Controversies in the evaluation and management of minor blunt head trauma in children
David Schnadower, Hector Vazquez, June Lee, Peter Dayan and Cindy Ganis Roskind

Purpose of review
We present data from recently conducted research regarding controversial aspects of the evaluation and management of children with minor blunt head trauma.

Recent findings
Clinicians frequently but at times indiscriminately perform computed tomography scans for children with minor blunt head trauma resulting in potentially harmful radiation exposure. Recent guidelines recognize the limited but increasing data available to make strong recommendations regarding appropriate neuroimaging decisions. Investigators have derived and validated clinical prediction models to accurately identify patients with substantial traumatic brain injury, though no clear definitive rule exists. Children younger than 2 years appear to have a higher risk of intracranial injury following minor head trauma. These patients can be difficult to assess, with the evidence suggesting the need for a more conservative approach to diagnostic imaging. We present current and accepted definitions of concussion along with risk factors and treatment for postconcussion syndrome. Current return-to-play guidelines suggest that athletes who have sustained concussion should not resume play until symptoms have resolved because of the possibility, though rare, of second impact syndrome.

Summary
Research in the management of children with minor head trauma is actively evolving. We present a review of recent developments that can influence current clinical practice.

Keywords
brain concussion, craniocerebral trauma, head injuries (closed), postconcussion syndrome, skull fractures

Abbreviations
CI confidence interval
CT computed tomography
ED Emergency Department
GCS Glasgow Coma Scale
LOC loss of consciousness
RR relative risk
SIS second impact syndrome
TBI traumatic brain injury

Introduction
Traumatic brain injury (TBI) from unintentional blunt trauma is the leading cause of death and disability among US children younger than 19 years of age, resulting in 7440 deaths, 642,000 emergency department (ED) visits and 65,000 hospitalizations annually [1]. Approximately 50–80% of patients presenting to the ED with head trauma have minor head trauma [2,3], which reasonably includes those with a Glasgow Coma Scale (GCS) or modified GCS of 14–15 but is defined differently among studies [3,4,5,6,7].

Although computed tomography (CT) scans are the diagnostic test of choice to evaluate children with minor head trauma, clinicians vary widely in their use, ranging from less than 5% to upwards of 50% of patients presenting to the ED [1,3,5–8,11]. In the US, less than 4–8% of head CT scans performed in children with minor head trauma display any evidence of TBI [2,3,7,12] and overall, less than 0.5% of children with minor blunt head trauma require neurosurgical intervention [5,7,13]. There is, therefore, valid concern that CT scans are overused and that they may be detecting a number of clinically inconsequential findings that require no intervention [3,14,15].

Much controversy exists in the management of children with minor blunt head trauma, particularly regarding the use of CT with its associated radiation risks, the assessment of the risk of TBI (particularly in children under 2 years of age) and the diagnosis and management of concussions and postconcussion syndrome. Our objective is to provide a review of the recent literature for each of these topics.
Clinical question: in children exposed to a single head CT, what are the risks of adverse effects from radiation?

There is concern that CT scans expose children to potentially harmful radiation doses. Children are considerably more sensitive to radiation than adults due to rapidly dividing cells associated with growth. Since children have longer life expectancies, they have more opportunity to express radiation damage, particularly cancer. Although ‘as low as reasonably achievable’ radiation dose guidelines have been advocated for pediatric CT, there is concern that they are not applied universally and that there may be widespread underestimation of radiation risks among patients and healthcare professionals [16–18]. A pediatric head CT with adjusted settings delivers 30 millisieverts to the brain, whereas a nonadjusted adult-based protocol delivers twice as much radiation. A single head CT exposes children to 200–600 times as much radiation as typical postero-anterior and lateral chest radiographs [19].

Brenner et al. [20,21] used data from radiation exposure of atomic bomb survivors in Japan to estimate that the lifetime attributable risk for fatal cancer from one head CT ranges from one per 2000 scans for young infants to one per 5000 scans in older children. In addition, a recent population-based cohort study from Sweden noted an association between early childhood exposure to radiation in doses similar to a single head CT and poor cognitive performance and academic achievement at 18 years of age [22]. These potential risks underscore the importance of using CT scans selectively, implementing ‘as low as reasonably achievable’ radiation dose guidelines, and promoting research in alternative imaging technologies.

Clinical question: in children presenting to the ED with acute, minor blunt head trauma, are there clinical predictors and prediction models that accurately identify patients with substantial traumatic brain injury?

