

Prediction of Persistent Postconcussion Symptoms in Youth Using a Neuroimaging Decision Rule

Gregory Faris, MD; Terri Byczkowski, PhD, MBA; Mona Ho, MS; Lynn Babcock, MD, MS

From the Division of Emergency Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio (all authors)

The authors declare that they have no conflict of interest.

Address correspondence to Lynn Babcock, MD, MS, Division of Emergency Medicine, Cincinnati Children's Hospital Medical Center, 3333 Burnet Ave, ML 2008, Cincinnati, OH 45229 (e-mail: Lynn.Babcock@cchmc.org).

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ABSTRACT

OBJECTIVE: To evaluate the ability of risk strata generated by a neuroimaging rule, developed to assess risk of clinically important traumatic brain injury (ciTBI), to predict postconcussive symptoms in youth with an acute mild traumatic brain injury.

METHODS: We performed a prospective cohort study of youth aged 5 to 17 years presenting to an emergency department (ED) within 24 hours of mild traumatic brain injury. Risk strata (very low, intermediate, and at risk) of ciTBI were determined in ED by criteria set forth by the neuroimaging rule. Postconcussive symptoms were assessed using the Health and Behavior Inventory (HBI) in the ED and at 1, 2, and 4 weeks after injury. General linear models were used to examine the relationship between the HBI score at 1 week and risk strata. Repeated measures analysis was used to measure change in HBI over time.

RESULTS: Of the 120 participants, 46 were categorized by the Pediatric Emergency Care Applied Research Network (PE-

CARN) rule as very low risk, 39 as intermediate risk, and 35 as at risk for ciTBI. Adjusted mean HBI scores (95% confidence intervals) at 1 week were 18.0 (13.9, 22.2) for at risk, 13.8 (9.9, 17.6) for intermediate risk, and 17.1 (13.4, 20.8) for very low risk. Risk strata were not significantly associated with the adjusted HBI score at 1 week ($P = .17$). While adjusted HBI scores declined significantly over time ($P < .0001$), the trajectories of the HBI score over time did not differ significantly by risk strata ($P = .68$).

CONCLUSIONS: Risk of ciTBI as determined by factors within a neuroimaging rule alone is insufficient to predict children with persistent postconcussive symptoms.

KEYWORDS: children; concussion; emergency department; mild traumatic brain injury; postconcussion syndrome

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WHAT'S NEW

Persistence of postconcussive symptoms cannot be predicted by the risk of clinically important traumatic brain injury. Multifactorial studies are needed to develop a clinical decision rule to predict persistent postconcussive symptoms in children.

TRAUMATIC BRAIN INJURY (TBI) results in over 650,000 emergency department (ED) visits annually for youth aged 0 to 19 years.¹ Acutely, many youth experience physical, cognitive, and behavioral symptoms that limit their ability to function in everyday settings.^{2–6} The proportion of youth experiencing postconcussive symptoms typically declines over the initial weeks after injury, from 60% at 1 week to 10% to 50% at 1 month after injury.^{2,7–10}

Acute management in the ED focuses on identifying patients with intracranial injury and managing symptoms. The Pediatric Emergency Care Applied Research Network (PECARN) developed and internally validated a 6-factor rule that predicts pediatric patients at very low risk of clinically important traumatic brain injury (ciTBI), where

ciTBI is defined as a patient requiring neurosurgical intervention, hospital admission for more than 2 nights, intubation for more than 24 hours, or death.¹¹ The intention of the rule was to decrease exposure to ionizing radiation in patients by decreasing the number of computed tomographic (CT) scans in children at very low risk of ciTBI. As outlined by Kuppermann et al,¹¹ risk of ciTBI can be stratified into 3 categories—very low (<0.05%), intermediate (0.9%), and at risk (4.3%)—on the basis of clinician assessment of the Glasgow Coma Scale (GCS) and the presence of the other signs and symptoms within 24 hours of head trauma (Table 1). Although factors contained within the rule, such as loss of consciousness, headache, and vomiting, have been associated with postconcussive symptoms, repurposing the rule to predict postconcussive symptoms has not been assessed.^{9,12,13} Evidence suggests children with intracranial injury may have a higher risk of postconcussive symptoms; thus, it seems reasonable to hypothesize that children at highest risk of ciTBI may have greater risk of postconcussive symptoms.^{14,15} Symptoms persisting for 1 month or longer generally imply a diagnosis of postconcussion syndrome and impose a significant public health burden as a result of its effect on daily functioning. Patients with symptoms

Table 1. Factors and Risk Stratification of ciTBI in PECARN Neuroimaging Rule

Sign and Symptom in PECARN Neuroimaging Rule ¹¹	Risk Stratification		
	Very Low Risk of ciTBI (<0.05%)	Intermediate Risk of ciTBI (0.9%)	At Risk of ciTBI (4.3%)
Glasgow Coma Scale <15**			X
Altered mental status*			X
Signs of basilar skull fracture†			X
Loss of consciousness		X	
Severe mechanism of injury‡		X	
Vomiting		X	
Headache		X	

PECARN indicates Pediatric Emergency Care Applied Research Network; ciTBI, clinically important traumatic brain injury.

