Children With Minor Blunt Head Trauma Presenting to the Emergency Department

Lise E. Nigrovic, MD, MPH,[a] Nathan Kuppermann, MD, MPH[b,c,d]

abstract

In our state-of-the-art review, we summarize the best-available evidence for the optimal emergency department management of children with minor blunt head trauma. Minor blunt head trauma in children is a common reason for emergency department evaluation, although clinically important traumatic brain injuries (TBIs) as a result are uncommon. Cranial computed tomography (CT) scanning is the reference standard for the diagnosis of TBIs, although they should be used judiciously because of the risk of lethal malignancy from ionizing radiation exposure, with the greatest risk to the youngest children. Available TBI prediction rules can assist with CT decision-making by identifying patients at either low risk for TBI, for whom CT scans may safely be obviated, or at high risk, for whom CT scans may be indicated. For clinical prediction rules to change practice, however, they require active implementation. Observation before CT decision-making in selected patients may further reduce CT rates without missing children with clinically important TBIs. Future work is also needed to incorporate patient and family preferences into these decision-making algorithms when the course of action is not clear.

[a]Division of Emergency Medicine, Boston Children's Hospital, Boston, Massachusetts; and [b]Departments of Emergency Medicine and [c]Pediatrics, School of Medicine, University of California, Davis, Davis, California; and [d]UC Davis Health, Sacramento, California

Dr Nigrovic wrote the first draft of this manuscript; and both authors conducted the literature review, interpreted the data, critically revised the manuscript, approved the final manuscript as submitted, and agree to be accountable for all aspects of the work.

DOI: https://doi.org/10.1542/peds.2019-1495

Accepted for publication Jun 10, 2019

Address correspondence to Lise E. Nigrovic, MD, MPH, Division of Emergency Medicine, Boston Children's Hospital, 300 Longwood Ave, Boston, MA 02115. E-mail: lise.nigrovic@childrens.harvard.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

To cite: Nigrovic LE and Kuppermann N. Children With Minor Blunt Head Trauma Presenting to the Emergency Department. *Pediatrics.* 2019;144(6): e20191495

Minor blunt head trauma is a common reason for emergency department (ED) evaluation across the globe.[1,2] Health care use for children with head trauma in the primary care setting and the ED has increased substantially over the past decade.[3,4] Among severely injured children, traumatic brain injury (TBI) remains a major cause of morbidity and mortality.

However, relatively few children with minor blunt head trauma, defined in this article by Glasgow Coma Scale (GCS) scores of 14 to 15, have clinically important TBIs (defined by TBIs requiring acute interventions, including neurosurgery or hospitalization, for ongoing symptoms or signs of TBI). Children with GCS scores of 13 and less after blunt head trauma have a 35% rate of TBIs on computed tomography (CT) scans[5] and therefore will not be further discussed. One of the challenges for clinicians evaluating children after minor blunt head trauma, however, is appropriately identifying children with TBIs without overtesting those children at very low risk. In this review, we will summarize the current evidence around the initial management of children with minor blunt head trauma.

NEUROIMAGING

The reference standard for the diagnosis of TBI is cranial CT, which is used to rapidly diagnose TBIs, allowing appropriate management of these injured children. Although access to and use of CT scans for children after minor blunt head trauma varies globally, the CT rate in children in EDs

STATE-OF-THE-ART REVIEW ARTICLE

in the United States with minor blunt head trauma ranges from 10% to 40%,[6–12] with lower rates seen in EDs using computerized decision support[10,13,14] or active quality improvement efforts.[11,12,15] In a recent cross-sectional study of US pediatric ED visits for children with head trauma from the National Hospital Ambulatory Medical Care Survey database, 32% had CT scans performed (2007–2015),[16] emphasizing the importance of active implementation to change practice.[16] Although cranial CT scan rates for children with head trauma have declined at US children's hospitals (adjusted odds ratio by year 2005–2009: 0.94; 95% confidence interval [CI]: 0.92–0.97),[8] only the minority of injured children are treated at pediatric centers.[17] However, <1% of children with minor blunt head trauma require any acute intervention,[7] suggesting that CT scans are still overused.

CT Scans and Ionizing Radiation

CT scans expose children to ionizing radiation, which increases the lifetime risk of lethal malignancies.[18–22] Children are at greater risk for radiation-induced malignancies than adults because of their rapid growth rates (ie, more-rapid cellular turnover) and longer life expectancies, with the youngest children being at the highest risk.[20,23] Although initial risk estimates were derived by applying mortality rates from studies of atomic bomb survivors,[18] more-recent estimates are based on long-term follow-up of children who underwent CT scans. In a retrospective cohort study of 178 604 children in Great Britain who had undergone at least 1 CT scan (of any type) before 22 years of age, investigators identified a dose-dependent increase in the risk of leukemia and brain tumors over the 10-year follow-up period.[20] Although the absolute risk from a single CT scan is small, the radiation exposure from diagnostic imaging presents a public health threat, given the high rates of CT use in childhood.

Trade-offs Between Clinical Evaluations With and Without CT Scans

Arguments can be made both for more aggressive and for more conservative use of CT scans in children after minor blunt head trauma. A normal CT scan in a child who is neurologically normal can facilitate appropriate ED discharge, sparing the costs and risks of hospitalization.[24] In a prospective cohort of children with minor blunt head trauma and initial GCS scores ≥14, 13 453 children had CT scans without evidence of intracranial injuries (ie, no intracranial hemorrhage, cerebral edema, pneumocephalus, or skull fracture).[24] Of these, 2485 (18% of those with normal CT scans) were nevertheless hospitalized, although none required neurosurgery (negative predictive value: 100%; 95% CI: 99.75%–100%). Another strategy to reduce CT use that is frequently used in Australia and New Zealand is to hospitalize rather than perform an ED CT scan, allowing more time for a child's head injury symptoms to either progress or resolve before CT decision-making.[25] However, that strategy incurs the costs and risks of hospitalization.[26,27]

Imaging Modalities of the Future

Advances in CT scan technology as well as customized pediatric imaging protocols have improved the CT scan safety profile by minimizing both ionizing radiation exposure as well as the requirement for pharmacological sedation while obtaining the needed images. The As Low as Reasonably Achievable campaign has taken a multifaceted approach to reduce patient radiation exposure.[19,28] Current-generation CT scanners have the potential for rapid acquisition of images with higher image quality at lower radiation doses compared with older CT scanners.[29] However, because scanner technology and imaging protocols vary by institution, the radiation dose at pediatric and trauma centers is often lower than at general EDs,[30] where most injured children receive care.[17] Additionally, with the widespread availability of high-speed helical CT scanners, only a minority of children undergoing CT scanning receive pharmacological sedation.[31]

"Quick-brain" MRI offers a potential radiation-sparing approach to the diagnostic imaging of children with head trauma.[32–34] Given the short time to acquire images (~90 seconds), most children will likely not require pharmacological sedation. In a pilot study of 54 children with head injury who had both a cranial CT and a quick-brain MRI performed, MRI had a 100% sensitivity (95% CI: 61%–100%) for clinically significant TBI but only an 85% specificity (95% CI: 73%–93%).[33] In a prospective study of 223 children with head injuries who had both a quick brain MRI and CT scan performed, MRI had a sensitivity of 92.8% for radiographically apparent TBI (95% CI 86.3–96.8%), but only missed one clinically important TBI (a child with a small subdural who required a two night hospitalization).[34] Although MRI appears to have excellent sensitivity for clinically significant TBI, this newer imaging modality needs more rigorous evaluation in children with head injury. In addition, even if new quick-brain imaging protocols for trauma were implemented, many EDs do not have 24-hour MRI access for emergency use.

