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Authors

Nishijima, Daniel K
Holmes, James F
Dayan, Peter S
et al.

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Association of a Guardian's Report of a Child Acting Abnormally With Traumatic Brain Injury After Minor Blunt Head Trauma

Daniel K. Nishijima, MD, MAS, **James F. Holmes, MD, MPH**, **Peter S. Dayan, MD, MSc**, and **Nathan Kuppermann, MD, MPH**

Department of Emergency Medicine, School of Medicine, University of California– Davis, Sacramento (Nishijima, Holmes, Kuppermann); Division of Pediatric Emergency Medicine, College of Physicians and Surgeons, Columbia University, New York, New York (Dayan)

Abstract

IMPORTANCE—Increased use of computed tomography (CT) in children is concerning owing to the cancer risk from ionizing radiation, particularly in children younger than 2 years. A guardian report that a child is acting abnormally is a risk factor for clinically important traumatic brain injury (ciTBI) and may be a driving factor for CT use in the emergency department.

OBJECTIVE—To determine the prevalence of ciTBIs and TBIs in children younger than 2 years with minor blunt head trauma and a guardian report of acting abnormally with (1) no other findings or (2) other concerning findings for TBI.

DESIGN, SETTING, AND PARTICIPANTS—Secondary analysis of a large, prospective, multicenter cohort study that included 43 399 children younger than 18 years with minor blunt head trauma evaluated in 25 emergency departments. The study was conducted on data obtained between June 2004 and September 2006. Data analysis was performed between August 21, 2014, and March 9, 2015.

Corresponding Author: Daniel K. Nishijima, MD, MAS, Department of Emergency Medicine, School of Medicine, University of California, Davis, 4150 V St, Patient Services Support Building, 2100, Sacramento, CA 95817 (dnishijima@ucdavis.edu).

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Study concept and design: All authors.
Acquisition, analysis, or interpretation of data: All authors.
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Critical revision of the manuscript for important intellectual content: All authors.
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Additional Contributions: Mark Faul, PhD, MS (Centers for Disease Control and Prevention), provided data on emergency department visits of children with blunt head trauma in the United States. There was no financial compensation.

Supplemental content at jamapediatrics.com

EXPOSURES—A guardian report that the child was acting abnormally after minor blunt head trauma.

MAIN OUTCOMES AND MEASURES—The prevalence of ciTBI (defined as death, neurosurgery, intubation for >24 hours, or hospitalization for ≥2 nights in association with TBI on CT imaging) and TBI on CT imaging in children with a guardian report of acting abnormally with (1) no other findings and (2) other concerning findings for TBI.

RESULTS—Of 43 399 children in the cohort study, a total of 1297 children had reports of acting abnormally, of whom 411 (31.7%) had this report as their only finding. Reported as percentage (95% CI), 1 of 411 (0.2% [0–1.3%]) had a ciTBI, and 4 TBIs were noted on the CT scans in 185 children who underwent imaging (2.2% [0.6%–5.4%]). In children with reports of acting abnormally and other concerning findings for TBI, 29 of 886 (3.3% [2.2%–4.7%]) had ciTBIs and 66 of 674 (9.8% [7.7%–12.3%]) had TBIs on CT.

CONCLUSIONS AND RELEVANCE—Clinically important TBIs are very uncommon, and TBIs noted on CT are uncommon in children younger than 2 years with minor blunt head trauma and guardian reports of the child acting abnormally with no other clinical findings suspicious for TBI. Computed tomographic scans are generally not indicated in these children although observation in the emergency department may be warranted.

