ONLINE FIRST | JOURNAL CLUB

Prevalence of Clinically Important Traumatic Brain Injuries in Children With Minor Blunt Head Trauma and Isolated Severe Injury Mechanisms

Lise E. Nigrovic, MD, MPH; Lois K. Lee, MD, MPH; John Hoyle, MD; Rachel M. Stanley, MD; Marc H. Gorelick, MD; Michelle Miskin, MS; Shireen M. Atabaki, MD; Peter S. Dayan, MD, MSc; James F. Holmes, MD, MPH; Nathan Kuppermann, MD, MPH; for the Traumatic Brain Injury (TBI) Working Group of the Pediatric Emergency Care Applied Research Network (PECARN)

Objective: To determine the prevalence of clinically important traumatic brain injuries (TBIs) with severe injury mechanisms in children with minor blunt head trauma but with no other risk factors from the Pediatric Emergency Care Applied Research Network (PECARN) TBI prediction rules (defined as isolated severe injury mechanisms).

Design: Secondary analysis of a large prospective observational cohort study.

Setting: Twenty-five emergency departments participating in the PECARN.

Patients: Children with minor blunt head trauma and Glasgow Coma Scale scores of at least 14.

Intervention: Treating clinicians completed a structured data form that included injury mechanism (severity categories defined a priori).

Main Outcome Measures: Clinically important TBIs were defined as intracranial injuries resulting in death, neurosurgical intervention, intubation for more than 24 hours, or hospital admission for at least 2 nights. We investigated the rate of clinically important TBIs in children with either severe injury mechanisms or isolated severe injury mechanisms.

Results: Of the 42 412 patients enrolled in the overall study, 42 099 (99%) had injury mechanisms recorded, and their data were included for analysis. Of all study patients, 6263 (15%) had severe injury mechanisms, and 3630 (9%) had isolated severe injury mechanisms. Overall, 367 children had clinically important TBIs (0.9%; 95% CI, 0.8%-1.0%). Of the 1330 children younger than 2 years with isolated severe injury mechanisms, 4 (0.3%; 95% CI, 0.1%-0.8%) had clinically important TBIs, as did 12 of the 2300 children 2 years or older (0.5%; 95% CI, 0.3%-0.9%).

Conclusion: Children with isolated severe injury mechanisms are at low risk of clinically important TBI, and many do not require emergent neuroimaging.

Arch Pediatr Adolesc Med. 2012;166(4):356-361.
Published online December 5, 2011.
doi:10.1001/archpediatrics.2011.1156

WHILE MINOR BLUNT head trauma in childhood is a common reason for emergency department (ED) evaluation, the risk of traumatic brain injury (TBI) in these children is low.[1] Cranial computed tomography (CT) is the reference standard for diagnosing children with TBI, and ED use of CT has been increasing substantially over the past several decades.[2,3] However, unnecessary CT scans expose children to an increased lifetime risk of lethal malignancy.[4-7] Clinical prediction rules can be used to identify children at very low risk of TBI after blunt head trauma for whom cranial CT can be safely withheld.[8-15]

CME available online at www.jamaarchivescme.com and questions on page 303

Journal Club slides available at www.archpediatrics.com

See also page 396

Injury mechanism has been previously identified as an independent predictor of TBI in children.[9,13-15] Mechanisms associated with increased risk of TBI in children after blunt head trauma include all of the following: high-speed motor vehicle accident (for both a vehicular

Author Affiliations are listed at the end of this article.
Group Information: A list of the PECARN Group Members appears at the end of this article.

©2012 American Medical Association. All rights reserved.
Corrected on April 28, 2014
Downloaded From: http://archpedi.jamanetwork.com/ on 02/08/2016

occupant or a pedestrian struck),[9,14,15] bicycle-related injury,[13] impact from high-speed projectile,[9,14] and fall from a height or down stairs.[9,14,15] However, the risk of TBI in children with isolated severe injury mechanisms (ie, a severe mechanism but with no or few signs or symptoms of TBI) has not been defined, and it is unclear whether emergent neuroimaging is needed on the basis of injury mechanism alone.

