that an adult-protocolled head CT scan delivers twice the amount of radiation as a similar pediatric-protocolled scan.55 The National
Figure 1. Suggested CT Algorithm For Children Younger Than 2 Years (A) And For Those Aged 2 Years And Older (B) With GCS Score Of 14–15 After Head Trauma*

### A

- **GCS score=14 or other signs of altered mental status† or palpable skull fracture**
  - **YES**: 13.9% of population
    - 4.4% risk of ciTBI
  - **NO**: 53.5% of population
    - < 0.02% risk of ciTBI
  - **CT not recommended§

- **Occipital, parietal, or temporal scalp haematoma; history of LOC ≥ 5 seconds; severe mechanism of injury‡; or not acting normally per parent**
  - **YES**: 32.6% of population
    - 0.9% risk of ciTBI
  - **NO**: 4.4% of population
    - < 0.02% risk of ciTBI
  - **CT recommended

### B

- **GCS score=14 or other signs of altered mental status† or signs of basilar skull fracture**
  - **YES**: 14.0% of population
    - 4.3% risk of ciTBI
  - **NO**: 58.3% of population
    - < 0.05% risk of ciTBI
  - **CT not recommended§

- **History of LOC, history of vomiting, severe mechanism of injury‡ or severe headache**
  - **YES**: 27.7% of population
    - 0.9% risk of ciTBI
  - **NO**: 32.6% of population
    - < 0.02% risk of ciTBI
  - **CT recommended

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**Observation versus CT on the basis of other clinical factors including:**
- Physician experience
- Multiple versus isolated§ findings
- Worsening symptoms or signs after emergency department observation
- Age < 3 months
- Parental preference

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**Abbreviations:** ciTBI, clinically important traumatic brain injury; GCS, Glasgow Coma Scale; LOC, loss of consciousness.

*Data are from the combined derivation and validation populations.

†Other signs of altered mental status: agitation, somnolence, repetitive questioning, or slow response to verbal communication.

‡Severe mechanism of injury: motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorized vehicle; falls of more than 0.9 m (3 feet) (or more than 1.5 m [5 feet] for panel B); or head struck by a high-impact object.

§Patients with certain isolated findings (ie, with no other findings suggestive of traumatic brain injury), such as isolated LOC, isolated headache, isolated vomiting, and certain types of isolated scalp haematomas in infants older than 3 months, have a risk of ciTBI substantially lower than 1%.

¶Risk of ciTBI exceedingly low, generally lower than risk of CT-induced malignancies. Therefore, CT scans are not indicated for most patients in this group.

