Risk of Traumatic Brain Injuries in Children Younger than 24 Months With Isolated Scalp Hematomas

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Study objective: We aimed to determine the association between scalp hematoma characteristics and traumatic brain injuries in young children with blunt head trauma who have no other symptoms or signs suggestive of traumatic brain injuries (defined as "isolated scalp hematomas").

Methods: This was a secondary analysis of children younger than 24 months with minor blunt head trauma from a prospective cohort study in 25 Pediatric Emergency Care Applied Research Network emergency departments. Treating clinicians completed a structured data form. For children with isolated scalp hematomas, we determined the prevalence of and association between scalp hematoma characteristics and (1) clinically important traumatic brain injury (death, neurosurgery for traumatic brain injury, intubation >24 hours for traumatic brain injury, or positive computed tomography (CT) scan in association with hospitalization ≥2 nights for traumatic brain injury); and (2) traumatic brain injury on CT.

Results: Of 10,659 patients younger than 24 months were enrolled, 2,998 of 10,463 (28.7%) with complete data had isolated scalp hematomas. Clinically important traumatic brain injuries occurred in 12 patients (0.4%; 95% confidence interval [CI] 0.2% to 0.7%); none underwent neurosurgery (95% CI 0% to 0.1%). Of 570 patients (19.0%) for whom CTs were obtained, 50 (8.8%; 95% CI 6.6% to 11.4%) had traumatic brain injuries on CT. Younger age, non-frontal scalp hematoma location, increased scalp hematoma size, and severe injury mechanism were independently associated with traumatic brain injury on CT.

Conclusion: In patients younger than 24 months with isolated scalp hematomas, a minority received CTs. Despite the occasional presence of traumatic brain injuries on CT, the prevalence of clinically important traumatic brain injuries was very low, with no patient requiring neurosurgery. Clinicians should use patient age, scalp hematoma location and size, and injury mechanism to help determine which otherwise asymptomatic children should undergo neuroimaging after minor head trauma. [Ann Emerg Med. 2014;64:153-162.]

Please see page 154 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background and Importance

Children with blunt head trauma account for more than 450,000 emergency department (ED) visits annually in the United States.[1] Approximately 25% of the visits for blunt head trauma are in children younger than 24 months.[2] Among these patients, ED clinicians must identify those with traumatic brain injuries, particularly those who require acute interventions. In the process, however, clinicians must remain cognizant of overuse of computed tomography (CT). More selective use of CT scans in the youngest children would reduce the number of children exposed to the risk of radiation-induced malignancy.[3-5]

The youngest children with blunt head trauma often have no symptoms or signs of traumatic brain injury other than scalp hematomas (ie, isolated scalp hematomas).[6] The Pediatric Emergency Care Applied Research Network (PECARN) traumatic brain injury study group derived and validated a clinical prediction rule for identifying children younger than 24 months at very low risk for clinically important traumatic brain injuries after blunt head trauma.[2] In the prediction rule, we identified non-frontal scalp hematomas as a factor associated with clinically important traumatic brain injury. However, further details about the prevalence of traumatic brain injuries in patients with isolated scalp hematomas and

†All members are listed in the Appendix.

Editor's Capsule Summary

What is already known on this topic

Scalp hematoma is a predictor of traumatic brain injury in infants with blunt head trauma, but the meaning of isolated scalp hematoma is unknown.

What question this study addressed

This secondary analysis of a multicenter study of 10,569 children younger than 24 months reported the prevalence of clinically important traumatic brain injuries after minor blunt head trauma in children with isolated scalp hematomas.

What this study adds to our knowledge

Two thousand nine hundred ninety-eight children had isolated scalp hematomas, and 0.4% had clinically important traumatic brain injuries, with none requiring neurosurgery. Higher risk was associated with age younger than 6 months and larger temporal or parietal scalp hematomas.