Approximately 900 000 children are evaluated in US emergency departments (EDs) annually for blunt head trauma, of whom 27% are younger than 2 years (Mark Faul, PhD, MS, Centers of Disease Control and Prevention, written communication, December 9, 2014).[1] The diagnostic evaluation of preverbal children (ie, <2 years) with head trauma presents unique challenges for health care professionals. These young children are at increased risk for intracranial injuries with more minor mechanisms of injury compared with older children.[2,3] Furthermore, these children are more difficult to evaluate than older children because of their inability to convey symptoms and display physical signs.[2] Finally, younger children are more susceptible to ionizing radiation–induced malignant neoplasms associated with computed tomography (CT), requiring particularly judicious use of CT imaging.[4–8]

One component of the evaluation of young children with minor blunt head trauma is the guardian's report of whether the child is acting abnormally at the time of ED evaluation. This report may be of concern to the physician since there is a common sense that the parent may perceive something that is not perceptible to the person performing the evaluation. A guardian's report of the child acting abnormally was a risk factor for clinically important traumatic brain injury (ciTBI) in the Pediatric Emergency Care Applied Research Network (PECARN) TBI prediction rule for children younger than 2 years.[9] However, abnormal behavior was not considered a risk factor for clinically significant brain injuries in 2 other prediction models of head-injured children.[10–12]

The objective of the present study was to determine the prevalence of ciTBI and TBI noted on CT in children younger than 2 years with reports of acting abnormally per the guardians when these reports occurred in isolation as well as when they occurred in conjunction with other signs or symptoms of TBI. Our goal was to provide physicians information in addition to what is available in the PECARN prediction rule.

Methods

Study Design and Setting

We performed a secondary analysis of the PECARN TBI public use data set.[9] This data set was based on a large, prospective, observational cohort study that enrolled children younger than 18 years with minor blunt head trauma at 25 EDs between June 2004 and September 2006, to derive and validate a prediction rule for ciTBI. The present study was approved by the University of California, Davis, institutional review board. Data were deidentified.

Selection of Participants

The PECARN TBI data set included children evaluated at EDs within 24 hours of head trauma with Glasgow Coma Scale scores of 3 to 15.[9] Excluded were children with trivial injury mechanisms (ground-level falls or walking or running into stationary objects and no signs or symptoms of head trauma other than scalp abrasions and/or lacerations), penetrating trauma, known brain tumors, preexisting neurologic disorders complicating assessment, ventricular shunts, bleeding disorders, and children who received neuroimaging at an outside hospital. For the main analysis, we included only children younger than 2 years who had initial ED Glasgow Coma Scale scores of 14 or 15. In a secondary analysis, however, we included children younger than 18 years.

Methods of Measurement

Physicians in the ED recorded patient history, injury mechanism, and symptoms and signs of TBI on a standardized case report form before they were aware of any available cranial CT results. On the case report forms, physicians answered the question, “Does the parent think the child is acting normally/like themselves?” (categorized as yes or no).

We defined acting abnormally per report of the guardian with no other concerning findings for TBI in 2 ways based on the absence of other patient history or physical examination findings suggestive of TBI (Table 1). The primary definition, termed *report of acting abnormally with no other PECARN findings*, was based on the absence of the other 5 clinical variables in the PECARN TBI prediction rule for children younger than 2 years. The second definition, termed *report of acting abnormally with no other extended findings*, was based on the absence of an extended list of clinical variables previously reported to be associated with TBI.[13–16] This extended list includes the PECARN TBI prediction variables for children younger than 2 years in addition to other clinical symptoms and signs of TBI, such as the absence of posttraumatic seizures and neurologic deficits (Table 1). In this analysis, we wanted to focus only on clinical symptoms and signs of TBI. Therefore, similar to prior studies, mechanism of injury was not included in the report of acting abnormally with no other extended findings because it is a historical component of the injury rather than a symptom or sign of TBI.[13–15]

Outcome Measures

Our primary outcome measure was ciTBI, defined as death from TBI, neurosurgical procedure performed for treatment of TBI, TBI noted on CT leading to intubation for more than 24 hours, or hospital admission of 2 nights or more in association with TBI noted on

CT.[9] The secondary outcome measure was TBI noted on CT, defined as any acute traumatic intracranial finding or a skull fracture depressed by at least the width of the skull.[9] Evaluation and treatment strategies, such as obtaining cranial CT scans, observing the child in the ED, or hospital admission, were at the discretion of the treating physician. Faculty radiologists at participating sites interpreted cranial CT scans, with equivocal findings interpreted definitively by the single study pediatric radiologist who was masked to both clinical information and previous radiologic interpretation. Follow-up procedures to identify children with unrecognized TBIs included standardized telephone surveys 7 to 90 days after the ED visit for children discharged from the ED (30 478 [79.0%] of the 38 591 surveys were successfully completed). For those unable to be contacted, the medical record, ED process improvement records, and county morgue records were evaluated to ensure that a TBI was not subsequently diagnosed in any patient discharged from the ED.