<table>
<thead>
<tr>
<th>Study</th>
<th>Criteria</th>
<th>Variables/Predictors of Decision Rule</th>
<th>Study Design</th>
<th># of Patients</th>
<th>Results</th>
</tr>
</thead>
</table>
• Acute minor head injury  
• GCS score 13-15  
• 10 pediatric hospitals in Canada | • GCS score < 15 within 2 hours  
• Suspicion of open skull fracture  
• Worsening headache  
• Worsening irritability | Prospective cohort | 3866 | Prediction of the need for neurologic intervention and requiring CT imaging:  
Sensitivity: 97.9%  
Specificity: 70.2% |
• CHI within the last 24 hours  
• GCS score 14-15  
• 25 PECARN EDs | • Severe injury mechanism  
• History of LOC or LOC > 5 seconds  
• Severe headache  
• History of vomiting  
• Acting abnormally per parents  
• GCS score 14-15  
• Altered mental status  
• Signs of basilar skull fracture or palpable skull fracture  
• Nonfrontal scalp hematoma | Prospective cohort, derived and validated | 42,412 | Validation  
Children < 2 years old (normal mental status, no scalp hematoma except frontal, no LOC or LOC < 5 seconds, nonsevere injury mechanism, no palpable skull fracture, and acting normally according to the parents):  
NPV 100%  
Sensitivity 100%  
Children ≥ 2 years (normal mental status, no LOC, no vomiting, non-severe injury mechanism, no signs of basilar skull fracture, and no severe headache):  
NPV 99.9%  
Sensitivity 96.8% |
• Minor head trauma  
• 4 US pediatric EDs | • Dizziness  
• Skull defect  
• Sensory deficit  
• Mental status change  
• Bicycle-related injury  
• < 2 years old  
• GCS score < 15  
• Evidence of a basilar skull fracture | Prospective observational study | 1000 | For detection of intracranial injury:  
Sensitivity 95.4%  
Specificity 48.9%  
NPV 99.3% |
• NEXUS II pediatric cohort  
• Acute blunt head trauma  
• 21 US EDs | • Abnormal mental status  
• Signs of skull fracture  
• Scalp hematoma in children ≤ 2 years old  
• High-risk vomiting  
• Severe headache | Retrospective cohort | 1666 | For detection of significant intracranial injury:  
Sensitivity 90.4%  
Specificity 42.7% |
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| Dunning J, Daly JP, Lomas JP, et al. Derivation of the children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children. *Arch Dis Child.* 2006;91(11):885–891. | • < 16 years old  • Any severity CHI  • 10 EDs in England | • LOC > 5 minutes  • Amnesia > 5 minutes  • Drowsiness  • Vomiting ≥ 3 times  • Suspicion of NCT  • Seizure after injury  • GCS score < 14 or GCS score >15 if < 1 year  • Penetrating or depressed skull injury  • Suspected or tense fontanel  • Signs of basilar skull fracture  • Positive focal neurology  • Bruise, swelling, or laceration ≥ 5 cm if < 1 year  • Road traffic crash at > 40 miles per hour  • Fall from > 3 m  • Injury from a high-speed projectile | Prospective cohort | 22,772 | For the prediction of clinically significant head injury:  
Sensitivity 98%  
Specificity 87%  
NPV 99.9% |
| Oman JA, Cooper RJ, Holmes JP, et al; NEXUS II Investigators. Performance of a decision rule to predict need for computed tomography among children with blunt head trauma. *Pediatrics.* 2006;117(2):e238-246. | • < 18 years old  • Closed head trauma  • 21 NEXUS II centers | • Evidence of significant skull fracture  • Altered level of alertness  • Neurologic deficit  • Persistent vomiting  • Scalp hematoma  • Abnormal behavior  • Coagulopathy | Retrospective cohort analysis | 1666 | Identification of clinically important intracranial injury in children < 3 years old:  
Sensitivity 98.6%  
Low-risk classification:  
NPV 100%  
Specificity 5.3%  
All children:  
Sensitivity 99.6%  
Low-risk classification:  
NPV 99.1%  
Specificity 15.1% |
| Da Dalt L, Marchi AG, Laudizi L, et al. Predictors of intracranial injuries in children after blunt head trauma. *Eur J Pediatr.* 2006;165(3):142–148. | • < 16 years old  • Acute closed head trauma  • 5 Italian pediatric EDs | • LOC > 20 seconds  • Persistent drowsiness  • Amnesia  • GCS score < 15  • Prolonged headache  • Clinical evidence of basilar or nonfrontal skull fracture | Prospective cohort | 3806 | For the prediction of intracranial injuries in children after blunt head trauma:  
Sensitivity 100%  
Specificity 73%  
NPV 100% |
| Haydel MJ, Shembekar AD. Prediction of intracranial injury in children aged 5 years and older with loss of consciousness after minor head injury due to nontrivial mechanisms. *Ann Emerg Med.* 2003;42(4):507–514. | • 5 to 17 years old  • Major mechanism of injury  • GCS score 15  • Normal neurological examination  • + LOC  • CT head imaging | • Headache  • Emesis  • Intoxication  • Seizure  • Memory deficit  • Trauma above clavicles | Prospective questionnaire | 175 | The presence of any of the 6 criteria was associated with an abnormal CT result:  
P < 0.05  
Identification of patients with ICI:  
Sensitivity 100% |
| Palchak MJ, Holmes JF, Vance CW, et al. A decision rule for identifying children at low risk for brain injuries after blunt head trauma. *Ann Emerg Med.* 2003;42(4):492–506. | • < 18 years old  • Blunt head trauma  • 1 US pediatric ED | • Abnormal mental status  • Signs of skull fracture  • Scalp hematoma if ≥ 2 years  • History of vomiting | Prospective observational cohort | 2043 | The presence of any of the 4 predictors for TBI on CT:  
Sensitivity 94.9%  
Specificity 49.5%  
Absence of all 4 predictors:  
NPV 99.6% |