How this is relevant to clinical practice

Clinicians may consider observation in place of imaging studies in young children with isolated scalp hematomas after minor blunt head trauma.

specific associations between scalp hematoma size and location with traumatic brain injury for these patients was not previously described, to our knowledge. In this study, we describe the risks of traumatic brain injury for infants whose only sign or symptom of a traumatic brain injury was a scalp hematoma.[2]

Previous studies suggest that patient age and scalp hematoma characteristics can risk-stratify young children with isolated scalp hematomas at high and low risk for skull fractures or traumatic brain injuries.[7,8] In a cohort of children younger than 24 months, young patient age, non-frontal scalp hematoma location, and medium to large hematoma size identified children with a higher prevalence of skull fractures, and a clinical score incorporating these variables was developed and subsequently validated to identify patients with a higher prevalence of skull fractures and traumatic brain injuries.[7,8] These 2 studies from the same group, as others on the same topic, have been limited by the relatively few patients for whom CT scans were obtained and the relatively small sample sizes of those with traumatic brain injuries associated with important but uncommon clinical events such as the need for neurosurgery.[6,8-10]

Goals of This Investigation

The goal of the current study was to determine in a large cohort of head-injured children younger than 24 months with isolated scalp hematomas: (1) the prevalence of traumatic brain injuries; and (2) the association between traumatic brain injury and patient age, scalp hematoma size and location, and the mechanism of injury.

MATERIALS AND METHODS

Study Design and Setting

We performed a planned secondary analysis of children younger than 24 months with isolated scalp hematomas, using data from a prospective observational cohort study conducted at 25 centers in the PECARN between June 2004 and September 2006. The study was approved by the Human Subjects Research Committee at each site. Full details of the parent study methods have been previously described.[2]

Selection of Participants

In the parent cohort study, we enrolled a consecutive sample of children with Glasgow Coma Scale scores of 14 to 15 after blunt head trauma who presented to the ED within 24 hours of the initial injury. Patients with trivial head trauma mechanisms (eg, ground-level falls or running into stationary objects) and who had either no signs of head trauma or only a scalp laceration or abrasion were excluded. We also excluded children with penetrating trauma, known brain tumors, preexisting neurologic disorders complicating the clinical assessment, ventricular shunts, bleeding disorders, or previous neuroimaging. For the subanalysis of patients with isolated scalp hematomas, we included only children younger than 24 months. We did not exclude patients with either trauma to other body regions (ie, multisystem trauma) or those who were possibly physically abused.

We defined isolated scalp hematomas in 2 ways, based on the absence of specific other clinical findings on initial ED history and physical examination (Table 1). We analyzed the data according to these 2 definitions because the medical literature suggests that clinicians often assess children younger than 24 months from the vantage point of having either no other signs or symptoms other than scalp hematomas in general ("extensive definition" of isolated scalp hematoma) or having a parietal, temporal, or occipital scalp hematoma and no other signs or symptoms solely using the other age-specific PECARN prediction rule variables ("PECARN-rule based definition" of isolated scalp hematoma). One particular difference of note between these 2 definitions is that the definition of isolated scalp hematoma according to the PECARN prediction rule factors removes patients who have had severe mechanisms of injury because that is one of the PECARN rule predictors (see Table 1 for the 2 definitions of isolated scalp hematomas used in the current study). All variables listed in the isolated scalp hematoma definitions were explicitly listed on the data collection instrument and collected prospectively before outcomes were known. We did not assess for headache or amnesia in this young population. Although we did not include "potential nonaccidental trauma" as a mechanism of injury on the data collection instrument, we did list "assault", and we also instructed assessors to use the "other" category for those who they thought were possibly victims of abuse, and to describe the event.

Methods of Measurement

A faculty or fellow physician performed a standardized history and physical examination before cranial CT and documented the findings on the study data form. Cranial CT scans were obtained at the discretion of the treating faculty or fellow physicians. Clinicians assessed the characteristics of scalp hematomas according to size and location in 4 anatomic regions (frontal, parietal, temporal, and occipital). Clinicians categorized scalp hematoma size as small (<1 cm or barely palpable), medium (1 to 3 cm), or large (>3 cm). We did not require tape measure assessment to determine size.

We divided injury mechanisms a priori into mild, moderate, and severe categories, with the following definitions: mild=ground-level falls or running into stationary objects, moderate=any mechanism not meeting mild or severe definitions, and severe=motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorized vehicle, falls 3 feet or greater, or head struck by a high-impact object.[2]

In the parent cohort, we determined the interobserver agreement of findings from patient history and physical examination on a convenience sample of 4% of patients. Scalp hematoma location (κ=0.87) and hematoma size (κ=0.74), as well as mechanism of injury (κ=0.88 in those younger than 2 years), had substantial interobserver reliability.[11]