TBI CLINICAL PREDICTION RULES

Clinical prediction rules combine available clinical factors to estimate the probability of an outcome to assist clinical decision-making[35–38] but must be derived and validated by using rigorous methodologic standards.[39] The need to reduce unnecessary CT scans while minimizing the risk of missing clinically important TBIs has driven the development of clinical prediction rules designed to guide clinicians through CT decision-making. In this review, we focus on the 3 CT decision rules in children with minor blunt head trauma with the largest derivation populations (Table 1): the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE) rule,[40] the Pediatric Emergency Care Applied Research Network (PECARN) rules (for those younger or older than 2 years),[7] and the Canadian Assessment of Tomography for Childhood Head Injury (CATCH).[41] Each of the rules had somewhat different aims and study populations, making the rules difficult to compare.[25,42] The inclusion criteria for each of these rules were different; the CHALICE rule including all children with head trauma, PECARN being used to evaluate children with GCS scores of 14 to 15, and CATCH rule including patients with GCS scores of 13 to 15. Because most children with head injury present for care within the first day,[43] the PECARN and CATCH rules were limited to children presenting within the first 24 hours after injury. Importantly, none of these 3 rules were designed to identify children with abusive head trauma,[44] which requires a comprehensive approach to evaluation.[45]

CHALICE TBI Rule

The CHALICE TBI clinical prediction rule was derived in a prospective cohort of 22 722 children presenting to 10 EDs in the United Kingdom between 2000 and 2002 for evaluation of head trauma of all severities.[40] The primary outcome measure was a clinically significant TBI defined by death, neurosurgery, or marked abnormalities on CT scan (281 children had 1 of these outcomes; 1.2% of enrolled). This rule includes 6 patient history, 5 physical examination, and 3 mechanism predictors. In the derivation population, 4 children with clinically significant TBIs were misclassified as very low risk for TBI (sensitivity: 98.6% [95% CI: 96.4%–99.6%]; specificity: 86.9% [95% CI: 86.5%–87.4%]).

The National Institute for Health and Clinical Excellence guideline for the management of infants and children in the United Kingdom is based on the CHALICE rule.[48] Subsequently, the CHALICE rule was used to identify all significant head injuries in 2 distinct retrospective cohorts of children with head injury (1091 from Australia[49] and 394 from the United Kingdom[50]). However, real-time implementation of the CHALICE rule could have increased cranial CT rates from 19% to 46% in the Australian cohort[25] and from 7% to 20% in the UK cohort.[50]

PECARN TBI Rules

The PECARN TBI prediction rules were derived in a prospective cohort of 33 785 children presenting to 1 of 25 EDs in the United States between 2004 and 2006 with minor blunt head trauma defined by GCS scores of 14 to 15.[7] The primary outcome measure was a clinically important TBI, defined as head injury resulting in 1 or more of the following: death, neurosurgery, intubation for 24 hours or more due to the head injury, or 2 or more nights in the hospital in association with TBI on CT. Only candidate clinical predictors with acceptable interrater reliability were considered for inclusion in the models.[46] The 2 age-based PECARN TBI rules (1 for children younger than 2 years old and 1 for children 2 years and older) each include 3 patient history and 3 physical examination predictors. The PECARN TBI clinical prediction rules, in broad terms, classify children in 3 groups on the basis of the risk of a clinically important TBI (Fig 1): high (14% of study population), intermediate (31%), and very low risk (55%).[7] To assess rule accuracy, the PECARN TBI clinical prediction rules were dichotomized (very low risk versus not very low risk). In the concurrent validation cohort of 8647 children, only 2 children (both older than 2 years) with clinically important TBIs were misclassified as very low risk for having a TBI (sensitivity of 100% [95% CI: 86.3%–100%] in children $<$2 years and sensitivity of 96.8% [95% CI: 89.0%–99.6%] in children $\geq$2 years).[7] Neither of the 2 misclassified patients required neurosurgery. In 4 independent validation studies of $>$15 000 children with minor blunt head trauma,[25,47,51,52] only 1 child with a clinically important TBI (who did not require neurosurgery) was classified as very low risk by the PECARN TBI rules.

How should the PECARN TBI rules be applied in clinical practice? Although children in the lowest risk group (ie, those with none of the 6 PECARN risk factors) can safely be managed without CT use, those in the high-risk group (those with altered mental status or signs of skull fracture) should have careful consideration of a cranial CT scan. However, many (and likely most) of the children in the intermediate-risk group do not require CT scanning, if they can be observed for a period of time in the ED. For children in the intermediate-risk group with an isolated intermediate-risk PECARN TBI predictor, the risk of a clinically important TBI was low (Table 2) but increased with multiple PECARN TBI risk factors.[53–58] Because clinical factors such as a history of a posttraumatic seizure substantially increase the risk of TBI on CT scan (seizure was not identified as a PECARN risk factor in the rule derivation, likely because it was sufficiently infrequent in the PECARN cohort and subsumed by the loss of consciousness variable),[59] clinicians should have a low threshold to perform CT after a posttraumatic seizure.