The Pediatric Emergency Care Applied Research Network (PECARN) head trauma clinical prediction rules were derived and validated using a prospective observational cohort of almost 45 000 children with minor blunt head trauma evaluated in 25 participating EDs.[14] A severe injury mechanism was identified as an independent risk factor in both of the resulting clinical prediction rules (one for children <2 years and another for children ≥2 years). However, it is unclear whether children with a severe injury mechanism with none of the other PECARN rule risk factors always require emergent neuroimaging. To address this question, we performed a secondary analysis of this large prospective cohort to determine the risk of clinically important TBI in children with isolated severe injury mechanisms to determine the risk of clinically important TBI when injury mechanism is the only clinical predictor from the PECARN TBI prediction rules. Ultimately, we were driving at the conundrum of whether emergent CT use is indicated on the basis of severe injury mechanism alone, as is common practice in the ED.

METHODS

STUDY DESIGN

We performed a planned secondary analysis of a large prospective cohort study of children younger than 18 years with nontrivial head trauma. The study was conducted at 25 participating PECARN EDs from 2004 through 2006. The institutional review board of each participating institution approved the study protocol. Study methods have been previously described in detail.[14] Specific substudy methods are described in the following subsections.

INCLUSION AND EXCLUSION CRITERIA FOR MAIN COHORT STUDY

Children with blunt head trauma and initial Glasgow Coma Scale (GCS) scores of 14 or 15 who presented to the ED within 24 hours of the traumatic event were eligible for enrollment. We defined trivial injury mechanisms as ground-level falls or running into stationary objects. We excluded patients with trivial injury mechanisms and no signs or symptoms of head injury or just scalp abrasions or lacerations. We also excluded children with penetrating trauma, comorbidities (eg, ventricular shunts, bleeding disorders), or previous neuroimaging at a transferring hospital.[14]

INJURY MECHANISM

For all enrolled patients, the treating staff physician completed a structured case report form, which included injury mechanism. Study investigators divided injury mechanisms into 3 categories (severe, moderate, and mild) determined a priori based on prior literature and biological plausibility. A severe injury mechanism was defined as a motor vehicle collision with patient ejection, death of another passenger, or rollover; a pedestrian or bicyclist without helmet struck by a motorized vehicle; falls (at a height of >3 feet for children <2 years and >5 feet for children ≥2 years); or the head struck with a high-impact object. Mild injury mechanisms were defined as ground-level falls or running into stationary objects with clinical symptoms or signs suggestive of TBI. All other nontrivial injury mechanisms not specifically listed herein were considered a moderate injury mechanism. Patients without an injury mechanism recorded on the study form were excluded from this secondary analysis.

PECARN PREDICTION RULES CLINICAL PREDICTORS

The published PECARN clinical prediction rules for both age groups include severe injury mechanism plus 5 additional clinical predictors.[14] For children younger than 2 years, the following clinical predictors were included in the rule: altered mental status (defined as a GCS score < 15, agitation, sleepiness, slow responses, or repetitive questioning), nonfrontal scalp hematoma, loss of consciousness for 5 seconds or greater, palpable skull fracture, and not acting normally per parents. For children 2 years or older, the following clinical predictors were included in addition to severe injury mechanism: altered mental status, any loss of consciousness, history of vomiting, clinical signs of basilar skull fracture, and severe headache.

For purposes of the main analysis, children with an isolated severe injury mechanism were defined as having a severe injury mechanism and none of the other clinical predictors in the age-specific PECARN prediction rules. In a separate analysis, we expanded the isolated severe mechanism definition by adding the following additional symptoms and signs known to be associated with TBI: seizures, neurologic deficits on examination, any scalp hematoma, any signs of skull fracture, any loss of consciousness, vomiting (in children of any age), any headache (in children ≥2 years), and amnesia (in children ≥2 years). Patients missing documentation of any of the PECARN TBI predictors were excluded from the corresponding analysis.