Outcome Measures

We defined 2 outcomes for the main study: (1) clinically important traumatic brain injury; and (2) traumatic brain injury on CT. We defined clinically important traumatic brain injury as death from traumatic brain injury, performance of a neurosurgical procedure for traumatic brain injury, intubation for at least 24 hours for traumatic brain injury, or hospitalization for 2 or more nights for head trauma in association with traumatic brain injury on CT. We considered patients to meet the criterion of hospitalization for greater than or equal to 2 nights for head trauma if they were hospitalized for at least 2 nights for persistent signs or symptoms of head injury (eg, vomiting) or were thought by the treating physician to require ongoing observation for potential acute complications of their traumatic brain injury. This definition excluded children hospitalized greater than or equal to 2 nights solely for suspicion of child abuse or for other social reasons, or for other important reasons not related to the traumatic brain injury (such as orthopedic injuries).[2] At each center, the site investigators, all of whom were experienced clinicians, reviewed the medical records, following strict instructions from the study manual of procedures, and verified that the hospital admission was mostly for the head injury and that the hospitalization of 2 or more nights was mostly because of concern for the acute course of the head injury (eg, for progression of traumatic brain injury, for progression or lack of resolution of symptoms). The site investigators made these determinations while unaware of ED data.

We defined traumatic brain injury on CT as the presence of any intracranial bleeding, pneumocephalus, cerebral edema, skull fracture depressed by at least the thickness of skull, or diastasis of the skull. We did not consider patients with isolated skull fractures that were not depressed the skull width as having traumatic brain injury on CT. Otherwise asymptomatic patients with nondepressed skull fractures but without intracranial abnormalities almost invariably have a favorable prognosis.[12] CT scans were read locally by faculty radiologists at each participating site. Equivocal findings were interpreted definitively by the study pediatric radiologist, who was blinded to the previous interpretation.

To determine outcomes, we reviewed the medical records of all hospitalized patients, and, for patients discharged home from the ED, we conducted telephone interviews at least 7 days after the initial ED visit or mail follow-up surveys if patients were unreachable by telephone. If there was no response to the follow-up survey, we reviewed the medical records of the patients in question, the continuous quality improvement logs, trauma registries, and morgue logs to ensure that we identified all patients with clinically important traumatic brain injuries.[2] For patients with traumatic brain injuries on CT, we reviewed the radiology reports to help determine whether there was suspicion for nonaccidental trauma.

Primary Data Analysis

For all analyses, we excluded patients missing any of the PECARN rule predictors. Additionally, for the analysis of the extensive definition of isolated scalp hematoma, we excluded patients if more than 1 of the other clinical signs or symptoms were missing or marked as unknown (because we could not be sure that the patient truly had an isolated scalp hematoma). We summarized our data, including the prevalence of clinically important traumatic brain injury and traumatic brain injury on CT, using descriptive statistics with 95% confidence intervals (CIs). According to the previous literature, for patients with more than 1 scalp hematoma location identified, we a priori categorized them in the group with the scalp hematoma location that would likely place them at higher risk of traumatic brain injury (ie, temporal/parietal>occipital>frontal).

In a multivariable logistic regression analysis, we assessed the association between traumatic brain injury on CT and the mechanism of injury severity, patient age (categorized as 0 to <3 months, 3 to <6 months, 6 to <12 months, or 12 to <24 months), scalp hematoma size, and location. No other clinical variables were adjusted for in the model. All variables included in the model were entered as categorical variables. Because a more severe mechanism of injury has been suggested as a predictor of intracranial injury,[13] we included mechanism of injury severity in this multivariable analysis. We did not conduct a multivariable regression analysis to identify factors associated with clinically important traumatic brain injury because there were too few of these outcomes. We used the Hosmer-Lemeshow test to assess goodness of fit. We used SAS/STAT software (version 9.2; SAS Institute, Inc., Cary, NC) for all analyses.

Table 1. Definitions of isolated scalp hematomas for children younger than 24 months.