TABLE 1 Comparison of TBI Clinical Prediction Rules

	CHALICE[46]	PECARN[6]	CATCH[47]
Study design	Prospective cohort	Prospective cohort	Prospective cohort
Setting	10 EDs in England	25 EDs in the United States	10 EDs in Canada
Enrollment period	February 2000 through August 2002	June 2004 through March 2006	July 2001 through November 2005
Inclusion and exclusion criteria	Age <16 y	Age <18 y	Age ≤16 y
	Any head injury regardless of time	Nontrivial blunt head trauma within 24 h	Blunt head trauma within 24 h
	All GCS scores	GCS score of 14–15	GCS score of 13–15
		No penetration injuries, coagulopathies, or preexisting neurologic disorders	Any of the following: LOC, amnesia, disorientation, ≥2 episodes of vomiting, irritability (<2 y)
Sample size	22 772 derivation	33 785 derivation, 8627 concurrent validation	3866 derivation
Enrollment rate	Not reported	77%	64%
Predictors	Patient history: witnessed LOC >5 min, amnesia >5 min, abnormal drowsiness, ≥3 episodes of vomiting, suspicion for nonaccidental trauma, and seizure (if no history of epilepsy)	<2 y of age: severe injury mechanism[a]; loss of consciousness >5 s; acting abnormally, per parent; GCS score <15 or altered mental status; palpable skull fracture; and nonfrontal scalp hematoma	High risk: GCS score <15 2 hours from injury, suspicion for open or depressed skull fracture, worsening headache, and irritability
	Physical examination: GCS score <14 or GCS score <15 if <1 y of age, penetrating or depressed injury or tense fontanel, signs of basilar skull fracture, focal neurologic examination, and bruise, swelling, or laceration >5 cm if ≤1 y old	≥2 y of age: severe injury mechanism[a], any loss of consciousness, severe headache, any vomiting, GCS score <15 or altered mental status, and signs of basilar skull fracture	Medium risk (used with high risk for positive CT secondary outcome): large, boggy scalp hematoma; signs of basal skull fracture; and dangerous injury mechanism
	Mechanism: high-speed motor vehicle collision as a pedestrian, cyclist, or occupant; fall >3 m; and high-speed projectile injury		
Outcome	Death, neurosurgery, marked abnormalities on CT	Death, intubation ≥24 h, neurosurgery, or ≥2 nights in the hospital for management of head injury in association with TBI on CT	Death, intubation, neurosurgery
Derivation: performance, % (95% CI)	Sensitivity: 98.6 (96.4–99.6); specificity: 86.9 (86.5–87.4)	<2 y: sensitivity of 98.6 (92.6–100), specificity of 53.7 (52.6–54.8)	High risk: sensitivity of 100 (86.2–100), specificity of 70.2 (68.8–71.6)
		≥2 y: sensitivity of 96.7 (93.4–98.7), specificity of 57.6 (57.0–58.2)	Medium risk: sensitivity of 98.1 (94.6–99.4), specificity of 50.1 (48.5–51.7)
		Concurrent validation: <2 y: sensitivity of 100 (86.3–100), specificity of 53.6 (51.5–55.7)	
		Concurrent validation: ≥2 y: sensitivity of 96.8 (89.0–99.6), specificity of 58.2 (57.0–59.4)	

LOC, loss of consiousness.

[a] Motor vehicle collision with patient ejection, death of another passenger, or rollover; a pedestrian or bicyclist without a helmet struck by a motorized vehicle; falls (at a height of ≥3 ft for children <2 y and ≥5 ft for children ≥2 y); or head struck with a high-impact object.

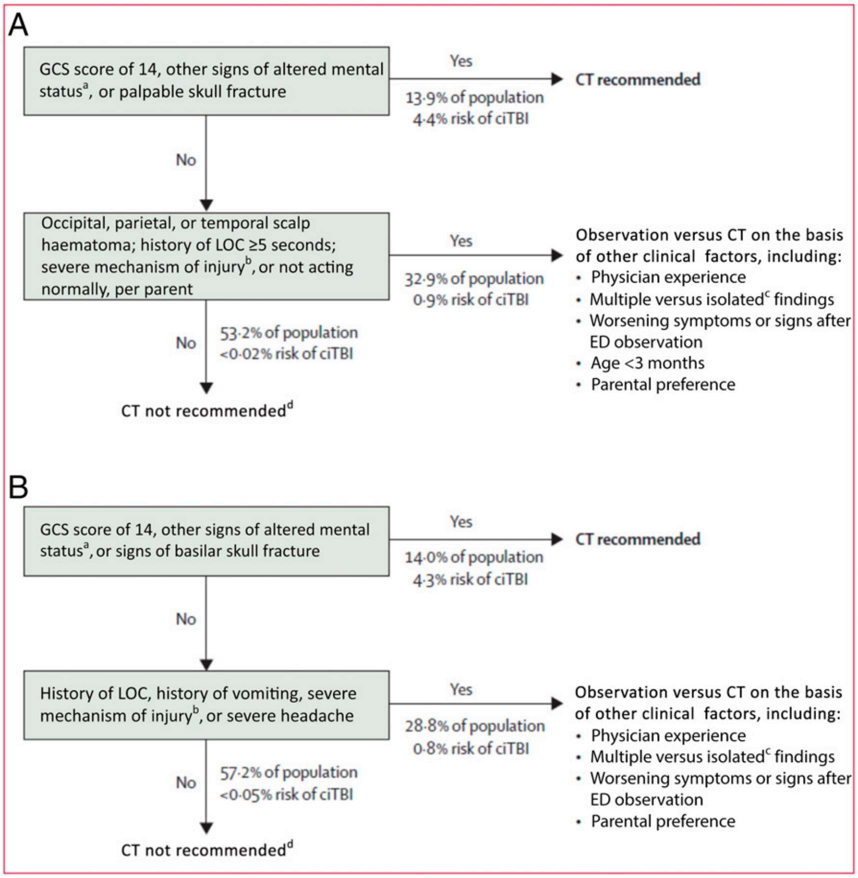

FIGURE 1
Suggested CT algorithm for children <2 years (A) and for those aged 2 years or older (B)[6] (reprinted with permission). ciTBI, clinically important traumatic brain injury. [a] Signs of altered mental status include agitation, somnolence, repetitive questioning, or slow response to verbal communication. [b] Severe mechanism of injury is defined as 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 3 feet (A) or more than 5 feet (B); or head struck by a high-impact object. [c] Risk of ciTBI increases with the number of risk factors present. [d] As risk of ciTBI is exceedingly low and may be lower than risk of CT-induced malignancy, CT scans are not recommended for most patients in this group.

CATCH TBI Rule

The CATCH TBI prediction rule was derived in a prospective cohort of 3866 children presenting to 10 EDs in Canada between 2001 and 2005 with mild to moderate head trauma, defined by GCS scores of 13 to 15 as well as loss of consciousness, amnesia, disorientation, persistent vomiting, or irritability, and was conducted by the Pediatric Emergency Research Canada network.[41] The clinical prediction rule for the primary outcome, need for neurosurgical intervention, included 1 patient history predictor and 3 physical examination predictors. In the validation study of 4060 children, 3 children requiring neurosurgery were misclassified as low risk (sensitivity: 91% [95% CI: 72%–99%]).[60] These investigators subsequently suggested adding 1 clinical predictor, 4 or more episodes of vomiting, to the CATCH rule to improve sensitivity (100% [95% CI: 85%–100%]),[60] but these modifications require additional validation.

Comparison Between 3 TBI Clinical Prediction Rules

The Pediatric Research in the Emergency Departments International Collaborative network of EDs in New Zealand and Australia performed a simultaneous prospective validation of the CHALICE, PECARN, and CATCH TBI prediction rules.[25] This study enrolled 20 317 children <18 years of age with minor blunt head trauma and GCS scores of 13 to 15, of whom, 2106 (10%) had CT scans performed and 83 (<1%) underwent neurosurgery. The TBI rules were applied only to those children who met the inclusion criteria for each of the respective prediction rules (CHALICE applicable to 99% of enrolled children, PECARN applicable to 75%, and CATCH applicable to 25%) (Table 3). Each of the 3 TBI rules worked well in the patient populations for which they were designed.