Abbreviations: CHI, closed head injury; CT, computed tomography; ED, emergency department; GCS, Glasgow Coma Scale; LOC, loss of consciousness; NAT, nonaccidental trauma; NPV, negative predictive value.
1. "I am concerned about child abuse, but this patient does not have current signs of MTBI." If there is any suspicion of nonaccidental trauma, the pediatric patient warrants a head CT for evaluation of acute as well as old intracranial injury. Physicians are required to report a suspicion of child abuse, not to prove the etiology.84

2. "Though the patient appears well and there wasn’t a suspicious history of severe injury, I am not comfortable with discharge unless I obtain a head CT to rule out injury.” Ordering imaging studies without true indications to completely rule out a diagnosis is a practice of defensive medicine that is not in the patient’s best interest nor is it cost efficient.85

3. "It’s the PMD’s job to discuss concussion management.” The emergency clinician is responsible for providing discharge instructions and return to activities information as well as recommended appropriate follow up.

4. “I will order the head CT because I don’t want to miss something and be sued.” Doctors with a higher fear of malpractice order more head CTs in pediatric patients with minor head injury.86 Such practices have been termed “defensive medicine” and are not in the patient’s best interest. Radiation exposure carries a risk of future malignancy which may be legally implicating in a patient who develops such a malignancy with identification of excessive scanning in the past.

5. “The patient has a mild head injury and seems well. Although there was a similar injury last week, this patient likely does not have TBI.” Second impact syndrome is an important concern for the re-injured concussive patient. The threshold to obtain imaging in a symptomatic patient with repeat injury should be lower.

6. “There’s a large cephalohematoma, but it’s frontal, so I am less concerned for skull fracture.” Large cephalohematomas may hinder identification of palpable skull fracture regardless of their location.

7. “The 7-year-old boy who hit his head while skateboarding appears well, despite vomiting. We can send him home with an antiemetic and pain medication.” Take caution in discharging an older child with an antiemetic after CHI that has not been evaluated with head CT, since vomiting may be an indicator of intracranial process.

8. “A 5-year-old boy who came to the ED after falling off his tricycle was diagnosed with an upper respiratory infection. He appeared well without cephalohematoma or vomiting and was sent home, but he returned the next day with vomiting and was found to have a basilar skull fracture.” Cerebrospinal fluid rhinorrhea or otorrhea is a sign of basilar skull fracture. Children who have these signs should have the fluid tested for the presence of CSF.

9. “A 5-month-old baby who rolled off the bed is now lethargic, has a large parietal cephalohematoma, and has been intubated. We do not have neurosurgery or PICU in our community hospital. I will obtain a head CT to confirm ICH prior to transfer.” If there is a suspicion for a medical condition that is not best managed in your institution, transfer to the appropriate facility should be discussed as soon as possible and should not be delayed for imaging.

10. “This family appears reliable to monitor the patient with a CHI and concussive symptoms at home.” It is the emergency clinician’s responsibility: (1) to ensure that the patient has a primary medical provider to follow up with, (2) to discuss a course of action with the patient’s family in the event of return to the ED, (3) to ensure that the family has a way to get to the hospital, and (4) to discuss returning to the nearest facility in case of an emergency.
Cancer Institute reports that a single unadjusted head CT (200 mAs) produces 1.8 to 3.8 mSv of radiation while a pediatric-adjusted head CT (100 mAs) produces 0.9 to 1.9 mSv.65

The decision to obtain a head CT need not be immediate if indications are unclear. Nigrovic et al studied approximately 40,000 children with minor blunt head trauma, comparing a subset of 5433 who were observed. It was found that the rate of head CT in those observed was 31.1% as compared to 35% in those not observed, supporting clinical monitoring as a factor in the decision to obtain head CT.34

Brain Magnetic Resonance Imaging
Sigmund et al published a prospective cohort of 40 pediatric patients with TBI examining the value of 4 different imaging modalities: CT, T2-weighted MRI, fluid-attenuated inversion recovery (FLAIR) MRI, and susceptibility-weighted imaging (SWI) MRI.62 The study showed that T2, FLAIR, and SWI MRI sequences were more accurate in assessing injury severity and detection of outcome-influencing lesions than CT. Computed tomography was inconsistent at lesion detection and outcome prediction classified by the Pediatric Cerebral Performance Category Scale. However, CT remains the gold standard for ED evaluation of intracranial pathology after CHI as it is quickly obtained and accurate in diagnosing clinically important TBI.