Statistical Analysis

Analysis of deidentified data was conducted between August 21, 2014, and March 9, 2015. Data formatting and recoding of variables were conducted using Stata, version 11.0 (StataCorp). We characterized the study population using descriptive statistics. Nonnormal interval data are reported with medians and interquartile ranges, and proportions are presented with 95% Clopper-Pearson (exact) binomial CIs.

For all analyses, we removed patients who were missing any of the PECARN rule predictors or who were missing the ciTBI or TBI on CT outcome variables. Because the original PECARN TBI prediction rule study included patients with missing variables (using surrogate variables when necessary), the number of patients in this study differed slightly.[9] For the analysis based on the report of acting abnormally with no other extended findings definition, we excluded patients who were missing more than 1 of the extended clinical signs or symptoms suggestive of TBI.

For the primary analysis, we compared the prevalence of ciTBI and TBI on CT in 2 groups of children younger than 2 years: (1) those with reports of acting abnormally with no other PECARN findings and (2) those with reports of acting abnormally with other PECARN findings (ie, report of acting abnormally per guardian plus ≥1 other PECARN TBI prediction variable) using the χ^2 test (or Fisher exact test in cases of small cell size). The denominator for the ciTBI analysis included all patients, but the denominator for the prevalence of TBI on CT was based only on children who received a cranial CT in the ED. To further understand the risk of TBI in patients who were described by the guardian as acting abnormally, we assessed the risk of ciTBI in children reported as acting abnormally with no other PECARN findings in addition to 1 other age-specific PECARN prediction rule variable. We also evaluated the prevalence of the 2 outcome measures in children younger than 2 years using the report of acting abnormally with no other extended findings definition and compared it with those who were reported to be acting abnormally and had 1 or more of the other extended definition variables.

Because a report of acting abnormally with no other extended findings may apply to children of all ages, in a secondary analysis, we compared the prevalence of outcomes in all children younger than 18 years with a guardian report of acting abnormally with no other extended

findings with the outcomes of those with a report of acting abnormally in association with other extended findings. We did not evaluate the outcomes in children with reports of acting abnormally with no other PECARN findings definition in the secondary analysis of all children because the report of acting abnormally was not a PECARN TBI prediction variable for children aged 2 up to 18 years.[9] To explore the possibility that the report of acting abnormally with no other findings and ED cranial CT use varied by age, we investigated the prevalence of these by age in months (children <2 years) and by years (children younger than 18 years).

Results

Characteristics of the Study Participants

The PECARN TBI public use data set included 43 399 children. After excluding children aged 2 years or older for the primary analysis, those with Glasgow Coma Scale scores less than 14, and patients with missing data, the primary study population consisted of 9675 children, of whom 1297 (13.4%) had guardian reports of acting abnormally (Figure). Of these children, 411 (31.7%) had reports of acting abnormally with no other PECARN findings and 886 (68.3%) had reports of acting abnormally in conjunction with other PECARN findings (Table 2).

Primary Outcomes

Of the 411 children younger than 2 years with reports of acting abnormally with no other PECARN findings (results reported as percentage [95% CI]), 1 child (0.2% [0–1.3%]) had a ciTBI and 4 of 185 children who received an ED CT scan (2.2% [0.6%–5.4%]) had TBIs on CT. The prevalence of ciTBI and TBI on CT in children with reports of acting abnormally with other PECARN findings was 3.3% (2.2%–4.7%) and 9.8% (7.7%–12.3%), respectively. Thus, the risk of ciTBI (absolute risk difference, 3.1% [1.5%–4.4%]; $P = .001$) and TBI on CT (absolute risk difference, 7.6% [3.8%–10.4%]; $P = .001$) was significantly greater in children with reports of acting abnormally in association with other PECARN findings than in children with reports of acting abnormally with no other PECARN findings.