Extensive definition: No signs or symptoms other than frontal, parietal, temporal, or occipital scalp hematoma	PECARN rule-based definition: No signs or symptoms other than parietal, temporal, or occipital scalp hematoma defined by the PECARN prediction rule variables for children younger than 24 mo
Patient met all of following:	Patient met all of the following*:
No history of any LOC	No LOC or LOC <5 s
Acting normally per parent/guardian	Acting normally per parent/guardian
Pediatric GCS score of 15	Pediatric GCS score of 15
No signs of altered consciousness (eg, sleepiness, agitation)	No signs of altered consciousness (eg, sleepiness, agitation)
No palpable skull fracture	No palpable skull fracture
No signs of basilar fracture	No severe mechanism of injury†
No neurologic deficits (eg, motor or sensory abnormalities)	
No vomiting after the head trauma	
No seizure after the head trauma	

LOC, Loss of consciousness; *GCS*, Glasgow Coma Scale.
*Predictors listed are those from the PECARN blunt head trauma prediction rules for children younger than 24 months. The list does not include one of the rule predictors, namely, parietal, temporal, or occipital scalp hematomas, because these scalp hematomas are the focus of this study group.
†Motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorized vehicle; falls 3 feet or greater; or head struck by a high-impact object.

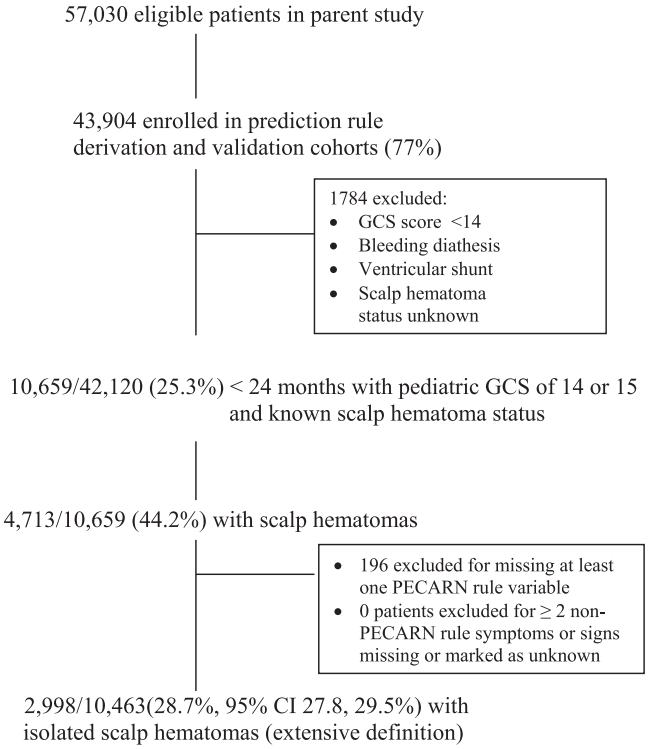

Figure. Flow diagram.

RESULTS

Characteristics of Study Subjects

In the parent study, we enrolled 43,904 (77.0%) of 57,030 eligible patients, of whom 2,998 met the extensive definition of isolated scalp hematomas (Figure); 142 of 2,998 (4.7%) had more than 1 scalp hematoma location identified, 123 (86.6%) of which included the temporal/parietal region. Clinical characteristics and disposition of the population with isolated scalp hematomas are detailed in Table 2. Compared with the overall cohort of patients younger than 24 months with Glasgow Coma Scale scores of 15 without isolated scalp hematomas, those with isolated scalp hematomas included proportionately more in the youngest group (<3 months) and fewer who were hospitalized. Of the 2,893 patients (96.5%) with isolated scalp hematomas who were discharged home from the ED, 77.0% had telephone follow-up, 2.7% had mail follow-up, and 20.3% had medical record, quality improvement log, trauma registry, or morgue log review to assess for clinically important traumatic brain injury not diagnosed on the day of ED enrollment.

Main Results

Clinicians obtained cranial CT scans on 570 (19.0%) of the patients with isolated scalp hematomas (Table 3). Clinicians obtained CTs more frequently for patients younger than 3 months, for those with temporal or parietal scalp hematomas, and for patients with large hematomas.

Of the 2,998 patients younger than 24 months who met the extensive definition of isolated scalp hematomas, 12 (0.4%; 95% CI 0.2% to 0.7%) had clinically important traumatic brain injuries (description of patients in Table 4). None of the 2,998 patients underwent neurosurgery (0%; 95% CI 0% to 0.1%). All 12 patients with clinically important traumatic brain injuries met this outcome definition by requiring hospitalization for 2 or more nights for their traumatic brain injuries, but did not require any other acute interventions. Of patients with clinically important traumatic brain injuries, 9 of 12 (75.0%) were younger than 6 months (which comprised 13.4% of the total sample population), 11 of 12 (91.7%) had non-frontal scalp hematomas, and 8 of 12 (66.7%) patients fell from heights of 3 feet or greater. Two of the 12 patients had injuries to other body areas; one had an extremity injury and the other had chest, back, flank, and pelvis injuries. For comparison, the prevalence of clinically important traumatic brain injury in the parent cohort of patients younger than 24 months who did not have scalp hematomas and met all of the other extensive definition criteria was 2 of 3,639 (0.05%), whereas the prevalence of clinically important traumatic brain injury in those who had scalp hematomas plus at least 1 other abnormal finding according to the extensive definition list was 49 of 1,519 (3.2%).