Another small study of 20 adult patients evaluated whether there was any detectable abnormalities in patients with head injury and concussion with maximum LOC of 5 minutes.63 Magnetic resonance imaging was obtained first at 24 hours, then at 3 months, and then compared to a matched group of 20 orthopedic patients without any findings of diffuse axonal injury or other abnormality in the concussion group.

Treatment
Symptom control is the main objective in MTBI when the concern for ICH or skull fracture has been effectively ruled out via imaging or clinical examination and observation. Nausea and vomiting are symptoms of concussion that may be ameliorated by antiemetics such as ondansetron. However, there is valid concern in administering ondansetron in pediatric patients who do not receive head CTs to rule out ICH as protracted vomiting in this population would likely warrant imaging.

Pain control of headache associated with direct blow, cephalohematoma, and concussion should be initiated and achieved in the ED. Acetaminophen, unlike ibuprofen, does not have an effect on platelet count or function and, unlike narcotics, does not have the potential for sedation. Acetaminophen is a prudent first-line medication in the patient who has not had ICH effectively ruled out by imaging.

There is no evidence that acetaminophen or nonsteroidal anti-inflammatory drugs (NSAIDs) alleviate or shorten the duration of concussive symptoms.64 A single animal study showed that chronic ibuprofen use post-TBI worsens cognitive outcome.65

If symptoms of severe concussion persist despite pain control and antiemetics, admission to an inpatient ward for further therapy is warranted. However, it is important to consider cost issues related to inpatient admission for MTBI and explore alternative approaches such as observation units.

Special Circumstances
Postconcussive Syndrome And Second Impact Syndrome
Postconcussive syndrome is a potential sequelae of TBI in which the symptoms of concussion persist longer than 7 to 10 days. Somatic, cognitive, and affective symptoms may be present such as headache, sleep disturbance, dizziness, nausea, fatigue, attention problems, irritability, anxiety, depression, and emotional lability.66 A recent study assessed for postconcussive symptoms in children with MTBI compared to children with uncomplicated orthopedic injuries.67 They found that LOC, acute CT scan abnormality, parenchymal lesion on MRI, hospitalization, and injuries to body regions other than the head predicted higher levels of postconcussive symptoms.

Molecular researchers have suggested that MTBI can potentiate complex biochemical derangements in the brain at the time of injury and through recovery. This period of recovery marks a “situation of metabolic vulnerability, to the point that if another, equally ‘mild’ injury were to occur, the 2 MTBIIs would show the biochemical equivalence of a [severe] TBI,” which may be part of the pathophysiology of the second impact syndrome.8

Second impact syndrome is a catastrophic brain injury occurring after an initial TBI, generally before the symptoms of concussion have resolved. The hypothesized pathology involves cerebral vascular congestion with progression to diffuse cerebral swelling and death.68 All reported cases have been in patients less than 20 years of age.69,70 It is important to elicit any history of recent head trauma (eg athletics, motor vehicle accidents, or simple play) in the patient presenting with CHI to evaluate for second impact syndrome.9

Nonaccidental Trauma
Closed head injury is more concerning in children less than 2 years of age, so the threshold to use imaging is lower despite the higher risks of radiation. Inherently, these young patients lack verbal skills to relate historical aspects of the injury or symptoms, making communication and evaluation by the clinician more complex. A PECARN study successfully
evaluated more than 10,000 children less than 2 years of age to derive and validate prediction rules in children at very low risk of clinically important TBI after head trauma. However, this study does not allude to incidences in which MTBI may have been sustained by NAT. Importantly, children under 2 are at higher risk for NAT. In circumstances in which NAT is suspected due to delay in seeking care, or the injury does not match the stated mechanism of injury or the child’s developmental stage, a head CT and skeletal survey are warranted.

Cognitively Impaired
There is paucity of literature and recommendations regarding the management of moderately to severely cognitively impaired children who sustain CHI. However, these patients are similar to patients less than 2 years of age in that they have poor verbal skills and are at higher risk for NAT. In addition, these patients may have abnormal baseline neurologic examinations that make clinical evaluation of MTBI very difficult. For these reasons, when there is any suspicion of ICH or skull fracture, head CT should be obtained.