The one child with a report of acting abnormally with no other PECARN findings who had a ciTBI was a 9-month-old boy with isolated head trauma who had a fall from less than 0.9 m. Other clinical signs and symptoms of TBI in this child (but not part of the age-based PECARN prediction rule) included a history of vomiting more than 2 times and a frontal scalp hematoma. This child had subarachnoid and subdural hemorrhage noted on cranial CT. He was hospitalized owing to head trauma but had no specific intervention for his brain injury.

The addition of 1 other PECARN TBI rule predictor in children younger than 2 years with a guardian report of acting abnormally slightly increased the prevalence of ciTBI to 6 of 726 children (0.8% [0.3%–1.8%]) (Table 3). The addition of 2 or more PECARN TBI rule predictors in children with a guardian report of acting abnormally, however, increased the prevalence of ciTBI to 23 of 160 children (14.4% [9.3%–20.8%]). eTable 1 in the Supplement demonstrates the prevalence of ciTBI and TBI on CT in children with reports of

acting abnormally with no other extended findings compared with children reported to be acting abnormally in association with other extended findings. None of the 188 children (0% [0–1.9%]) younger than 2 years with reports of acting abnormally with no other extended findings had ciTBIs, and 1 of the 71 children (1.4% [0–7.6%]) with a cranial CT had a TBI noted on the scan. This child was a 2-month-old girl who sustained a fall from less than 0.9 m and had a cerebral hemorrhage/intracerebral hematoma. When a guardian report of the child acting abnormally was present in conjunction with other extended findings suggestive of TBI in children younger than 2 years, the incidence of ciTBI (43 [3.7%]) and TBI (83 [9.8%]) noted on CT were higher.

Secondary Analyses

We explored the prevalence of ciTBI and TBI on CT in all children younger than 18 years who were described by the guardian as acting abnormally with (1) no other extended findings and (2) 1 or more extended variables. No children younger than 18 years with a report of acting abnormally and with no other extended findings had a ciTBI or TBI noted on CT (eTable 2 in the Supplement) except for the 2-month-old child with a TBI documented on CT as described above. When a guardian report of acting abnormally was present with other extended findings suggestive of TBI in children younger than 18 years, the incidence of ciTBI (201 [3.7%]) and TBI (298 [7.3%]) observed on CT was higher.

We evaluated the frequency of guardian report of a child acting abnormally in all children younger than 18 years to explore whether younger children had this report more often. The frequency of this report did not vary substantially by age in months (0–24 months) or years (<18 years) (eFigures 1–4 in the Supplement). We also evaluated the frequency of ED cranial CT in all children with reports of acting abnormally with no other findings to explore whether younger children had cranial CT scans performed more frequently. The use of CT scans was similar across children’s age in months (0–24 months) and years (<18 years).

A total of 1046 of 10 721 children (9.7%) younger than 2 years with a GCS score of 14 or 15 had missing data, and the exclusion of these patients may have influenced the results of the study. We conducted a sensitivity analysis and found any influence of exclusion to be unlikely since the prevalence of ciTBI in children with missing data and the potential for having reports of acting abnormally with no other PECARN findings was 1 of 42 (2.4% [95% CI, 0–12.6%]) vs 1 of 411 (0.2% [95% CI 0–1.3%]) in children with complete data.

Discussion

We evaluated a large number of children younger than 2 years with minor blunt head trauma whose only clinical finding was that they were acting abnormally per the report of the guardian. We found that ciTBI was uncommon in this group, suggesting that CT scans are not routinely required in these children. The one child reported to be acting abnormally with no other PECARN findings and who sustained a ciTBI did not require neurosurgery.