Of patients with isolated scalp hematomas for whom CTs were obtained (N=570), 50 (8.8%; 95% CI 6.6% to 11.4%) had traumatic brain injuries on CT; 12 of these 50 patients (24.0%) also had clinically important traumatic brain injuries. The prevalence of traumatic brain injuries on CT was higher in the younger age groups, in children with temporal and parietal scalp hematomas, and in those with larger scalp hematomas

Table 2. Characteristics of children younger than 24 months with isolated scalp hematomas (extensive definition).*

Characteristic	Patients with Isolated Scalp Hematomas (N=2,998)	Patients with Isolated Scalp Hematomas for Whom CT Was Completed (N=570)	Patients <24 Months With Pediatric GCS Score 15 From Parent Study (Excluding Those With Isolated Scalp Hematomas) (N=7,008)
Mean age, mo (SD)	12.9 (6.2)	8.1 (6.1)	11.2 (6.7)
Age group, No. (%), mo			
0–<3	181 (6.0)	120 (21.1)	856 (12.2)
3–<6	222 (7.4)	101 (17.7)	886 (12.6)
6–<12	850 (28.4)	201 (35.3)	1,965 (28.0)
12–<24	1,745 (58.2)	148 (26.0)	3,301 (47.1)
Male, No. (%)	1,682 (56.1)	313 (54.9)	3,813 (54.4)
Mechanism of injury, No. (%)			
Fall from elevation	1,365 (45.5)	341 (59.8)	4,073 (58.1)
<3 ft	847 (62.1)	161 (47.2)	2,475 (60.8)
3–5 ft	483 (35.4)	166 (48.7)	1,469 (36.1)
6–10 ft	21 (1.5)	9 (2.6)	47 (1.2)
>10 ft	2 (0.1)	1 (0.3)	34 (0.8)
Unknown height	12 (0.9)	4 (1.2)	48 (1.2)
Fall down stairs	481 (16.0)	87 (15.3)	925 (13.2)
Fall from standing/walking/running	375 (12.5)	24 (4.2)	546 (7.8)
Walked or ran into stationary object	306 (10.2)	18 (3.2)	270 (3.9)
Object struck head–accidental	161 (5.4)	30 (5.3)	322 (4.6)
Motor vehicle crash†	38 (1.3)	11 (1.9)	177 (2.5)
Assault	15 (0.5)	7 (1.2)	45 (0.6)
Other	236 (7.9)	43 (7.5)	579 (8.3)
Unknown	21 (0.7)	9 (1.6)	71 (1.0)
Mechanism of injury severity‡			
Mild	681 (22.7)	42 (7.4)	816 (11.6)
Moderate	1,779 (59.3)	338 (59.3)	4,502 (64.2)
Severe	517 (17.2)	181 (31.8)	1,618 (23.1)
Unknown	21 (0.7)	9 (1.6)	72 (1.0)
Disposition, No. (%)			
Discharged home	2,893 (96.5)	471 (82.6)	6,544 (93.4)
General inpatient	48 (1.6)§	47 (8.2)	234 (3.3)
Short-stay/observation unit	30 (1.0)§	28 (4.9)	118 (1.7)
ICU	19 (0.6)§	19 (3.3)	59 (0.8)
OR	0	0	4 (0.1)
Other/transferred to another hospital/AMA/missing	8 (0.3)	5 (0.9)	49 (0.7)

GCS, Glasgow Coma Scale; *ICU*, intensive care unit; *OR*, operating room; *AMA*, against medical advice.

*Extensive definition of isolated scalp hematomas defined by meeting all of the following: pediatric GCS score of 15 and no other signs of altered consciousness; no history of loss of consciousness, seizure, or vomiting; patient acting normally per parent; and no palpable skull fracture, signs of basilar fracture, or neurologic deficit on physical examination.

†For patients with isolated scalp hematomas who were in motor vehicle collisions, none were ejected or had death of another passenger.