Cutting Edge
A hot topic in TBI diagnosis over the last 10 years has been the identification of brain biomarkers that could reflect injury. Biochemical serum markers measured after TBI may be used in identification of the injury, determining the injury extent, and potentially predicting outcome. This field of research is relatively new to pediatrics but of special interest in supporting the ever-present pediatric question of “to CT or not to CT.”

Neuron specific enolase (NSe) is a glycolytic enzyme found mainly in the cytoplasm of neurons and released into the serum after traumatic damage. A study from Children’s Hospital of Pittsburgh showed that the number of hours that NSE was abnormally elevated in serum correlated to short-term outcomes. They also noted that initial and peak levels only were correlated to outcome in children 4 years and under. A study by Geyer et al in 2009 looked at S100B and NSE specifically in the pediatric population with MTBI. The study was unable to show a significant difference of levels in patients with symptomatic MTBI and in those without symptomatic injury. Neuron specific enolase has the potential to correlate with moderate to severe TBI; however, its value lies in younger children and may require several samples to identify a correlation to outcome, making this a less-than-ideal marker in the ED.

S100B is a calcium-binding protein found in the astroglial cells of the central nervous system (CNS), though it is not exclusive to the CNS. A limited study of 152 children suggested that S100B is elevated in children with ICH, those with long bone fractures, and children of certain races. With a short half-life, in the event of multiple injuries, and in the non-white patient, S100B has limits in the acute ED setting. A study by Castellani showed that normal S100B levels ruled out ICH in MTBI pediatric patients with a strong sensitivity (sensitivity of 1.00 and specificity of 0.42). However, the large number of false positive patients in the study limits it use as an ideal confirmatory tool. An interesting study by Geyer sought to evaluate a difference in NSE and S100B levels in children with MTBI presenting with concussion and those with CHI without concussive symptoms. They demonstrated no difference in either NSE or S100B levels in these populations, which is supportive of these biomarkers having more diagnostic potential in ruling out moderate to severe pediatric TBI, especially in the symptomatic patient.

Glial Fibrillary Acidic Protein (GFAP) is found in the cytoskeleton of astrocytes exclusive to the CNS. Studies reflect elevated levels of GFAP in serum and CSF after severe TBI in children, but there is nothing to date quantifying it in pediatric MTBI.

Myelin basic protein (MBP) is found in CNS white matter. Berger et al evaluated levels of MBP in children with TBI, along with NSE and S100B. It was noted that initial levels of MBP were not correlated with outcome in older children, and similar to NSE, levels were correlated with outcome in children 4 years and younger. This study alludes to the value of MBP in NAT. Myelin basic protein was comparably elevated initially in children 4 years of age and younger whose injury was the result of NAT rather than with noninflicted trauma. The article suggests that a delay in initial presentation in cases of NAT may influence this finding. Berger et al went on to look at trajectory analysis of MBP and similar biomarkers in 2011 and reported a
half-life of approximately 24 hours for MBP. The study went on to intuitively confirm that elevations in MBP were present in hypoxic ischemic encephalopathy as well as TBI, further limiting its use as a specific marker for acute pediatric TBI.

In a recent small retrospective study of 57 children, a D-dimer level < 500 pg/mL had a 94% negative predictive value for TBI on head CT. This test has the potential to be used in current ED settings and laboratories, but more research is needed.

Identifying a brain biomarker that reliably suggests clinically important pediatric TBI would be the answer to concerns for unnecessary CT scans and would change pediatric CHI protocols. A challenge will be to identify a laboratory test that will isolate this biomarker in a timely fashion.

### Disposition

The pediatric patient with MTBI may be observed in the ED or an observation unit, admitted for inpatient hospitalization, or discharged home.

A study by Hamilton et al in 2010 examined the incidence of delayed ICH in children after uncomplicated minor CHI. This 8-year retrospective cohort study evaluated 17,962 children less than 14 years of age presenting to an ED with minor CHI. It was found that 2 of these patients had delayed symptomatic presentation of ICH at 8 and 38 hours. This data was extrapolated to summarize that the incidence of delayed deterioration following minor head injuries was 0.57 cases per 100,000 children per year. Nigrovic’s study reported a lower rate of head CT in pediatric patients with CHI who were observed in the ED versus those who were not initially observed. This again supports the fact that patients with MTBI rarely exhibit neurologic deterioration; however, ED observation may be justified in those patients with concern for intermediate risk for clinically important TBI.