In a metaanalysis of 16 studies that included a total of 22,420 children with minor head trauma, Dunning et al. [4] described individual risk factors associated with the presence of TBI. In his study, the presence of skull fracture [relative risk (RR) 6.1, 95% confidence interval (CI) 3.4–11.2], focal neurological signs (RR 9.4, 95% CI 2.9–30.8), loss of consciousness (LOC) (RR 2.2, 95% CI 1.2–4.2) and GCS less than 15 (RR 5.5, 95% CI 1.6–19) was statistically associated with TBI, whereas headache (RR 1.0, 95% CI 0.6–1.7) and vomiting (0.88, 95% CI 0.7–1.2) were not. The presence of seizures (RR 2.8, 95% CI 0.9–9) showed a trend toward an association with TBI.

As these individual risk factors do not predict the presence of TBI with sufficient sensitivity, investigators have sought to derive and validate clinical prediction models that use combinations of factors to accurately identify those with TBI and/or clinically important head injury (Table 1). Unfortunately, each study in Table 1 used different inclusion criteria, making comparisons among them difficult. Additionally, the investigators frequently did not confine the study populations to those with minor head trauma. The studies performed by Haydel and Shembekar [7] and Oman et al. [14] are validation studies of clinical prediction rules derived in adults and children. Both rules have high sensitivities but low specificities, making it unclear if implementation of the rules may actually increase the use of CT scans if applied to less symptomatic populations (who would not meet each study’s inclusion criteria). Palchak et al.’s [3] single-center derivation of a clinical decision rule resulted in prediction models that would identify those either with a positive CT or who required acute intervention. Dunning et al. [5] recently published the largest study to derive a clinical decision rule to identify pediatric patients at high risk of clinically significant head injury (defined as death, need for neurosurgical intervention or abnormality on a CT scan).

The prediction rule is complex and, like other models, includes predictors that are difficult to assess in young patients. If applied, this rule may theoretically increase the number of CT scans performed in the UK (from 3% to 13%). This study also included patients with very minor head trauma and CTs were performed very infrequently. As for all newly derived prediction models, validation must occur prior to clinical use [23].

Clinical question: in children younger than 2 years presenting to the ED with minor blunt head trauma, are there clinical predictors that accurately identify patients with traumatic brain injury or skull fracture?

Although the data presented above include children younger than 2 years, this group is often considered independently. Signs and symptoms are difficult to assess, particularly in the very young, and the threshold for obtaining imaging studies has traditionally been lower in this population [2,24–26]. The incidence of skull fractures and intracranial injury following minor head trauma seems to be higher in this age group. Skull fractures occur in 2% of all children following minor head trauma [57] whereas the incidence is as high as 11% in children under 2 years of age [27]. Furthermore, 15–30% of patients under 2 years with a skull fracture will have TBI and the presence of skull fracture is a clear predictor of TBI [3,14,26,28].

An American Academy of Pediatrics expert panel issued consensus guidelines specific for the management of minor head trauma in children younger than 2 years [26]. They recommended that clinicians perform CT scans on patients at high risk for TBI, defined as those with any of the following: signs of depressed or basilar skull fracture, acute skull fracture, altered mental status,
<table>
<thead>
<tr>
<th>Author</th>
<th>Sample size</th>
<th>Inclusion criteria</th>
<th>Outcome(s)</th>
<th>Clinical decision model to predict outcome(s)</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
</tr>
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<tbody>
<tr>
<td>Heydel, 2003</td>
<td>14/175</td>
<td>Children 5–17 yrs, GCS = 15, normal neurological exam, and LOC</td>
<td>Any acute traumatic intracranial lesion on CT</td>
<td>Headache, emesis, intoxication, trauma above the clavicles, seizure or short-term memory deficit</td>
<td>100% (73–100%)</td>
<td>26% (19–33%)</td>
</tr>
<tr>
<td>Oman, 2006</td>
<td>138/1666</td>
<td>All children ≤18 yrs with blunt head trauma who had CT</td>
<td>Clinically important intracranial injury based on expert consensus (does not include all acute traumatic intracranial CT findings)</td>
<td>Significant skull fracture, altered level of alertness, neurological deficit, persistent vomiting, scalp hematoma, abnormal behavior, coagulopathy</td>
<td>98.6% (95–99.8%)</td>
<td>15% (13–17%)</td>
</tr>
<tr>
<td>Palchak, 2003</td>
<td>N = 2043, 1271 of whom had CT</td>
<td>Children &lt;18 yrs with nontraumatic blunt head trauma</td>
<td>TBI requiring acute intervention (103/2043 patients had this outcome)</td>
<td>Abnormal mental status, clinical signs of skull fracture, history of vomiting, scalp hematoma in children ≤2 yrs of age, headache</td>
<td>100% (97–100%)</td>
<td>43% (41–45%)</td>
</tr>
<tr>
<td>Dunning, 2006</td>
<td>281/22,772</td>
<td>All children &lt;16 yrs with any severity of head injury</td>
<td>Clinically significant head injury (death, need for neurosurgical intervention or abnormality on CT) Note: only 766 (3.3%) had CTs performed</td>
<td>History: Witnessed LOC ≥5 min, amnesia &gt;5 min, drowsiness, ≥3 vomits, suspicion of non-accidental injury, seizure. Exam: GCS &lt;14 or GCS &lt;15 if ≤1 year of age, suspicion of penetrating or depressed skull injury or tense fontanelle, signs of basilar skull fracture, focal neurological exam, or bruise, swelling or laceration &gt;5 cm if &lt;1 year of age. Mechanism: high speed traffic accident, fall &gt;3 meters, high speed injury from an object.</td>
<td>98.6% (96–99.6%)</td>
<td>87% (86.5–87.4%)</td>
</tr>
</tbody>
</table>

Note: only 766 (3.3%) had CTs performed.