OUTCOME MEASURES

The primary outcome measure was clinically important TBI, which was defined as any of the following: intracranial injury resulting in death, neurosurgical intervention, intubation for more than 24 hours for management of TBI or hospital admission for 2 or more nights due to the head trauma, in association with TBI on CT scan. After patient enrollment, study staff unaware of the clinical data from the ED reviewed patient medical records to determine the frequency of clinically important TBI. Cranial CT scans were obtained at the discretion of the treating health care provider and according to institutional practice guidelines. For children discharged from the ED after head injury, clinical follow-up was performed.[14]

STATISTICAL ANALYSIS

We performed all analyses for children younger than 2 years and 2 years or older separately using counts, percentages, and 95% CIs for categorical variables and the median and interquartile range (IQR) (25th-75th percentiles) for continuous variables. We calculated the rate of clinically important TBI in the following 4 injury mechanism groups: (1) all severe injury mechanisms, regardless of associated signs or symptoms of TBI; (2) isolated severe injury mechanism (ie, a

©2012 American Medical Association. All rights reserved.
Corrected on April 28, 2014
Downloaded From: http://archpedi.jamanetwork.com/ on 02/08/2016

Table 1. Distribution of Injury Mechanisms (IMs) and Clinically Important Traumatic Brain Injuries (ciTBIs) by Patient Age

	SIM					Mod IM	MIM		
IM	MV Collision[a]	Pedestrian or Bicyclist w/o Helmet Struck by MV	Falls[b]	Head Struck With HIO	All SIMs	All Other IMs NOL	Ground-Level Falls	Running Into Stationary Objects	All MIMs
Age <2 y (10 610 Patients)									
No. with IM	40	39	2240	20	**2339**	6700	969	602	**1571**
(row %)	(0.4)	(0.4)	(21)	(0.2)	(**22**)	(63)	(9)	(6)	(**15**)
No. with ciTBI	5 of 40	0 of 39	41 of 2240	0 of 20	**46 of 2339**	42 of 6700	3 of 969	1 of 602	**4 of 1571**
Col % (95% CI)	13	0	2	0	**2**	0.6	0.3	0.2	**0.3**
	(4-27)	(0-9)	(1-2)	(0-17)	(**1-3**)	(0.5-0.8)	(0.1-0.9)	(0-0.9)	(**0.1-0.7**)
Age ≥2 y (31 489 Patients)									
No. with IM	555	1551	957	861	**3924**	22 030	3697	1838	**5535**
(row %)	(2)	(5)	(3)	(3)	(**12**)	(70)	(12)	(6)	(**18**)
No. with ciTBI	17 of 555	43 of 1551	30 of 957	13 of 861	**103 of 3924**	155 of 22 030	15 of 3697	2 of 1838	**17 of 5535**
Col % (95% CI)	3	3	3	2	**3**	0.7	0.4	0.1	**0.3**
	(2-5)	(2-4)	(2-4)	(0.8-3)	(**2-3**)	(0.6-0.8)	(0.2-0.7)	(0-0.4)	(**0.2-0.5**)

Abbreviations: Col %, percentage of children within injury mechanism type; HIO, high-impact object; MIM, mild injury mechanism; mod, moderate; MV, motor vehicle; NOL, not otherwise listed; row %, percentage of children within age group; SIM, severe injury mechanism; TBI, traumatic brain injury; w/o, without.
[a] With patient ejection, death of another passenger, or rollover.
[b] More than 3 feet for a child younger than 2 years and more than 5 feet for a child 2 years or older.