The PECARN group evaluated over 13,000 children with a GCS score of 14 or 15 and normal ED head CT scan. The study stated that this population is at very low risk for traumatic findings on neuroimaging and extremely low risk of needing neurosurgical intervention. The authors concluded that hospitalization of this population for neurologic observation is generally unnecessary. However, neurologic observation is not the only reason why such patients would be admitted to the hospital – protracted vomiting, severe pain, and inability to tolerate fluids orally would be reasons to admit children with a GCS score of 14 to 15 and normal head CT. The article did mention that 18% of the admissions documented vomiting.

A retrospective study of 1033 children without neurologic deficit and a GCS score of 15 admitted to the hospital for observation found that all were discharged alive within 3 days irrespective of the fact that a comparable cohort had skull fracture or “intracerebral diagnosis.” A study by Holst et al evaluated blunt head injuries treated in an observation unit and found that 96% of the observed pediatric patients with small intracranial hematomas, skull fractures, and concussions were discharged safely within 24 hours without serious complications. While 4% of these patients required further inpatient management for basilar skull fracture, head laceration, and the need for ED intravenous fluids, most of these patients with mild CHI do not need further intervention. This raises the question of whether an observation unit is even necessary in a reliable home environment.

This being said, pediatric patients who sustained MTBI must pass discharge criteria prior to leaving the ED. Criteria for discharge include:

1. Hemodynamic stability with clinician expectation of persisting stability
2. No alteration in mental status
3. Resolved or tolerably mild headache
4. Tolerating oral fluids
5. Reliability of follow up with primary care physician, neurologist, neurosurgeon, or sports medicine physician to re-evaluate symptoms of MTBI
6. Family communication and understanding of discharge instructions including reasons to return to the ED

Some pediatric patients will not fit these discharge criteria and will require admission for evaluation and further treatment or close monitoring. Such patients would have:

- Clinician concern of potential for change in medical stability
- Severe headache
- Inability to tolerate fluid orally either by refusal or with frequent vomiting

It is important to stress the need for cessation of return to sports and need for medical clearance on follow up visit with the family and discuss post-concussive syndrome as well as the risks for second impact syndrome. The CDC has created an online resource called “Heads Up: Concussion” for children and their families as well as school personnel and healthcare professionals to provide important information on preventing, recognizing, and responding to a concussion. These materials can be utilized by the emergency clinician and referred to families.

Depending on the standard in your hospital, follow-up care may involve reassessment by a neurologist, neurosurgeon, and/or sports medicine physician in addition to the PMD.

As demonstrated by prospective cohort by Polissar et al, there is a potential decline in eating and living skills shortly after MTBI, with further...
effects on neurobehavioral skills initially and at 1 year. For this reason, follow up in these pediatric patients is imperative.

Summary

Emergency clinicians are faced with the presenting complaint of pediatric CHI on a regular basis. The vast majority of these are manifestations of MTBI with concussion. As discussed, this diagnosis can be made with or without imaging. Due to the increasing concerns for ionizing radiation and the risks of procedural sedation, emergency clinicians must exercise stricter criteria for neuroimaging and use clinical acumen (which may include ED observation time) in making the diagnosis of MTBI. As there are discrepancies in the current literature as to what exactly defines concussion and MTBI and as these terms may be interpreted differently by caregivers, we must mindfully make these diagnoses and discuss their implications with the families involved. Aided by our knowledge of the potential for residual neurobehavioral skills deficits, postconcussive syndrome, and second impact syndrome, we are responsible for educating patients and parents and ensuring that follow up is in place prior to discharge.

Case Conclusion

The height of this patient’s fall is defined as a severe injury mechanism by the PECARN study. Though there is a small occipital cephalohematoma, there is no suggestion of skull fracture in this patient and she denies headache. She is well appearing in your ED and tolerates a popsicle without nausea or vomiting, and she speaks and ambulates without neurologic deficit. It is now 4 hours post injury and her parents are reliable and live near the hospital. At this point, your suspicion for significant intracranial pathology in this patient is low. However, discussion of the risks and benefits of CT with the patient’s parents is still warranted as is ascertaining their comfort level with return precautions and home monitoring. The girl’s parents are worried for their daughter but do not want to expose her to unnecessary radiation and assure you that they will watch her closely at home. You confirm that the family has a pediatrician and decide to discharge this well-appearing patient home with follow-up with her regular doctor. A follow-up phone call from the ED on the next day confirmed that the patient is doing very well.