- Sample is a subset of a larger population of adults and children from whom decision rule was derived; CI, confidence interval; CT, computed tomography; GCS, Glasgow Coma Scale; LOC, loss of consciousness; TBI, traumatic brain injury.

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Table 1 Recent clinical decision rules to predict substantial head injuries in children

- There is controversy regarding the role of skull radiographs as a screening tool for children under 2 years of age with possible skull fracture, as negative skull radiographs are often misread by nonradiologists [34]. Chung et al. [35] noted that the sensitivity of skull radiographs read by pediatric radiologists for TBI was 84% (±4%) compared to 76% (±15%) for skull radiographs read by pediatric emergency medicine attendings for the detection of skull fractures. The specificity of skull radiographs was 76% (±15%) and the specificity of skull radiographs read by pediatric radiologists was 80% (±5%). When choosing an imaging modality, clinicians must therefore consider the risk of false-positive and false-negative results.

Data from Greenes and Schutzman [27] provide useful information regarding which young patients with TBI in the absence of skull fractures were more likely to be associated with skull fractures. There is controversy regarding the role of skull radiographs as a screening tool for children under 2 years of age with possible skull fracture, as negative skull radiographs are often misread by nonradiologists [34]. Chung et al. [35] noted that the sensitivity of skull radiographs read by pediatric radiologists for TBI was 84% (±4%) compared to 76% (±15%) for skull radiographs read by pediatric emergency medicine attendings for the detection of skull fractures. The specificity of skull radiographs was 76% (±15%) and the specificity of skull radiographs read by pediatric radiologists was 80% (±5%). When choosing an imaging modality, clinicians must therefore consider the risk of false-positive and false-negative results.

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TBI, the availability of a CT scanner, the expertise at imaging interpretation and the need for sedation. We recommend that clinicians perform a CT for children younger than 2 years with an acute skull fracture on skull radiographs because the presence of skull fracture significantly increases the likelihood of TBI.

**Clinical questions: what is the risk of, and what are the risk factors for, post concussion syndrome? Does post concussion syndrome result in long term sequelae?**

The term concussion is usually applied to a subgroup of patients with minor head trauma, although multiple definitions have been proposed. The American Academy of Neurology [36] defines concussion as ‘a trauma induced alteration in mental status that may or may not involve loss of consciousness’ but typically includes confusion and amnesia. In 2004, the Second International Conference on Concussion in Sport [37] defined sports concussion as a complex physiological process following head trauma resulting in rapid onset of short-lived functional impairment, though in some cases associated with prolonged post concussive symptoms, and typically associated with a normal CT scan. MRI, single photon emission CT and PET scans may demonstrate subtle abnormalities such as small areas of hemorrhage, contusion, or axonal injury [38–41]. Imaging findings do not seem to be closely associated with functional outcome [40,41].

Post concussion syndrome has been defined as the persistence beyond 7–10 days of the injury of any one of the following symptoms not present before injury: headaches, easy fatigability, sleep disturbances, dizziness, irritability, aggressiveness, anxiety, depression, missed work, relationship troubles, personality change, trouble with simple math, and trouble with short-term memory [37,42]. The concept of post concussion syndrome as a comprehensive entity is somewhat controversial, with limited data available and substantial overlap of symptoms with psychiatric illnesses [43–46]. Nevertheless, the presence of post concussion syndrome has been reported in as many as 13–35% of children 6 weeks to 3 months following ‘minor’ head trauma, defined in most studies as GCS 13–15 and symptoms such as amnesia, LOC, or vomiting [47–49].

Researchers have sought to identify risk factors for the development of post concussion syndrome with the hope that early identification of those at risk may improve outcomes. In adults, female gender, prior axis I and axis II disorders, severe balance deficits, severe pain, poor performance on neurocognitive tests, presence of dizziness, headache, skull fracture or a serum protein S-100B above 50 µg/l on presentation to the ED have been found to be associated with a higher risk of post concussion syndrome [50–53]. Pediatric data are limited. Studies suggest that post concussion syndrome is more likely to develop in patients with low GCS score and anxiety upon presentation and in those with a history of prior head injuries, learning disabilities and neuropsychiatric disturbances [47–49,54,55]. Levels of biochemical serum markers such as S-100B, c-tau, and neuron-specific enolase have not been clearly shown to correlate with the onset, duration, or severity of post concussion syndrome; however, they may be useful when considered in conjunction with other clinical factors [38,56–60].