The PECARN TBI prediction rule suggests that, in the absence of any of the PECARN TBI predictors in children younger than 2 years with head trauma, cranial CT scanning is not needed since the risk of ciTBI is exceedingly low (0 of 1175; 0% [95% CI, 0%–0.3%] in the

validation cohort). This risk is generally lower than the risk of CT-induced malignant neoplasms (estimated lifetime attributable risk of death from cancer from a single cranial CT scan in a 1-year-old child is 1 in 1000).[6] However, even in the presence of the isolated risk factor that the guardian reports that the child is not acting normally, the risk of ciTBI (1 of 411, 0.2% [95% CI, 0–1.3%]) remains sufficiently low so that observation before CT decision making is justified, and routine CT scanning is not needed. A period of ED observation for the development of clinical symptoms or signs may provide a good alternative to immediate CT imaging.[17] The prevalence of ciTBI and TBI on CT imaging was also uncommon in children younger than 18 years with reports of acting abnormally with no other extended findings.

The prevalence of ciTBI increased slightly, however, when the report of acting abnormally per guardian was accompanied by 1 other PECARN clinical predictor. In addition, the addition of 2 or more other PECARN clinical prediction rule factors greatly increased the risk of ciTBI to a degree that CT imaging is typically warranted.

Similar to the findings of the present study, other investigations of children with minor blunt trauma who have specific single findings on patient history or physical examination are typically at low risk for ciTBI. In prior studies of children with isolated scalp hematomas,[14] isolated vomiting,[15] isolated severe mechanisms of injury,[16] or isolated history of loss of consciousness,[13] the risk of ciTBI was low. As in the present study, however, the prevalence of ciTBI increased when combined with another PECARN TBI predictor.[13–16] These data suggest that, when evaluating young children for the risk of ciTBI, focusing on specific important predictors and determining whether they are present in isolation should help to determine the need for emergent cranial CT imaging or whether that decision can be delayed by a period of observation.

Our results should be interpreted in the context of several limitations. This was a secondary analysis of the data set used to derive and validate the PECARN TBI prediction rule. Use of the same data set to evaluate the guardian report that the child is acting abnormally may create inherent bias.

Although physician agreement on the presence of the guardian reporting that the child is acting abnormally was previously shown to be acceptable,[18] the assessment of acting abnormally may be interpreted differently by different guardians. The primary study did not evaluate interrater agreement between guardians of the same injured child. However, physicians' reliance on a single guardian interpretation of this clinical factor is typical of clinical practice. In addition, the guardian report that the child is acting abnormally is perhaps the most subjective of the PECARN risk factors. Therefore, this variable could be subject to change over time, particularly with increased public awareness of concussion and mild TBI during the past decade.

Conclusions

Clinically important TBIs are very uncommon, and TBIs noted on CT are uncommon in children younger than 2 years with minor blunt head trauma and guardian reports of the

child acting abnormally with no other clinical findings suspicious for TBI. Computed tomographic scans are generally not indicated in these children although a period of ED observation before the decision to obtain a CT scan may be warranted to assess for the development of clinical symptoms or signs of TBI. Clinically important TBI and TBI noted on CT imaging are more frequent in children with reports of acting abnormally per guardian when accompanied by other signs or symptoms suggestive of TBI.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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At a Glance

- Guardian reports that the child is not acting normally in children younger than 2 years may be a key driver of computed tomography (CT) use after minor blunt head trauma.
- In this secondary analysis of a large, prospective, multicenter cohort study, clinically important traumatic brain injuries were uncommon (0.2%; 95% CI, 0%–1.3%) in children younger than 2 years with reports of acting abnormally and no other concerning findings for traumatic brain injury (TBI).
- In children with guardian reports of acting abnormally and other concerning findings for TBI, 29 of 886 (3.3%; 95% CI, 2.2%–4.7%) had clinically important TBIs.
- Routine CT scans are generally not indicated in children with guardian reports of acting abnormally and no other concerning findings for TBI although observation in the emergency department may be warranted.