Clinician Judgment

The question remains whether head trauma clinical prediction rules improve the care of children with head injury compared with usual care (aka clinician judgment). In a recent large prospective study, clinician judgment had similar sensitivity to the CHALICE, PECARN, and CATCH clinical prediction rules for the identification of children with clinically important TBIs.[61] Importantly, because this study was conducted at high-volume pediatric centers in Australia and New Zealand, these results may not be applicable to low-volume centers in different regions of the world or those without pediatric emergency practitioners because clinician judgment is developed over time caring for children with head injury. Because the prediction rules were already published at the time of the study and clinicians in the study had to document the presence or absence of the predictors that were in the rules, it is likely that "clinician judgment" was informed by the rules.[26,27] Furthermore, increasing clinician awareness of ionizing radiation risks may also have reduced CT use.

TABLE 2 The Risk of Clinically Important TBI for Children With "Isolated" PECARN TBI Predictors by Patient Age (<2 vs ≥2 y of Age)

	Children <2 y	Children ≥2 y
	N = 10 718	*N* = 31 694
	n Out of *N* (%) (95% CI)	*n* Out of *N* (%) (95% CI)
Severe injury mechanism[60]	4 out of 1327 (0.3) (0.1–0.8)	12 out of 1975 (0.6) (0.3–1.1)
History of loss of consciousness[61,a]	1 out of 157 (0.6) (0–3.5)	12 out of 2623 (0.5) (0.2–0.8)
Nonfrontal scalp hematoma[62]	4 out of 820 (0.5) (0.1–1.2)	n/a
Vomiting[63]	n/a	10 out of 1501 (0.7) (0.3–1.2)
Severe headache[64]	n/a	3 out of 209 (1.4) (0.3–4.1)
Not acting normally, as per parent[65]	1 out of 411 (0.2) (0–1.3)	n/a

n/a, not applicable.
[a] Loss of consciousness >5 s for children <2 y and any for children ≥2 y.

Additionally, clinician judgment had a higher specificity than the 3 TBI clinical prediction rules, raising the concern that implementation of these prediction rules might increase CT rates. Clinical prediction rule implementation can occur in a variety of ways, including provider education, clinical pathways, and computerized decision support. Although only PECARN TBI implementation studies have been published to date, researchers in these studies have demonstrated a safe, evidence-based decrease in CT scan use for children with head injury.[10,14] In an Italian pediatric ED, cranial CT rates decreased after implementation of the PECARN rules despite relatively low baseline CT rates (8.4% preimplementation versus 7.3% postimplementation).[63] Quality improvement initiatives based on the PECARN TBI rules at a tertiary care children's ED,[11] a community pediatric ED,[12] and a general ED[15] have also been associated with safe reductions in cranial CT rates.

Observation

Rarely, children with apparently minor blunt head trauma but who actually have clinically important TBIs will initially be asymptomatic (or minimally symptomatic) but will later clinically deteriorate. Such clinical deterioration is typically due to increased intracranial pressure from either an expanding intracranial hematoma or progressive cerebral edema. Although rare, epidural hematomas are classically associated with delayed development of symptoms after an initial lucid interval.[62,64]

In clinical practice, children with significant TBIs only rarely have a delayed presentation after presenting with apparently minor head trauma. Researchers in an 8-year population-based study in the Calgary Health Region investigated the incidence of delayed diagnosis of intracranial injury (defined as a child with initial normal GCS score and normal physical examination who had any type of intracranial injury diagnosed by neuroimaging >6 hours after injury).[65] In this retrospective cohort study of 17 692 children with minor blunt head trauma presenting to EDs in Calgary, no child had a delayed diagnosis of intracranial hemorrhage after 6 hours (upper limit 95% CI of 0.02%), suggesting that the vast majority of clinically important TBIs will become apparent in this time period.

Clinical observation is an important management strategy for children with minor blunt head trauma in the ED who have more-than-negligible risk for TBI but who are not at high risk (for whom CT scans are typically indicated). This approach allows time for the child's symptoms and signs to improve or evolve and hence inform CT decision-making. Observation before the decision of whether to obtain a CT allows clinicians to selectively image those children whose symptoms fail to improve (or whose symptoms worsen) over the observation period. By delaying the decision of whether to obtain a CT scan for a few hours, clinicians can safely reduce unnecessary CT scans without missing clinically important TBIs.[66] The Choosing Wisely campaign has been adopted by >70 medical specialties,[67] including the American Academy of Pediatrics and the American College of Emergency Physicians. Both societies have recommended the use of the PECARN TBI prediction rules in children with minor blunt head trauma to limit inappropriate CT scan use, with observation in a monitored setting as an important management strategy to further limit CT use.[68] All children discharged after observation without a CT scan should have a reliable caregiver with the ability to return to medical

TABLE 3 Performance of the 3 TBI Rules in the Prospective Cohort of Children With Head Injury Presenting to 10 EDs in Australia and New Zealand[24]

	CHALICE	PECARN <2 y	PECARN ≥2 y	CATCH
No. included	20 029	4011	11 152	4957
No. with outcome	401 clinically important TBI	38 clinically important TBI	98 clinically important TBI	21 neurosurgery, 141 brain injury on CT
Sensitivity, % (95% CI)	92.3 (89.2–94.7)	100 (90.7–100)	99.0 (94.4–100)	High risk: 95.2 (76.2–99.9) Medium risk: 88.7 (82.2–93.4)
Specificity, % (95% CI)	78.1 (77.5–78.7)	53.8 (52.3–55.4)	45.8 (44.9–46.8)	High risk: 84.2 (83.2–85.2) Medium risk: 56.4 (55.0–57.8)

attention if the child's symptoms worsen.

Clinical observation has been associated with a lower CT rate. In a planned secondary analysis of the PECARN TBI study, clinical observation before CT decision-making was associated with a lower rate of overall CT use, with no change in rate of clinically important TBI after adjustment for head injury severity (adjusted odds ratio of CT use: 0.53 [95% CI: 0.43–0.66]).[66] In a subsequent prospective single-center study of children with minor blunt head trauma, each hour of ED observation was associated with a decrease in cranial CT rate for children in each of the 3 PECARN TBI risk groups (very low, intermediate, and high risk) after adjusting for time from injury to ED evaluation.[69] None of the observed children in either of these studies had a missed clinically important TBI. Rigorous evidence combined with common sense suggests that ~4 to 6 hours of monitored observation from the time of head injury will substantially decrease the CT rate without missing important TBIs or needlessly prolonging ED stays.