References


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70. Saunders RL, Harbaugh RE. The second impact in catastrophic contact sports head trauma. *JAMA.* 1984;252(4):538-539. (Case report)


85. Selbst SM. Standards for clinical evaluation and documentation by the emergency medicine provider. *Ped Rad.* 2008;38:645-650. (Case review)


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1. A 3-year-old female comes to the ED with vomiting and headache after a CHI 1 hour ago. These symptoms are indicative of:
   a. Mild traumatic brain injury
   b. Moderate traumatic brain injury
   c. Concussion
   d. Altered mental status
2. Which of the following is true regarding concussion?
   a. It involves a trauma-induced alteration in mental status
   b. It requires a loss of consciousness
   c. It is always associated with amnesia
   d. It only occurs in patients with a GCS score of 13 or above

3. An 8-year-old boy fell from a 10-foot ladder while stringing Christmas lights 1 hour ago. He had a 5-second loss of consciousness. He did not vomit, there is no cephalohematoma, and he is back to his baseline mental status. What is the best management for this patient?
   a. Immediate head CT
   b. ED monitoring for several hours
   c. Discharge home with older sister
   d. Morphine for pain and lorazepam for agitation

4. A 17-year-old boy sustained a mild traumatic brain injury while playing hockey. Four days later, he slips and falls on the ice while wearing his helmet and develops a large cerebral contusion. Which of the following is true regarding second impact syndrome?
   a. It occurs when symptoms of concussion last more than 10 days.
   b. A patient must have a minimum of 1 week between injuries to define a second impact.
   c. It typically occurs after a moderate to severe initial brain injury.
   d. It has only been reported in children and young adults.

5. A 2-year-old female came to the ED after falling from a second story window. She has vomited 3 times and her parents are concerned because she is fussy. What is the best course of action?
   a. Immediate head CT
   b. 2-to-4 hours of ED monitoring
   c. Discharge with parents for home monitoring
   d. Administer an antiemetic

6. An 8-year-old boy sustained a mild traumatic brain injury 2 weeks ago after being hit in the head with a hockey puck and losing consciousness for 5 seconds. He has had persisting headache and difficulty concentrating at school. What is the best diagnosis of these symptoms?
   a. Concussion
   b. Postconcussive syndrome
   c. Second impact syndrome
   d. Migraine

7. A 5-year-old girl fell down a flight of stairs 12 hours ago and had a 5-second loss of consciousness but has been well since. What statement is true regarding this ED patient?
   a. She does not have moderate or severe traumatic brain injury.
   b. She does not require further monitoring.
   c. She is at risk for postconcussive syndrome and second impact syndrome.
   d. She should have a head CT due to severe mechanism of injury.

8. A 2-month-old infant is brought to the ED because of a frontal cephalohematoma and bruise to his left shin noted by his mother when she picked him up from daycare. The daycare provider reported that the infant rolled off the bed approximately 2 feet to carpeted ground and the baby appears well. What is your next step?
   a. Observe in the ED for 6 hours
   b. Obtain a head CT
   c. Obtain a head CT and skeletal survey
   d. Obtain a head ultrasound and skeletal survey

9. A 14-year-old boy hit a tree while skiing. He was wearing a helmet but lost consciousness for 5 minutes. In the ED, he has a GCS score of 12 and has vomited 3 times. This patient most likely has what type of injury?
   a. Mild traumatic brain injury
   b. Second impact syndrome
   c. Moderate to severe brain injury
   d. Moderate to severe brain injury and concussion

10. A 4-year-old female fell from the monkey bars sustaining a 2-minute LOC without any external signs of injury. She is well-appearing in the ED, and you decide to observe her for 4 hours including a food and ambulatory trial. Which of the following statements regarding ED observation post head injury is true?
    a. Children observed in the ED post head injury are less likely to get a head CT.
    b. ED observation times should not exceed 2 hours.
    c. There is a 30% chance of delayed presentation of intracranial injury in this patient.
    d. The AAP recommends 8 hours of medical observation post-head injury.