Table 2. Bivariable Analysis Comparing the Rate of Clinically Important TBIs in Children With SIMs (Isolated vs Nonisolated SIM) for Patients Younger Than 2 Years or 2 Years or Older

	Prevalence of Clinically Important TBIs				
	In Children With an Isolated SIM[a]		In Children With a Nonisolated SIM[b]		Clinically Important TBI in Children With Isolated vs Nonisolated SIM, RR (95% CI)
Patient Age Group, y	No.	Row % (95% CI)	No.	Row % (95% CI)	
<2	4 of 1330	0.3 (0.1-0.8)	40 of 988	4 (3-5)	0.07 (0.03-0.21)
≥2	12 of 2300	0.5 (0.3-0.9)	90 of 1553	6 (5-7)	0.09 (0.05-0.16)

Abbreviations: PECARN, Pediatric Emergency Care Applied Research Network; row %, percentage of children within age group; RR, relative risk; SIM, severe injury mechanism; TBI, traumatic brain injury.
[a] A SIM with no other PECARN head trauma prediction rule predictors.
[b] A SIM with 1 or more additional PECARN head trauma prediction rule predictors.

severe injury mechanism with no other age-specific PECARN TBI predictors); (3) severe injury mechanism plus 1 additional PECARN TBI predictor; and (4) isolated severe injury mechanism using an expanded definition of isolated (ie, with no signs or symptoms of TBI extending beyond the clinical predictors in the PECARN TBI rules). For all the analyses, we used SAS/STAT software (version 9.2; SAS Institute Inc, Cary, North Carolina).

RESULTS

We enrolled 42 412 patients in the overall cohort study (78.3% of the 54 161 eligible patients). Enrolled and missed eligible patients had a similar rate of TBIs identified on CT scan.[14] Of these, 42 099 (99%) had an injury mechanism recorded and thus were included in the current substudy. The median patient age was 5.7 years (IQR, 2.0-12.0 years), and 26 209 (62%) were male. Cranial CT scans were obtained for 14 696 (35% of study patients); 367 (0.9%) had clinically important TBIs.

Of the study patients, 6263 (15%) had severe injury mechanisms, 28 730 (68%) had moderate injury mechanisms, and 7106 (17%) had mild injury mechanisms. Injury mechanism varied by patient age (**Table 1**). For children younger than 2 years, most severe injury mechanisms were falls from a height greater than 3 feet. For children 2 years or older, being a pedestrian or bicyclist without helmet struck by a motor vehicle was the most frequent severe mechanism. Children with severe injury mechanisms had a higher rate of clinically important TBIs than those with mild to moderate injury mechanisms (Table 1). In addition, the cranial CT rate was associated with severity of injury mechanism: 3237 of 6263 of patients with severe injury mechanisms (52%) had a CT performed, 9565 of 28 730 of patients with moderate injury mechanisms (33%), and 1894 of 7106 of patients with mild injury mechanisms (27%) ($P<.001$).

Children with isolated severe injury mechanisms (ie, no other PECARN age-specific TBI predictors) had a lower rate of clinically important TBI than those with severe injury mechanisms and other PECARN predictors (**Table 2**), both for patients younger than 2 years and those 2 years or older. The risk of clinically important TBI increased for patients with severe injury mecha-

©2012 American Medical Association. All rights reserved.
Corrected on April 28, 2014
Downloaded From: http://archpedi.jamanetwork.com/ on 02/08/2016

nisms and 1 additional PECARN TBI prediction rule criteria (**Table 3**).