‡Mechanism of injury severity defined as follows: Severe: motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorized vehicle; falls of 3 feet or greater; or head struck by a high-impact object. Mild: ground-level falls or running into stationary objects. Moderate: any mechanism that is neither severe nor mild.

§Fifty-two patients with isolated scalp hematomas were hospitalized who did not have traumatic brain injury on CT; of these, 28 of 52 (53.8%) had skull fractures, 4 of 52 (7.7%) were victims of child abuse, and 7 of 52 (13.5%) had other substantial injuries (eg, orthopedic).

(Table 3). Of patients whose mechanisms of injury were falls and who had CTs performed, those who fell greater than or equal to 3 feet had a higher prevalence of traumatic brain injuries on CT (27/176; 15.3%; 95% CI 10.4% to 21.5%) compared with those with falls lower than 3 feet (9/161; 5.6%; 95% CI 2.6% to 10.4%). Most traumatic brain injuries on CT were subdural or nonspecified extra-axial hematomas (Table 5). Of patients with traumatic brain injuries on CT, 7 of 50 (14.0%) had suspicion of nonaccidental trauma according to clinical evaluation or radiologic report.

The prevalence of traumatic brain injuries on CT based on age and isolated scalp hematoma characteristics is displayed in Table 6. Infants younger than 3 months for whom CT scans were obtained had a 19.2% prevalence of traumatic brain injuries on CT (95% CI 12.6% to 27.4%), with traumatic brain injuries observed even when the scalp hematomas were small and in frontal locations. Of the 4 infants younger than 3 months with frontal scalp hematomas and traumatic brain injuries on CT, 3 fell from heights of 3 to 5 feet (ie, meeting the PECARN definition of severe mechanism of injury) and 1 was suspected of having been a victim of child abuse. In this one infant, the degree to which suspected abuse was the reason for obtaining the CT is unclear; the concern for abuse was heightened based on the radiologist's report.

Table 3. Frequency of cranial imaging and traumatic brain injury on CT (of the 2,998 infants with isolated scalp hematomas [extensive definition]).

Characteristic	Skull Radiographs Obtained, n/N (%)	CT Obtained, n/N (%)*	TBI on CT, n/N (%; 95% CI)*
Age, mo			
0–<3	19/181 (10.5)	120/181 (66.3)	23/120 (19.2; 12.6–27.4)
3–<6	37/222 (16.7)	101/222 (45.5)	13/101 (12.9; 7.0–21.0)
6–<12	91/850 (10.7)	201/850 (23.6)	11/201 (5.5; 2.8–9.6)
12–<24	83/1,745 (4.8)	148/1,745 (8.5)	3/148 (2.0; 0.4–5.8)
Scalp hematoma location			
Frontal	131/2,035 (6.4)	271/2,035 (13.3)	7/271 (2.6; 1.0–5.2)
Occipital	30/383 (7.8)	77/383 (20.1)	8/77 (10.4; 4.6–19.4)
Temporal/parietal	69/552 (12.5)	215/552 (38.9)	35/215 (16.3; 11.6–21.9)
Scalp hematoma size			
Small (<1 cm or barely palpable)	51/741 (6.9)	96/741 (13.0)	4/96 (4.2; 1.1–10.3)
Medium (1–3 cm)	121/1,769 (6.8)	298/1,769 (16.8)	20/298 (6.7; 4.1–10.2)
Large (>3 cm)	47/370 (12.7)	146/370 (39.5)	25/146 (17.1; 11.4–24.2)
Mechanism of injury severity			
Mild	30/681 (4.4)	42/681 (6.2)	4/42 (9.5; 2.7–22.6)
Moderate	153/1,779 (8.6)	338/1,779 (19.0)	18/338 (5.3; 3.2–8.3)
Severe	43/517 (8.3)	181/517 (35.0)	27/181 (14.9; 10.1–21.0)

TBI, Traumatic brain injury.
*Denominator indicates total with known data for the characteristic.

No patients aged 3 months or older with small isolated scalp hematomas had traumatic brain injuries on CT (0/65; 95% CI 0% to 5.5%), irrespective of location. Patients aged 6 to 24 months with large frontal hematomas also had a low prevalence of traumatic brain injuries on CT. For patients with medium to large temporal or parietal scalp hematomas, traumatic brain injuries on CT were observed in 15 of 45 (33.3%; 95% CI 20.0% to 49.0%) of those younger than 3 months, 6 of 37 (16.2%; 95% CI 6.2% to 32.0%) of those aged 3 to younger than 6 months, 9 of 64 (14.1%; 95% CI 6.6% to 25.0%) of those aged 6 to younger than 12 months, and 2 of 29 (6.9%; 95% CI 0.9% to 22.8%) of those aged 12 to 24 months.