COMPUTERIZED DECISION SUPPORT

Historically, translating knowledge including clinical prediction rules into routine clinical practice has taken decades.[70] Passive diffusion of evidence through publication and presentation is typically not sufficient to change behavior on a broad scale and in a sustained fashion.[71,72] In the complex and chaotic ED environment, effective implementation strategies are especially challenging.[73]

Clinical decision support (CDS) tools are important aids to enable evidence uptake[74] but have only recently been studied in the ED setting and require local clinical informatics support for development and deployment. A collaborative group conducted a multisite qualitative study to describe the existing ED environment and workflow for the care of children with minor blunt head trauma[75] to inform the design of an optimal computerized decision support system. The resulting multisite implementation study successfully integrated the PECARN TBI rules into electronic medical records and delivered both TBI risk estimates and CT-versus-observation recommendations to clinicians at the point of care. This implementation study included 4 pediatric and 7 general EDs as well as 1 pediatric and 1 general ED control sites to monitor secular trends.[10] Although the impact of the CDS on CT rates for children at the lowest risk for clinically important TBI varied across centers, the overall CT rate decreased at CDS intervention sites compared with control sites (intervention sites CT rate: 5.3% vs 4.2%, $P = .04$ versus control sites CT rate: 4.1% vs 2.7%, $P = .13$). Three children with clinically important TBIs were missed by the tool but identified by treating clinicians, although 2 had missing or inaccurately recorded risk factors, and the other had a clinical concern for nonaccidental trauma; none underwent neurosurgery. Importantly, computerized decision support did not increase the rate of CT for children at non-neglible risk for clinically important TBI by the PECARN rules, despite these theoretical concerns.[10,14] However, CDS implementation can be time-consuming and expensive, making widespread implementation challenging.

COST-EFFECTIVENESS ANALYSES

For an individual child with blunt head trauma, the risk of missing a clinically important TBI must be balanced against the potential of future lethal malignancy from exposure to ionizing radiation from CT scans, among other concerns (eg, cost, waiting time, parental and clinician comfort level). Decision and cost-effective analysis allow rigorous mathematical modeling to be applied to clinical decision-making to compare various management strategies. One model compared 2 management strategies (CT all versus no immediate CT) for children <2 years with minor blunt head trauma presenting to the ED for evaluation.[76] The "no immediate CT" strategy was optimal if the expected probability of a clinically important TBI was <5%. In a separate cost-effectiveness analysis comparing the PECARN TBI rules to usual care, application of the PECARN rules (ie, comparing PECARN risk group assignment to unstructured CT decision-making) was both more effective and less costly for children with minor blunt head trauma.[77] The PECARN strategy dominated despite a slight increase in the rate of missed clinically important TBIs, reflecting the lower costs and reduced rate of radiation-induced malignancies. A recent analysis of a cohort of nearly 19 000 children with head injuries in Australia and New Zealand demonstrated that usual care was the most cost-effective approach in that country ($36 Australian cost savings per child with head injury; 95% CI: $7–$77 savings) when compared with the PECARN, CATCH, and CHALICE TBI prediction rules.[78] However, given that the latter study was conducted on a different continent than the other 2 cost-effectiveness studies and cost assumptions were different by necessity, direct comparison is challenging.

SHARED DECISION-MAKING

Patient, parental, and physician preferences should each play a role in clinical decision-making for all children with minor blunt trauma, particularly when a course of action is not clear. In 2 prospective cohorts from the United States[79] and Japan,[80] parental preference was associated with obtaining a cranial CT scan. However, parents are often willing to consider observation rather than an immediate CT scan when they understand the trade-offs involved.

In a recent clinical trial, researchers investigated the optimal method of risk communication as well as parenteral preferences for the ED management of children with minor head trauma at intermediate risk of clinically important TBI by the PECARN rules (ie, having 1 or 2 intermediate PECARN TBI risk factors).[81] A pictorial shared decision-making aid was developed, which included a representation of the child's individual risk of having a clinically important TBI and the risks and benefits of observation without CT scan versus immediate CT scan (Fig 2). Providers at each of the 7 participating pediatric EDs were randomly assigned to either the pictorial shared decision-making aid or usual care. Of the 971 patients enrolled, parents cared for by providers using the decision aid compared with usual care providers were more knowledgeable and had greater physician trust after the intervention, although the ED CT rate was similar. No clinically important TBIs were missed in either group. Interestingly, there was less health care use, laboratory testing, and other imaging tests in the 7-day follow-up period in the decision-aid group. Use of shared decision-making with similar tools has the potential to inform patient and family-centered decision-making for children with minor blunt head trauma, although further study is needed.[82,83]

CONCLUSIONS

Across the globe, children with minor blunt head trauma frequently present to EDs for evaluation. Clinicians caring for these children must decide whether to obtain a cranial CT scan, the diagnostic gold standard, as part of their evaluation. CT scans, however, expose children to ionizing radiation that increases long-term risks of lethal malignancies. High-quality validated TBI clinical prediction rules can assist clinical decision-making by estimating the risk of clinically important TBIs on the basis of presenting signs and symptoms. These prediction rules are best used in conjunction with clinical judgment, based on many factors, including setting and clinician experience. Observation before CT decision-making is an important management strategy for children at low to intermediate risk that allows selective CT use for those children whose symptoms worsen or fail to improve during the observation period. Importantly, shared decision-making between provider and patient-parent dyad is an important strategy when the decision to obtain a CT scan is not clear. Investigators in future research should focus on the optimal strategies for clinical prediction rule implementation in different clinical settings as well as better integration of shared decision-making into ED encounters for children with head injuries.