The rate of clinically important TBIs for children with isolated severe injury mechanisms who met none of the PECARN predictors and none of the variables in the expanded definition of isolated severe injury mechanism was 1 of 758 (0.1%; 95% CI, 0%-0.7%) for children younger than 2 years and 2 of 876 (0.2%; 95% CI, 0%-0.8%) for children 2 years or older. The 3 children with clinically important TBIs and severe injury mechanisms and no other TBI symptoms listed herein were as follows: (1) a 4-month-old child who had fallen more than 3 feet, with evidence of facial trauma, who had a subarachnoid hemorrhage and a subdural hematoma; (2) a 10-year-old child ejected during a motor vehicle collision who sustained multisystem trauma and a traumatic hyphema, who also had a cerebral hemorrhage; and (3) a 12-year-old child struck by a motor vehicle who sustained multisystem trauma and facial trauma and had a subarachnoid hemorrhage and subdural hematoma. None of these children required neurosurgery.

Table 3. Risk of Clinically Important TBIs for Children With Isolated SIMs With 1 Additional Age-Specific PECARN Head Trauma Prediction Rule Criterion for Patients Younger Than 2 Years or 2 Years or Older

PECARN Head Trauma Prediction Rule Factors	Clinically Important TBI	
	No.	Row % (95% CI)
Children <2 y		
Isolated severe injury mechanism	4 of 1330	0.3 (0.1-0.8)
Plus 1 additional PECARN clinical predictor		
Altered mental status[a]	3 of 103	3 (0.6-8)
Nonfrontal scalp hematoma	9 of 258	3 (2-7)
Loss of consciousness ≥5 s	2 of 57	4 (0.4-12)
Palpable skull fracture	0 of 22	0 (0-15)
Not acting normally per parent	1 of 156	0.6 (0-4)
Children ≥2 y		
Isolated severe injury mechanism	12 of 2300	0.5 (0.3-0.9)
Plus 1 additional PECARN clinical predictor		
Altered mental status[a]	11 of 272	4 (2-7)
Any loss of consciousness	16 of 622	3 (1-4)
History of vomiting	5 of 125	4 (1-9)
Clinical signs of basilar skull fracture	0 of 13	0 (0-25)
Severe headache	0 of 28	0 (0-12)

Abbreviations: PECARN, Pediatric Emergency Care Applied Research Network; row %, percentage of children within predictor group; SIM, severe injury mechanism; TBI, traumatic brain injury.

[a] Defined as a Glasgow Coma Scale score lower than 15, agitation, sleepiness, slow responses, or repetitive questioning.

COMMENT

In this study, we measured the rate of clinically important TBIs in children with severe injury mechanisms in a large prospective cohort of children with minor blunt head trauma. Overall, children with severe injury mechanisms were at higher risk of clinically important TBI when compared to those with mild or moderate injury mechanisms. However, the risk of clinically important TBI was very low for children with isolated severe injury mechanisms (ie, with none of the other PECARN TBI predictors). In this group, clinically important TBIs occurred in only 0.3% of children younger than 2 years and in 0.5% of children 2 years or older. These risks were even lower for children with isolated severe injury mechanisms and no other signs or symptoms of TBI in addition to those of the PECARN TBI predictors.

Similar to several previously published studies, injury mechanism was an important risk factor for TBI in children with blunt head trauma.[9,13,15,16] However, the definitions of injury mechanism as well as TBI varied greatly between studies. Although expanding the severe injury mechanism definition may have identified additional patients with clinically important TBI, injury mechanisms were categorized a priori based on previous literature and biological plausibility. Of greatest importance, our study reports the risk of clinically important TBI in children with a severe injury mechanism and no other signs of TBI, defined by either the absence of other PECARN TBI rule predictors or the absence of any other signs or symptoms suggestive of TBI.