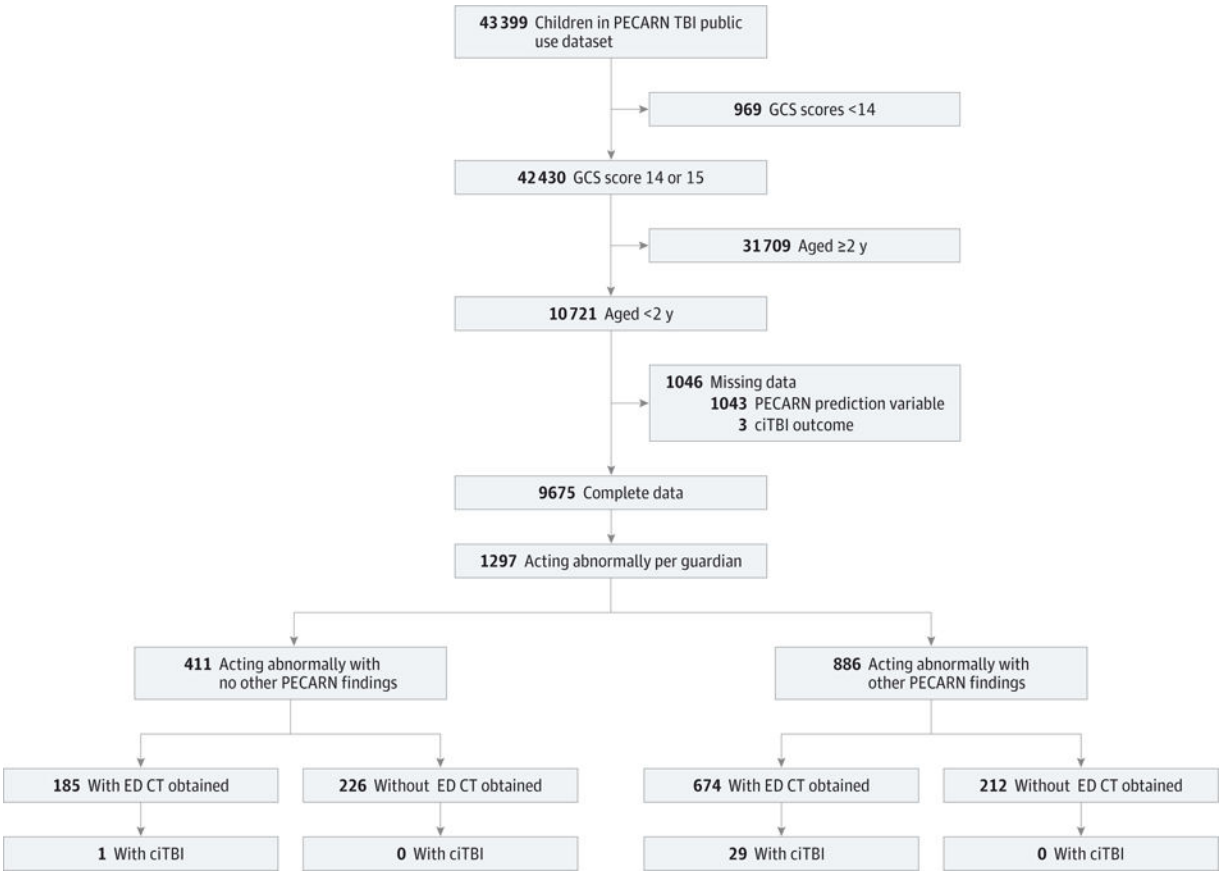

Figure. Flowchart of Patients in Primary Analysis

Abbreviations: ciTBI, clinically important traumatic brain injury (TBI); CT, computed tomography; ED, emergency department; GCS, Glasgow Coma Scale; and PECARN, Pediatric Emergency Care Applied Research Network.

Table 1

Definitions of Report of Acting Abnormally per Guardian With No Other Findings for Children Younger Than 2 Years

Type of Characteristic	Acting Abnormally, No. (%)	
	With No Other PECARN Findings (n = 411)[a]	With No Other Extended Findings (n = 188)[b]
Historical	No history of LOC >5 s No severe mechanism of injury[c]	No history of LOC No history of vomiting after the head trauma No history of seizure after the head trauma
Physician examination	GCS score, 15 No signs of altered mental status[d] No palpable skull fracture No occipital, parietal, or temporal scalp hematoma	GCS score, 15 No signs of altered mental status[d] No palpable skull fracture No signs of basilar skull fracture[e] No scalp hematoma or other traumatic scalp finding (eg, abrasion or laceration) No neurologic deficits (eg, motor or sensory abnormalities

Abbreviations: GCS, Glasgow Coma Scale; LOC, loss of consciousness; PECARN, Pediatric Emergency Care Applied Research Network.