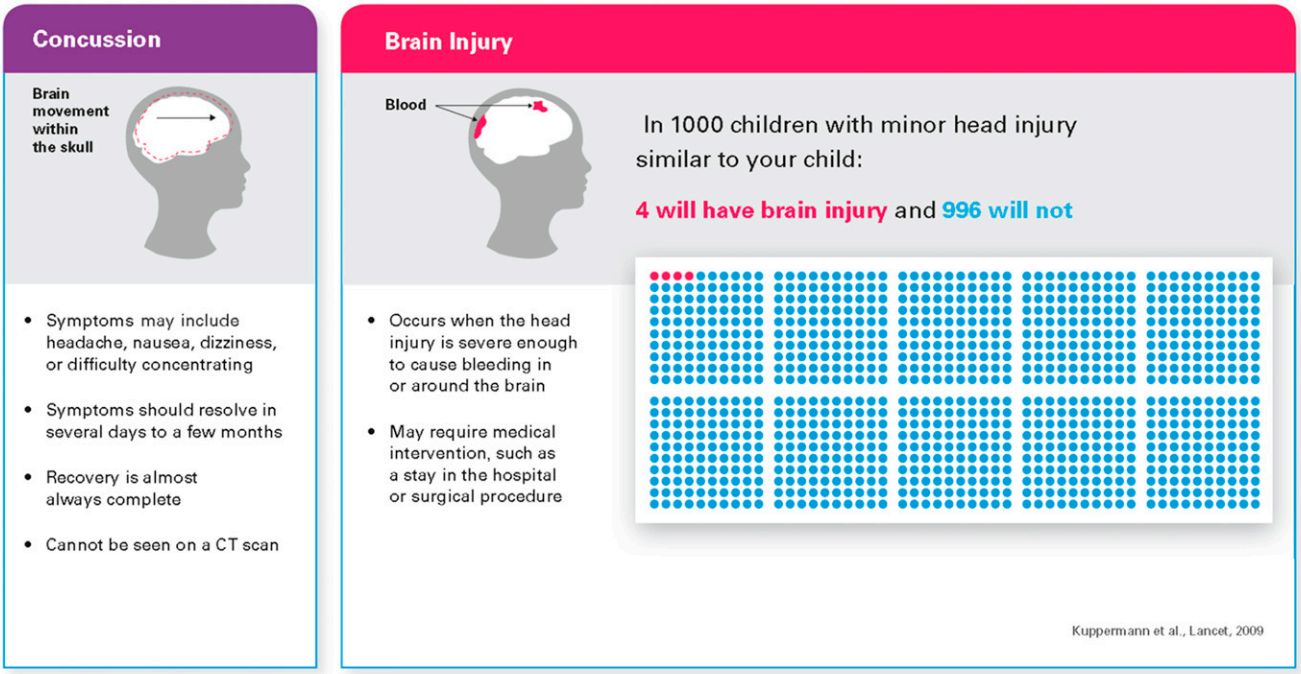

FIGURE 2
A sample head CT choice decision aid shared with permission (E. Hess, MD, MSc; personal communication).

ABBREVIATIONS

CATCH: Canadian Assessment of Tomography for Childhood Head Injury
CDS: clinical decision support
CHALICE: Children's Head Injury Algorithm for the Prediction of Important Clinical Events
CI: confidence interval
CT: computed tomography
ED: emergency department
GCS: Glasgow Coma Scale
PECARN: Pediatric Emergency Care Applied Research Network
TBI: traumatic brain injury

REFERENCES

1. Lumba-Brown A, Yeates KO, Sarmiento K, et al. Diagnosis and management of mild traumatic brain injury in children: a systematic review. *JAMA Pediatr*. 2018;172(11):e182847
2. Dewan MC, Mummareddy N, Wellons JC III, Bonfield CM. Epidemiology of global pediatric traumatic brain injury: qualitative review. *World Neurosurg*. 2016;91:497–509.e1
3. Taylor AM, Nigrovic LE, Saillant ML, et al. Trends in ambulatory care for children with concussion and minor head injury from eastern Massachusetts between 2007 and 2013. *J Pediatr*. 2015;167(3):738–744
4. Marin JR, Weaver MD, Yealy DM, Mannix RC. Trends in visits for traumatic brain injury to emergency departments in the United States. *JAMA*. 2014;311(18):1917–1919
5. Quayle KS, Powell EC, Mahajan P, et al. Epidemiology of blunt head trauma in children in U.S. emergency departments. *N Engl J Med*. 2014;371(20):1945–1947
6. Blackwell CD, Gorelick M, Holmes JF, Bandyopadhyay S, Kuppermann N. Pediatric head trauma: changes in use of computed tomography in emergency departments in the United States over time. *Ann Emerg Med*. 2007;49(3):320–324
7. Kuppermann N, Holmes JF, Dayan PS, et al; Pediatric Emergency Care Applied Research Network (PECARN). Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *Lancet*. 2009;374(9696):1160–1170
8. Mannix R, Meehan WP, Monuteaux MC, Bachur RG. Computed tomography for minor head injury: variation and trends in major United States pediatric emergency departments. *J Pediatr*. 2012;160(1):136–9.e1
9. Menoch MJ, Hirsh DA, Khan NS, Simon HK, Sturm JJ. Trends in computed tomography utilization in the pediatric emergency department. *Pediatrics*. 2012;129(3). Available at: www.pediatrics.org/cgi/content/full/129/3/e690
10. Dayan PS, Ballard DW, Tham E, et al; Pediatric Emergency Care Applied Research Network (PECARN); Clinical Research on Emergency Services and Treatment (CREST) Network; and Partners Healthcare; Traumatic Brain Injury-Knowledge Translation Study Group. Use of traumatic brain injury prediction rules with clinical decision support. *Pediatrics*. 2017;139(4):e20162709
11. Nigrovic LE, Stack AM, Mannix RC, et al. Quality improvement effort to reduce cranial CTs for children with minor blunt head trauma. *Pediatrics*. 2015;136(1). Available at: www.pediatrics.org/cgi/content/full/136/1/e227
12. Jennings RM, Burtner JJ, Pellicer JF, et al. Reducing head CT use for children with head injuries in a community emergency department. *Pediatrics*. 2017;139(4):e20161349
13. Atabaki SM, Jacobs BR, Brown KM, et al. Quality improvement in pediatric head trauma with PECARN rules implementation as computerized decision support. *Pediatr Qual Saf*. 2017;2(3):e019
14. Ballard DW, Kuppermann N, Vinson DR, et al; Pediatric Emergency Care Applied Research Network (PECARN); Clinical Research on Emergency Services and Treatment (CREST) Network; Partners HealthCare. Implementation of a clinical decision support system for children with minor blunt head trauma who are at nonnegligible risk for traumatic brain injuries. *Ann Emerg Med*. 2019;73(5):440–451
15. Puffenbarger MS, Ahmad FA, Argent M, et al. Reduction of computed tomography use for pediatric closed head injury evaluation at a nonpediatric community emergency department. *Acad Emerg Med*. 2019;26(7):784–795
16. Burstein B, Upton JEM, Terra HF, Neuman MI. Use of CT for head trauma: 2007-2015. *Pediatrics*. 2018;142(4):e20180814
17. Hudgins JD, Monuteaux MC, Bourgeois FT, et al. Complexity and severity of pediatric patients treated at United States emergency departments. *J Pediatr*. 2017;186:145–149.e1
18. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med*. 2007;357(22):2277–2284
19. Newman B, Callahan MJ. ALARA (as low as reasonably achievable) CT 2011—executive summary. *Pediatr Radiol*. 2011;41(suppl 2):453–455
20. Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukemia and brain tumours: a retrospective cohort study. *Lancet*. 2012;12(6736):1–7
21. Smith-Bindman R, Lipson J, Marcus R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. *Arch Intern Med*. 2009;169(22):2078–2086
22. Miglioretti DL, Johnson E, Williams A, et al. The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. *JAMA Pediatr*. 2013;167(8):700–707
23. Frush DP. Justification and optimization of CT in children: how are we performing? *Pediatr Radiol*. 2011;41(suppl 2):467–471
24. Holmes JF, Borgialli DA, Nadel FM, et al; TBI Study Group for the Pediatric Emergency Care Applied Research Network. Do children with blunt head trauma and normal cranial computed tomography scan results require hospitalization for neurologic

observation? *Ann Emerg Med*. 2011; 58(4):315–322

25. Babl FE, Borland ML, Phillips N, et al; Paediatric Research in Emergency Departments International Collaborative (PREDICT). Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study. *Lancet*. 2017;389(10087):2393–2402