The published PECARN TBI prediction rules identify a subset of children who are at very low risk of clinically important TBI for whom clinicians can safely forgo an emergent CT scan. However, not all children who are not classified as very low risk by the PECARN TBI rules require neuroimaging because other clinical factors and clinician judgment are pertinent. In our study, we demonstrate that the risk of clinically important TBI is quite low in children with severe injury mechanisms without other PECARN TBI predictors. The presence of additional predictors, however, increases this risk in a nonnegligible fashion. For example, the risk of clinically important TBI increases substantially when a second factor is present in addition to severe injury mechanism (although the number of children in some of these subgroups was quite small). The risk of clinically important TBI is substantially lower in patients with no PECARN predictors other than a severe injury mechanism. Of note, the 3 children with a severe injury mechanism and no other apparent symptoms or signs of TBI who nevertheless had a clinically important TBI did not require neurosurgery. All 3 of these patients had evidence of facial trauma, however, and 2 had multisystem trauma. Therefore, many children with blunt head trauma with isolated severe injury mechanisms and no initial signs or symptoms of TBI may be observed for a period of time before CT decision making, and CT may be obviated if no signs or symptoms appear.

Our study has several potential limitations. Only 76% of all eligible patients seen at participating sites during the study period were included in this substudy. However, patients enrolled in the original study did not differ significantly from those not enrolled, either by patient age or prevalence of TBI identified by CT scan, suggesting that we enrolled a nonbiased sample.[14] Furthermore, not all children had a cranial CT performed, although all study patients had some form of clinical follow-up allowing accurate assessment of the primary outcome (clinically important TBI). In addition, the possibility exists that clinicians completing study forms may

©2012 American Medical Association. All rights reserved.
Corrected on April 28, 2014
Downloaded From: http://archpedi.jamanetwork.com/ on 02/08/2016

not have used standardized definitions for injury mechanisms. However, a previous analysis of this study population has demonstrated excellent interrater reliability for injury mechanism (κ statistic, 0.83; lower confidence limit, 0.81).[17] It is important to note that caregivers of children after nonaccidental trauma may not report injury mechanism accurately. Therefore, ED clinicians must always maintain a high index of suspicion of child abuse when evaluating any child with injuries.

Children with blunt head trauma and isolated severe injury mechanisms are at very low risk for having clinically important TBIs. All children with blunt head trauma and severe injury mechanisms require a careful history and physical examination by an ED health care provider skilled in the evaluation of children. Clinical observation for development of symptoms or signs of TBI may provide an effective clinical strategy for many of these patients with isolated severe injury mechanisms. After careful evaluation and observation without development of signs or symptoms of TBI, many children with isolated severe injury mechanisms may not require emergent neuroimaging.