On multivariable analysis, patient age group, scalp hematoma location and size, and mechanism of injury severity were each associated with traumatic brain injury on CT (Table 7). In a subanalysis of patients whose mechanisms of injury were falls from heights, falls greater than or equal to 3 feet were associated with an increased prevalence of traumatic brain injury on CT (adjusted odds ratio 3.5; 95% CI 1.5 to 8.5).

Of the 4,713 patients younger than 24 months in the parent study with scalp hematomas, 820 had parietal, temporal, or occipital scalp hematomas and none of the other PECARN traumatic brain injury rule predictors for children younger than 24 months, listed in Table 1. Four patients (0.5%; 95% CI 0.1% to 1.2%) had clinically important traumatic brain injuries (none requiring neurosurgery), and 22 of 234 (9.4%; 95% CI 6.0% to 13.9%) had traumatic brain injuries on CT. Table 8 provides the prevalence of clinically important traumatic brain

Table 4. Clinical findings in children with isolated scalp hematomas (extensive definition) and clinically important traumatic brain injuries (n=12) (none underwent neurosurgical procedure).

Age	Reported Injury Mechanism	Scalp Hematoma Location	Scalp Hematoma Size	CT Findings	Skull Fracture on CT
15 days	Fall from 3–5 ft	Temporal/parietal	Large	Subdural hematoma	Yes
21 days	Fall from 3–5 ft	Temporal/parietal	Large	Subdural hematoma	No
1 mo	Fall from 3–5 ft	Temporal/parietal	Medium	Subdural hematoma; cerebral hemorrhage/intracerebral hematoma	No
1 mo	Fall from 3–5 ft	Frontal	Medium	Extra-axial hematoma*	No
3 mo	Fall from 3–5 ft	Temporal/parietal	Large	Subarachnoid hemorrhage; skull fracture depressed skull width; extra-axial hematoma	Yes
3 mo	Fall from 3–5 ft	Occipital	Large	Epidural hematoma	Yes
4 mo	Fall from 6–10 ft	Occipital	Large	Extra-axial hematoma*	Yes
5 mo	Fall from <3 ft	Temporal/parietal	Large	Subdural hematoma	Yes
5 mo	Fall from 3–5 ft	Temporal/parietal	Large	Subdural hematoma	Yes
8 mo	Fall down 6–15 stairs	Temporal/parietal	Medium	Subdural hematoma	No
11 mo	Fall down 6–15 stairs	Temporal/parietal	Large	Subdural hematoma; pneumocephalus	Yes
18 mo	Walked or ran into stationary object	Occipital	Medium	Subdural hematoma	Yes

*Intracranial hemorrhages that were not further categorized as subdural hematomas, epidural hematomas, or subarachnoid hemorrhages.

Table 5. Traumatic brain injuries on CT in children younger than 24 months with isolated scalp hematomas for whom CT was obtained (n=570, 50 [8.8%] with traumatic brain injuries on CT).

Type of TBI	No. (%)*
Subdural hematoma	15 (2.6)
Extra-axial hematoma†	13 (2.3)
Epidural hematoma	7 (1.2)
Subarachnoid hemorrhage	6 (1.1)
Cerebral hemorrhage	5 (0.9)
Cerebral contusion	5 (0.9)
Skull fracture depressed skull width	5 (0.9)
Midline shift	2 (0.4)
Diastasis	2 (0.4)
Pneumocephalus	1 (0.2)

*Nine patients (1.6%) had more than 1 TBI on CT.
†Intracranial hemorrhages that were not further categorized as subdural hematomas, epidural hematomas, or subarachnoid hemorrhages.

injuries and traumatic brain injuries on CT for children younger than 24 months with temporal, parietal, or occipital scalp hematomas plus 1 other age-specific PECARN prediction rule finding.

LIMITATIONS

Our study had some limitations. Clinicians obtained CT scans for the minority of patients, with selection bias likely toward those with more severe findings. Because this bias would be expected to inflate the prevalence of traumatic brain injury on CT, the actual prevalence of traumatic brain injuries on CT in patients with isolated scalp hematomas is likely lower than that reported here. Because CT scans were not obtained uniformly, our data do not allow more exact estimates of the prevalence of traumatic brain injury on CT for all combinations of age, scalp hematoma characteristics, and mechanism of injury severities. However, we had complete verification for clinically important traumatic brain injuries.