26. Kuppermann N, Holmes JF, Dayan PS. Head injury decision rules in children. *Lancet*. 2017;390(10101):1487–1488

27. Vinson DR, Ballard DW, Dayan PS, Kuppermann N. Clinical judgment and the Pediatric Emergency Care Applied Research Network head trauma prediction rules. *Ann Emerg Med*. 2018; 72(3):323–325

28. Frush DP, Frush KS. The ALARA concept in pediatric imaging: building bridges between radiology and emergency medicine: consensus conference on imaging safety and quality for children in the emergency setting, Feb. 23-24, 2008, Orlando, FL - Executive Summary. *Pediatr Radiol*. 2008;38(suppl 4): S629–S632

29. Chen MY, Shanbhag SM, Arai AE. Submillisievert median radiation dose for coronary angiography with a second-generation 320-detector row CT scanner in 107 consecutive patients. *Radiology*. 2013;267(1):76–85

30. Sadigh G, Kadom N, Karthik P, et al. Noncontrast head CT in children: national variation in radiation dose indices in the United States. *AJNR Am J Neuroradiol*. 2018;39(8):1400–1405

31. Goldwasser T, Bressan S, Oakley E, Arpone M, Babl FE. Use of sedation in children receiving computed tomography after head injuries. *Eur J Emerg Med*. 2015;22(6):413–418

32. Rozovsky K, Ventureyra ECG, Miller E. Fast-brain MRI in children is quick, without sedation, and radiation-free, but beware of limitations. *J Clin Neurosci*. 2013;20(3):400–405

33. Sheridan DC, Newgard CD, Selden NR, Jafri MA, Hansen ML. QuickBrain MRI for the detection of acute pediatric traumatic brain injury. *J Neurosurg Pediatr*. 2017;19(2):259–264

34. Lindberg DM, Stence NV, Grubenhoff JA, et al. Feasibility and accuracy of fast MRI versus CT for traumatic brain injury in young children. *Pediatrics*. 2019;144(4):e20190419

35. Wasson JH, Sox HC, Neff RK, Goldman L. Clinical prediction rules. Applications and methodological standards. *N Engl J Med*. 1985;313(13):793–799

36. Wasson JH, Sox HC. Clinical prediction rules. Have they come of age? *JAMA*. 1996;275(8):641–642

37. McGinn TG, Guyatt GH, Wyer PC, Naylor CD, Stiell IG, Richardson WS; Evidence-Based Medicine Working Group. Users' guides to the medical literature: XXII: how to use articles about clinical decision rules. *JAMA*. 2000;284(1):79–84

38. Reilly BM, Evans AT. Translating clinical research into clinical practice: impact of using prediction rules to make decisions. *Ann Intern Med*. 2006;144(3): 201–209

39. Green SM, Schriger DL, Yealy DM. Methodologic standards for interpreting clinical decision rules in emergency medicine: 2014 update. *Ann Emerg Med*. 2014;64(3):286–291

40. Dunning J, Daly JP, Lomas J-PP, Lecky F, Batchelor J, Mackway-Jones K; Children's Head Injury Algorithm for the Prediction of Important Clinical Events Study Group. 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

41. Osmond MH, Klassen TP, Wells GA, et al; Pediatric Emergency Research Canada (PERC) Head Injury Study Group. CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury. *CMAJ*. 2010;182(4): 341–348

42. Lyttle MD, Cheek JA, Blackburn C, et al. Applicability of the CATCH, CHALICE and PECARN paediatric head injury clinical decision rules: pilot data from a single Australian centre. *Emerg Med J*. 2013; 30(10):790–794

43. Borland ML, Dalziel SR, Phillips N, et al; Paediatric Research in Emergency Department International Collaborative (PREDICT) Group. Delayed presentations to emergency departments of children with head injury: a PREDICT study. *Ann Emerg Med*. 2019;74(1):1–10

44. Magana JN, Kuppermann N. The PECARN TBI Rules do not apply to abusive head trauma. *Acad Emerg Med*. 2017;24(3): 382–384

45. Choudhary AK, Servaes S, Slovis TL, et al. Consensus statement on abusive head trauma in infants and young children. *Pediatr Radiol*. 2018;48(8): 1048–1065

46. Gorelick MH, Atabaki SM, Hoyle J, et al; Pediatric Emergency Care Applied Research Network. Interobserver agreement in assessment of clinical variables in children with blunt head trauma. *Acad Emerg Med*. 2008;15(9): 812–818

47. Easter JS, Bakes K, Dhaliwal J, Miller M, Caruso E, Haukoos JS. Comparison of PECARN, CATCH, and CHALICE rules for children with minor head injury: a prospective cohort study. *Ann Emerg Med*. 2014;64(2):145–152, 152.e1–152.e5

48. National Collaborating Centre for Acute Care. *Head Injury: Triage, Assessment, Investigation and Early Management of Head Injury in Infants, Children and Adults*. London, United Kingdom: National Collaborating Centre for Acute Care; 2007

49. Crowe L, Anderson V, Babl FE. Application of the CHALICE clinical prediction rule for intracranial injury in children outside the UK: impact on head CT rate. *Arch Dis Child*. 2010;95: 1017–1022

50. Ghosh R, Docherty E, Schickerling S, Heinz P, Campbell-Hewson G, Boyle A. Application of the 2007 NICE guidelines in the management of paediatric minor head injuries in a UK emergency department. *Emerg Med J*. 2012;29(3): 197–200

51. Schonfeld D, Bressan S, Da Dalt L, Henien MN, Winnett JA, Nigrovic LE. Pediatric Emergency Care Applied Research Network head injury clinical prediction rules are reliable in practice. *Arch Dis Child*. 2014;99(5):427–431

52. Lorton F, Poullaouec C, Legallais E, et al. Validation of the PECARN clinical decision rule for children with minor head trauma: a French multicenter prospective study. *Scand J Trauma Resusc Emerg Med*. 2016;24(1):98

53. Nigrovic LE, Lee LK, Hoyle J, et al; Traumatic Brain Injury (TBI) Working

Group of Pediatric Emergency Care Applied Research Network (PECARN). Prevalence of clinically important traumatic brain injuries in children with minor blunt head trauma and isolated severe injury mechanisms. *Arch Pediatr Adolesc Med*. 2012;166(4): 356–361