Accepted for Publication: September 23, 2011.
Published Online: December 5, 2011. doi:10.1001/archpediatrics.2011.1156
Author Affiliations: Division of Emergency Medicine, Children's Hospital–Boston, Harvard Medical School, Boston, Massachusetts (Drs Nigrovic and Lee); Division of Emergency Medicine, Helen DeVos Children's Hospital, Michigan State University School of Medicine, Grand Rapids (Dr Hoyle); Department of Emergency Medicine, University of Michigan Health System, University of Michigan, Ann Arbor (Dr Stanley); Division of Emergency Medicine, Children's Hospital of Wisconsin, Medical College of Wisconsin, Milwaukee (Dr Gorelick); University of Utah School of Medicine, Salt Lake City (Ms Miskin); Departments of Pediatrics and Emergency Medicine, Children's National Medical Center, George Washington University School of Medicine, Washington, DC (Dr Atabaki); Department of Pediatrics, Morgan Stanley Children's Hospital of New York–Presbyterian, Columbia University College of Physicians and Surgeons, New York, New York (Dr Dayan); and Departments of Emergency Medicine (Drs Holmes and Kuppermann) and Pediatrics (Dr Kuppermann), School of Medicine, University of California–Davis Medical Center, Davis.
Correspondence: Lise E. Nigrovic, MD, MPH, Division of Emergency Medicine, Children's Hospital, Boston, 300 Longwood Ave, Boston, MA 02115 (lise.nigrovic@childrens.harvard.edu).
Author Contributions: Drs Nigrovic and Kuppermann had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Nigrovic, Dayan, Holmes, and Kuppermann. *Acquisition of data:* Lee, Hoyle, Stanley, Gorelick, Atabaki, Dayan, Holmes, and Kuppermann. *Analysis and interpretation of data:* Nigrovic, Miskin, and Kuppermann. *Drafting of the manuscript:* Nigrovic and Kuppermann. *Critical revision of the manuscript for important intellectual content:* Nigrovic, Lee, Hoyle, Stanley, Gorelick, Miskin, Atabaki, Dayan, Holmes, and Kuppermann. *Statistical analysis:* Nigrovic, Miskin, and Kuppermann. *Obtained funding:* Kuppermann. *Study supervision:* Kuppermann.
PECARN Group Members: Atlantic Health System/Morristown Memorial Hospital, Morristown, New Jersey (M. Gerardi); Bellevue Hospital Center, New York, New York (M. Tunik and J. Tsung); Calvert Memorial Hospital, Prince Frederick, Maryland (K. Melville); Children's Hospital–Boston, Boston, Massachusetts (L. Lee); Children's Hospital of Buffalo, Buffalo, New York (K. Lillis); Children's Hospital of Michigan, Detroit (P. Mahajan); Children's Hospital of New York–Presbyterian, New York (P. Dayan); Children's Hospital of Philadelphia, Philadelphia, Pennsylvania (F. Nadel); Children's Memorial Hospital, Chicago, Illinois (E. Powell); Children's National Medical Center, George Washington University School of Medicine, Washington, DC (S. Atabaki and K. Brown); Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio (T. Glass); Helen DeVos Children's Hospital, Michigan State University School of Medicine, Grand Rapids (J. Hoyle); Harlem Hospital Center, New York (A. Cooper); Holy Cross Hospital, Silver Spring, Maryland (E. Jacobs); Howard County Medical Center, Columbia, Missouri (D. Monroe); Hurley Medical Center, Flint, Michigan (D. Borgialli); Medical College of Wisconsin/Children's Hospital of Wisconsin, Milwaukee (M. Gorelick and S. Bandyopadhyay); St Barnabas Health Care System, West Orange, New Jersey (M. Bachman and N. Schamban); SUNY–Upstate Medical University, Syracuse, New York (J. Callahan); University of California–Davis Medical Center, Davis (N. Kuppermann and J. Holmes); University of Maryland, Baltimore (R. Lichenstein); University of Michigan, Ann Arbor (R. Stanley); University of Rochester, Rochester, New York (M. Badawy and L. Babcock-Cimpello); University of Utah/Primary Children's Medical Center, Salt Lake City (J. Schunk); Washington University/St Louis Children's Hospital, St Louis, Missouri (K. Quayle and D. Jaffe).
Financial Disclosure: None reported.
Funding/Support: This work was supported by a grant from the Health Resources and Services Administration/Maternal and Child Health Bureau (HRSA/MCHB), Division of Research, Training and Education (DRTE), and the Emergency Medical Services of Children (EMSC) Program (R40MC02461). The Pediatric Emergency Care Applied Research Network (PECARN) is supported by cooperative agreements U03MC00001, U03MC00003, U03MC00006, U03MC00007, and U03MC00008 from the EMSC program of the MCHB/HRSA.
Online-Only Material: This article is featured in the *Archives* Journal Club. Go to http://archpediatrics.com to download teaching PowerPoint slides.
Additional Contributions: We acknowledge the efforts of the following individuals participating in PECARN at the time this study was initiated. *PECARN Steering Committee:* N. Kuppermann, Chair; E. Alpern, J. Chamberlain, J. M. Dean, M. Gerardi, J. Goepp, M. Gorelick, J. Hoyle, D. Jaffe, C. Johns, N. Levick, P. Mahajan, R. Maio, K. Melville, S. Miller (deceased), D. Monroe, R. Ruddy, R. Stanley, D. Treloar, M. Tunik, and A. Walker. *MCHB/EMSC Liaisons:* D. Kavanaugh, H. Park. *Central Data Man-*