*Altered mental status: agitation, sleepiness, slow responses, or repetitive question.

**Glasgow Coma Scale and altered mental status represent a single factor “altered mental status” in the published neuroimaging rule; however, they are asked as 2 separate questions in the electronic health version of the rule implemented at our institution.

†Signs of basilar skull fracture: retroauricular bruising, periorbital bruising, hemotympanum, cerebral spinal fluid otorrhea, or cerebral spinal fluid rhinorrhea.

‡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 1.5 m (5 feet); or head struck by a high-impact object.

persisting for more than 1 week usually require reevaluation by a medical professional for additional guidance on symptom management and safe return to activities.

The primary objective of this pilot study was to determine if the risk strata outlined in the PECARN neuroimaging rule for detecting ciTBI would also be prognostic of postconcussive symptoms at 1 week. We hypothesized that postconcussive symptom burden would vary significantly as a function of risk for ciTBI, with those in the highest risk stratum (at risk) reporting the highest symptom burden. The secondary objective was to determine if the risk strata would predict postconcussive symptom burden over a month’s duration among youth presenting to the ED with mild TBI. The ability to use one tool to identify patients at risk of both ciTBI and postconcussive symptoms would streamline ED and follow-up care.

MATERIALS AND METHODS

STUDY POPULATION

This prospective cohort study involved youth between the ages of 5 and 17 years who presented between August 2012 and August 2013 to a large urban tertiary care ED within 24 hours of a reported direct or indirect blow to the head and a GCS score of ≥ 14 . This study was approved by the institutional review board before patient enrollment. Patients were excluded if they had penetrating head trauma, preexisting neurologic impairment (eg, stroke, cerebrospinal fluid shunt, brain tumor), preexisting significant psychological problems (eg, depression, anxiety,

bipolar, oppositional defiant disorder, conduct disorder), developmental delay, altered mental status due to ingestion of substances of abuse or alcohol, had been prescribed medication that impairs cognition, and non-English-speaking families. All inclusion and exclusion criteria were verified by a combination of chart review, treating physician, patient, and guardian/parent.

STUDY DESIGN

Trained research coordinators in the ED screened, obtained the assent of, and obtained consent from eligible participants, typically during the hours between 8 AM and midnight. Information collected included age, self-described race/ethnicity, presence of premorbid conditions associated with postconcussive symptoms including history of headaches,¹⁶ history of concussions,^{17–19} and attention and learning disability (eg, attention deficit hyperactivity disorder, special education classes, speech therapy, or other learning disabilities), mechanism of injury, findings of physical examination, and results of head CT scans (if obtained). Physicians answered questions in our electronic health record about the 7 variables contained in the PECARN neuroimaging rule for children ≥ 2 years of age (Table 1). These responses were used to calculate the risk of ciTBI. The published rule lists 6 factors because GCS <15 and other signs of altered mental status were combined into a single factor; however, GCS and altered mental status are asked as separate questions in our electronic health record, resulting in 7 separate variables. Postconcussive symptoms were assessed using the 20-item version of Health and Behavior Inventory (HBI) administered in the ED and at 1, 2, and 4 weeks after injury.²⁰ The HBI is a validated inventory of cognitive, somatic, emotional, and behavioral symptoms rated on a 4-point scale ranging from 0 (never) to 3 (often) present over the past week. A higher total score signifies a higher burden of symptoms, where HBI score greater than 0 at follow-up was defined as postconcussive symptoms. HBI somatic (9 items) and cognitive (11 items) subscores were also calculated.^{20,21} Forms for parents and participants differed in wording to reflect first- versus third-person viewpoints.^{20,22} During the ED visit, parents completed the HBI to assess the child’s premorbid level of functioning. Patients aged 9 to 17 completed the HBI in the ED to measure current symptom burden. For participants under the age of 9 or those who were too impaired to complete the questionnaire, their parents completed a second survey pertaining to their current symptom levels. At 1, 2, and 4 weeks after injury, participants, or their parents for participants 5 to 8 years old, completed the HBI via structured phone follow-up interviews conducted by research coordinators who were blinded to initial risk categorization. Patients who had no symptoms (ie, a score of 0 on the HBI) at the 2-week follow-up were not contacted for the 4-week assessment.

Typical ED care was provided to all participants, and management was at the discretion of the treating physician.

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