[a] More information on the PECARN findings is found in Kuppermann et al.[9]

[b] Severe mechanism of injury was not included in this definition because it is not a sign or symptom of traumatic brain injury.

[c] Severe mechanism of injury was 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 greater than 0.9 m; or struck by a high-impact object.

[d] Signs of altered mental status include agitation, somnolence, repetitive questioning, or slow response to verbal communication.

[e] Signs of basilar skull fracture include hemotympanum, cerebrospinal fluid otorrhea, periorbital ecchymosis (raccoon eyes), retroauricular ecchymosis (Battle sign), or cerebrospinal fluid rhinorrhea.

Table 2

Characteristics of Children Younger Than 2 Years With Reports of Acting Abnormally in Isolation and With Other PECARN Findings[a]

Characteristic	Acting Abnormally, No. (%)	
	With No Other PECARN Findings (n = 411)	With Other PECARN Findings (n = 886)
Age, median (IQR), mo	12 (6–16)	11 (5–17)
Male	232 (56.4)	465 (52.5)
Mechanism of injury		
Fall from elevation	189 (46.0)	555 (62.6)
Fall down stairs	61 (14.8)	99 (11.2)
Fall to ground from standing/walking/running	53 (12.9)	76 (8.6)
Walked or ran into stationary object	29 (7.1)	34 (3.8)
Object struck head, accidental	23 (5.6)	29 (3.3)
Occupant in motor vehicle collision	12 (2.9)	15 (1.7)
Assault	3 (0.7)	3 (0.3)
Other	41 (10.0)	64 (7.2)
Concomitant significant injury to other part of body[b]	11 (2.7)	36 (4.1)

Abbreviations: IQR, interquartile range; PECARN, Pediatric Emergency Care Applied Research Network; TBI, traumatic brain injury.

[a]Report of acting abnormally with no other PECARN findings is defined in Table 1; report of acting abnormally with other PECARN findings was defined as acting abnormally per guardian report with any other age-specific PECARN traumatic brain injury prediction rule variable present.

[b]Concomitant significant injury to other part of the body was defined as extremity fractures, intra-abdominal injuries, intrathoracic injuries, and lacerations requiring operating room repair.

Table 3

Prevalence of Clinically Important Traumatic Brain Injuries in Children Younger Than 2 Years[a]

	ciTBI	
PECARN TBI Prediction Rule Variable	**No./Total No. of Cases**	**% (95% CI)**
Report of acting abnormally with no other PECARN findings	1/411	0.2 (0–1.3)
Report of acting abnormally with 1 additional PECARN rule clinical predictor		
GCS score of 14	3/288	1.0 (0.2–3.0)
Signs of altered mental status other than GCS score of 14[b]	1/206	0.5 (0–2.3)
Severe mechanism of injury[c]	1/143	0.7 (0–3.8)
Nonfrontal scalp hematoma	1/59	1.7 (0–9.1)
LOC >5 s	0/20	0 (0–1.7)[d]
Palpable skull fracture	0/10	0 (0–30.8)[d]
Overall with 1 additional PECARN clinical predictor	6/726	0.8 (0.3–1.8)
Overall with ≥2 additional PECARN rule clinical predictors	23/160	14.4 (9.3–20.8)

Abbreviations: ciTBI, clinically important traumatic brain injury (TBI); GCS, Glasgow Coma Scale; LOC, loss of consciousness; PECARN, Pediatric Emergency Care Applied Research Network.

[a]Report of acting abnormally with no other PECARN findings is defined in Table 1; report of acting abnormally with other PECARN findings was defined as acting abnormally per guardian report with any other PECARN TBI prediction rule variable present.

[b]Signs of altered mental status other than GCS score of 14 include agitation, somnolence, repetitive questioning, or slow response to verbal communication.

[c]Severe mechanism of injury was defined as a motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorized vehicle; falls of greater than 0.9 m; or struck by a high-impact object.

[d]One-sided, 97.5% CI.