©2012 American Medical Association. All rights reserved.
Downloaded From: http://archpedi.jamanetwork.com/ on 02/08/2016
Corrected on April 28, 2014

agement and Coordinating Center (CDMCC): M. Dean, R. Holubkov, S. Knight, and A. Donaldson. *Data Analysis and Management Subcommittee (DAMS):* J. Chamberlain, Chair; M. Brown, H. Corneli, J. Goepp, R. Holubkov, P. Mahajan, K. Melville, E. Stremski, and M. Tunik. *Grants and Publications Subcommittee (GAPS):* M. Gorelick, Chair; E. Alpern, J. M. Dean, G. Foltin, J. Joseph, S. Miller (deceased), F. Moler, R. Stanley, and S. Teach. *Protocol Concept Review and Development Subcommittee (PCRADS):* D. Jaffe, Chair; K. Brown, A. Cooper, J. M. Dean, C. Johns, R. Maio, N. C. Mann, D. Monroe, K. Shaw, D. Teitelbaum, and D. Treloar. *Quality Assurance Subcommittee (QAS):* R. Stanley, Chair; D. Alexander, J. Brown, M. Gerardi, M. Gregor, R. Holubkov, K. Lillis, B. Nordberg, R. Ruddy, M. Shults, and A. Walker. *Safety and Regulatory Affairs Subcommittee (SRAS):* N. Levick, Chair; J. Brennan, J. Brown, J. M. Dean, J. Hoyle, R. Maio, R. Ruddy, W. Schalick, T. Singh, and J. Wright. We thank Sally Jo Zuspan, Rene Enriquez, and Li Dong at the PECARN Data Center (University of Utah) for their dedicated and diligent work; the research coordinators in PECARN, without whose dedication and hard work this study would not have been possible; and all the clinicians around the PECARN who enrolled children in this study.

REFERENCES

1. Langlois JA, Rutland-Brown W, Thomas KE. *Traumatic Brain Injury in the United States*. In: Centers for Disease Control and Prevention, ed. Atlanta, GA: National Center for Injury Prevention and Control; 2006.
2. 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.
3. Dorfman AL, Fazel R, Einstein AJ, et al. Use of medical imaging procedures with ionizing radiation in children: a population-based study. *Arch Pediatr Adolesc Med*. 2011;165(5):458-464.
4. Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative. *Pediatr Radiol*. 2002;32(4):228-244.
5. Brenner DJ, Hall EJ. Computed tomography: an increasing source of radiation exposure. *N Engl J Med*. 2007;357(22):2277-2284.
6. 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.
7. Frush DP. Radiation, CT, and children: the simple answer is . . . it's complicated. *Radiology*. 2009;252(1):4-6.
8. Maguire JL, Boutis K, Uleryk EM, Laupacis A, Parkin PC. Should a head-injured child receive a head CT scan? a systematic review of clinical prediction rules. *Pediatrics*. 2009;124(1):e145-e154.
9. Dunning J, Daly JP, Lomas JP, 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.
10. 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.
11. Haydel MJ, Shembekar AD. Prediction of intracranial injury in children aged five years and older with loss of consciousness after minor head injury due to nontrivial mechanisms. *Ann Emerg Med*. 2003;42(4):507-514.
12. Oman JA, Cooper RJ, Holmes JF, 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-e246.
13. Atabaki SM, Stiell IG, Bazarian JJ, et al. A clinical decision rule for cranial computed tomography in minor pediatric head trauma. *Arch Pediatr Adolesc Med*. 2008;162(5):439-445.
14. 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.
15. 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.
16. Kuppermann N. Intracranial injury in minor head trauma. *Arch Dis Child*. 2004;89(7):593-594.
17. 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.

©2012 American Medical Association. All rights reserved.
Corrected on April 28, 2014
Downloaded From: http://archpedi.jamanetwork.com/ on 02/08/2016