54. Lee LK, Monroe D, Bachman MC, et al; Traumatic Brain Injury (TBI) Working Group of Pediatric Emergency Care Applied Research Network (PECARN). Isolated loss of consciousness in children with minor blunt head trauma. *JAMA Pediatr*. 2014;168(9):837–843
55. Dayan PS, Holmes JF, Atabaki S, et al; Traumatic Brain Injury Study Group of the Pediatric Emergency Care Applied Research Network (PECARN). Association of traumatic brain injuries with vomiting in children with blunt head trauma. *Ann Emerg Med*. 2014; 63(6):657–665
56. Dayan PS, Holmes JF, Hoyle J Jr, et al; Pediatric Emergency Care Applied Research Network (PECARN). Headache in traumatic brain injuries from blunt head trauma. *Pediatrics*. 2015;135(3): 504–512
57. Dayan PS, Holmes JF, Schutzman S, et al; Traumatic Brain Injury Study Group of the Pediatric Emergency Care Applied Research Network (PECARN). Risk of traumatic brain injuries in children younger than 24 months with isolated scalp hematomas. *Ann Emerg Med*. 2014;64(2):153–162
58. Nishijima DK, Holmes JF, Dayan PS, Kuppermann N. Association of a guardian's report of a child acting abnormally with traumatic brain injury after minor blunt head trauma. *JAMA Pediatr*. 2015;169(12):1141–1147
59. Badawy MK, Dayan PS, Tunik MG, et al. Prevalence of brain injuries and recurrence of seizures in children with posttraumatic seizures. *Acad Emerg Med*. 2017;24(5):595–605
60. Osmond MH, Klassen TP, Wells GA, et al; Pediatric Emergency Research Canada (PERC) Head Injury Study Group. Validation and refinement of a clinical decision rule for the use of computed tomography in children with minor head injury in the emergency department. *CMAJ*. 2018;190(27): E816–E822
61. Babl FE, Oakley E, Dalziel SR, et al. Accuracy of clinician practice compared with three head injury decision rules in children: a prospective cohort study. *Ann Emerg Med*. 2018;71(6):703–710
62. Schutzman SA, Barnes PD, Mantello M, Scott RM. Epidural hematomas in children. *Ann Emerg Med*. 1993;22(3): 535–541
63. Bressan S, Romanato S, Mion T, Zanconato S, Da Dalt L. Implementation of adapted PECARN decision rule for children with minor head injury in the pediatric emergency department. *Acad Emerg Med*. 2012;19(7):801–807
64. Snoek JW, Minderhoud JM, Wilmink JT. Delayed deterioration following mild head injury in children. *Brain*. 1984; 107(pt 1):15–36
65. Hamilton M, Mrazik M, Johnson DW. Incidence of delayed intracranial hemorrhage in children after uncomplicated minor head injuries. *Pediatrics*. 2010;126(1). Available at: www.pediatrics.org/cgi/content/full/126/1/e33
66. Nigrovic LE, Schunk JE, Foerster A, et al; Traumatic Brain Injury Group for the Pediatric Emergency Care Applied Research Network. The effect of observation on cranial computed tomography utilization for children after blunt head trauma. *Pediatrics*. 2011;127(6):1067–1073
67. Cassel CK, Guest JA. Choosing wisely: helping physicians and patients make smart decisions about their care. *JAMA*. 2012;307(17):1801–1802
68. Chosing Wisely. American College of Emergency Physicians. 2014. Available at: www.choosingwisely.org/societies/american-college-of-emergency-physicians/. Accessed October 12, 2018
69. Schonfeld D, Fitz BM, Nigrovic LE. Effect of the duration of emergency department observation on computed tomography use in children with minor blunt head trauma. *Ann Emerg Med*. 2013;62(6):597–603
70. Agency for Healthcare Research and Quality. *Translating Research into Practice (TRIP)-II*. Rockville, MD: Agency for Healthcare Research and Quality; 2001
71. Bero LA, Grilli R, Grimshaw JM, Harvey E, Oxman AD, Thomson MA; The Cochrane Effective Practice and Organization of Care Review Group. Closing the gap between research and practice: an overview of systematic reviews of interventions to promote the implementation of research findings. *BMJ*. 1998; 317(7156):465–468
72. Grimshaw JM, Shirran L, Thomas R, et al. Changing provider behavior: an overview of systematic reviews of interventions. *Med Care*. 2001;39(8, suppl 2):II2-II45
73. Lang ES, Wyer PC, Haynes RB. Knowledge translation: closing the evidence-to-practice gap. *Ann Emerg Med*. 2007;49(3):355–363
74. Kawamoto K, Houlihan CA, Balas EA, Lobach DF. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *BMJ*. 2005; 330(7494):765
75. Sheehan B, Nigrovic LE, Dayan PS, et al; Pediatric Emergency Care Applied Research Network (PECARN). Informing the design of clinical decision support services for evaluation of children with minor blunt head trauma in the emergency department: a sociotechnical analysis. *J Biomed Inform*. 2013;46(5):905–913
76. Hennelly KE, Mannix R, Nigrovic LE, et al. Pediatric traumatic brain injury and radiation risks: a clinical decision analysis. *J Pediatr*. 2013;162(2):392–397
77. Nishijima DK, Yang Z, Urbich M, et al. Cost-effectiveness of the PECARN rules in children with minor head trauma. *Ann Emerg Med*. 2015;65(1):72–80.e6
78. Dalziel K, Cheek JA, Fanning L, et al; Pediatric Research in Emergency Departments International Collaborative (PREDICT). A cost-effectiveness analysis comparing clinical decision rules PECARN, CATCH, and CHALICE with usual care for the management of pediatric head injury. *Ann Emerg Med*. 2019;73(5): 429–439
79. Natale JE, Joseph JG, Rogers AJ, et al; PECARN (Pediatric Emergency Care Applied Research Network). Cranial computed tomography use among children with minor blunt head

trauma: association with race/ ethnicity. *Arch Pediatr Adolesc Med*. 2012;166(8):732–737

80. Ishida Y, Manabe A, Oizumi A, et al. Association between parental preference and head computed tomography in children with minor blunt head trauma. *JAMA Pediatr*. 2013; 167(5):491–492

81. Hess EP, Homme JL, Kharbanda AB, Tzimenatos L, Louie JP, Cohen DM. Effect of shared decision-making on patient centered outcomes and healthcare utilization in children with blunt head trauma: a multicenter randomized trial. *JAMA Open*. 2018;1(5):e182430

82. Melnick ER, Probst MA, Schoenfeld E, et al. Development and testing of shared decision making interventions for use in emergency care: a research agenda. *Acad Emerg Med*. 2016;23(12): 1346–1353

83. Probst MA, Kanzaria HK, Schoenfeld EM, et al. Shared decisionmaking in the emergency department: a guiding framework for clinicians. *Ann Emerg Med*. 2017;70(5):688–695

Children With Minor Blunt Head Trauma Presenting to the Emergency Department

Lise E. Nigrovic and Nathan Kuppermann

Pediatrics originally published online November 26, 2019;

PEDIATRICS®
OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Children With Minor Blunt Head Trauma Presenting to the Emergency Department

Lise E. Nigrovic and Nathan Kuppermann

Pediatrics originally published online November 26, 2019;