Most children with post concussion syndrome will have resolution of symptoms by 3 months after injury. Some children, however, may have more subtle lasting difficulties, such as behavioral and school problems [48,61,62]. Anderson et al. [63,64] prospectively demonstrated no significant differences on cognitive measures or behavioral function 30 months after injury, but found some deficit in story recall and verbal fluency in children with mild head injury as compared with matched noninjured controls.

**Clinical question: in children with post concussion syndrome, are medications or psychosocial–behavioral measures effective in decreasing the severity of symptoms?**

Early diagnosis, education and implementation of multidisciplinary intervention strategies may help alleviate disabilities from post concussion syndrome. Post concussive symptoms have been shown to decrease after an educational intervention in the form of an information booklet [48] and early supportive care [65]. In a small randomized controlled trial bed rest was not shown to improve outcome [66]. Some patients may warrant referrals to specialty services such as physical therapy for postural imbalances, neurology for headaches, behavioral therapy for attention/hyperactivity symptoms, or concussion-specific follow-up clinics [67].

Few data exist to evaluate the potential benefit of pharmacological treatment of post concussion syndrome. Symptomatic management with nonsteroidal anti inflammatory medications for post concussion headache is encouraged, with consideration for therapies directed at tension-type headache and migraine [68]. Newer modalities such as occipital nerve block are being studied [69] and treatments previously aimed at severe brain injury, such as corticosteroids, and hyperbaric oxygen therapy, are potential interventions for future investigation [70]. Antidepressants, anxiolytics, methylphenidate alone or in combination with psychotherapy, and cytidine 5’ diphosphocholine (CDP) have also been used though large randomized controlled trials have not been performed [71–73]. Although the effectiveness of existing therapies is unclear, ED clinicians should provide anticipatory guidance.
regarding postconcussive syndrome and recommend pediatric follow-up for any child who sustains a concussion. Follow-up will allow clinicians and parents to explore potential behavioral and pharmacological therapies if symptoms persist.

**Clinical question: in children with concussion, are published return-to-play guidelines effective in preventing second-impact syndrome?**

Second-impact syndrome (SIS) refers to the vulnerability of the brain following repeated trauma during the postconcussive period. It is hypothesized that loss of cerebrovascular autoregulation can lead to vascular congestion, swelling, and transtentorial brainstem herniation when re-injury occurs while still symptomatic from a prior concussion [74]. The existence of SIS is controversial and has only been described in case reports. McCrory and Berkovic [75] analyzed 17 published cases and found that 11 out of 17 cases had no witnessed second impact, and no cases could be classified as ‘definite SIS’. Nevertheless, various return-to-play guidelines have been advocated to prevent SIS and repeated damage from multiple concussions [36,76]. It is generally accepted that an athlete must not return to play until all concussive symptoms have completely resolved, and a similar conservative approach is uniformly recommended in children and adolescents [76]. One of the more recent and more accepted return-to-play guidelines comes from the Second International Conference on Concussion. They propose [37] that initially there should be no activity but, once an athlete is asymptomatic, they may proceed to light aerobic exercise and then to a stepwise, gradual progression to full game play. A substantial percentage of patients with concussive symptoms seen by medical providers do not receive specific follow-up instructions [77–79]. Return-to-play guidelines, though lacking high-level evidence, have become standard of care, and should be conveyed to ED patients.

**Conclusions**

Although there are no perfect individual predictors for TBI in children with minor head trauma, guidelines have been published and clinical prediction models are being developed that help clinicians predict which patients have a low risk of TBI and can forego neuroimaging. More data will be especially useful to aid clinicians in the evaluation of children younger than 2 years who can be difficult to assess and for whom we presently recommend a more conservative approach to diagnostic imaging. While precise estimates are lacking, many children experience postconcussive symptoms. We recommend pediatric follow-up after a concussion and appropriate behavioral intervention with or without pharmacologic therapy for children with persistent symptoms. Finally, return-to-play guidelines, though lacking high-level evidence, have become standard of care, and clinicians should convey this information to patients and their parents.

**References and recommended reading**

Papers of particular interest, published within the annual period of review, have been highlighted as:

* of special interest
** of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 363).

6. This is the largest derivation study to date of a prediction rule to identify children with minor head trauma at high risk of TBI.
23. The ALARA (as low as reasonably achievable) concept in pediatric CT: going from the awareness among pediatricians. Pediatr Radiol 2001; 31:823–832.


This prospective observational study of children with head injury evaluates long-term outcome of children following head injury as well as risk factors for poor outcome.