In addition, the limited number of traumatic brain injuries on CT and selective use of CT for those with more concerning findings potentially decreased our power to identify associations (with narrow 95% CIs) that exist between the prevalence of traumatic brain injuries on CT and patient age, mechanism of injury severity, and scalp hematoma characteristics (including combinations of these characteristics).

Furthermore, we focused our current analyses on traumatic brain injury on CT in addition to clinically important traumatic brain injuries. Clinicians may be reluctant to miss any CT findings in young children, regardless of the need for an acute intervention, because the importance of traumatic brain injuries on CT in relation to neurocognitive sequelae, ongoing development, socialization, and school performance is unclear.

We did not specifically ask whether children were suspected victims of abuse on the data collection form. This may have led to an underreporting of children with potential nonaccidental traumatic brain injury, which may or may not be identified by prediction rules, given the frequent inaccuracy the history of trauma, the mechanism, and the timing in victims of abuse.

Table 6. Prevalence of traumatic brain injuries on CT based on patient age and isolated scalp hematoma characteristics in patients for whom CT obtained (N=536).*

Patient Age and Scalp Hematoma Size	Scalp Hematoma Location		
	Frontal (%)	Occipital (%)	Temporal/Parietal (%)
<3 mo			
Small	2/13 (15.4)	0/4 (0)	2/13 (15.4)
Medium	2/25 (8.0)	1/4 (25.0)	7/29 (24.1)
Large	0/4 (0)	1/3 (33.3)	8/16 (50.0)
3–<6 mo			
Small	0/11 (0)	0/6 (0)	0/7 (0)
Medium	1/21 (4.8)	0/6 (0)	2/23 (8.7)
Large	1/4 (25.0)	4/6 (66.7)	4/14 (28.6)
6–<12 mo			
Small	0/14 (0)	0/3 (0)	0/7 (0)
Medium	1/64 (1.6)	0/16 (0)	3/39 (7.7)
Large	0/17 (0)	1/6 (16.7)	6/25 (24.0)
<12–24 mo			
Small	0/9 (0)	0/4 (0)	0/4 (0)
Medium	0/40 (0)	1/9 (11.1)	2/20 (10.0)
Large	0/35 (0)	0/6 (0)	0/9 (0)

*Hematoma size or location was unknown for 34 of the 570 patients with a CT obtained.

Table 7. Multivariable logistic regression analysis of factors associated with traumatic brain injury on CT.

Clinical Factors	Adjusted Odds Ratio (95% CI)*,† (n=527)
Age group, mo	
0–<3	17.0 (3.7–78.5)
3–<6	6.6 (1.4–31.7)
6–<12	3.6 (0.8–17.0)
12–<24	Reference
Hematoma location	
Frontal	Reference
Occipital	3.3 (1.1–10.1)
Temporal/parietal	4.5 (1.9–10.8)
Hematoma size‡	
Small	0.5 (0.1–1.5)
Medium	Reference
Large	3.3 (1.6–6.8)
Mechanism of injury severity	
Mild/moderate	Reference
Severe	2.4 (1.2–4.7)

*Age group, mechanism of injury severity, and hematoma location and size were the only variables controlled for in the multivariable logistic regression model.
†Multivariable logistic regression model had an adequate fit (Hosmer-Lemeshow goodness of fit P=.40).
‡Medium-size group was used as the referent because there were too few outcomes in patients with small hematomas.

DISCUSSION

In this large prospective cohort of children with blunt head trauma, children younger than 24 months who had scalp hematomas but who did not have other symptoms or signs of

Table 8. Prevalence of traumatic brain injuries in patients with parietal, temporal, or occipital (non-frontal) scalp hematomas plus 1 other risk factor, based on the PECARN prediction rule for children younger than 24 months.

PECARN Prediction Rule Variables	ciTBI, n/N (%; 95% CI)	TBI on CT, n/N (%; 95% CI)
Isolated non-frontal scalp hematoma	4/820 (0.5; 0.1–1.2)	22/234 (9.4; 6.0–13.9)
Non-frontal scalp hematoma plus altered mental status*	1/45 (2.2; 0.1–11.8)	6/34 (17.6; 6.8–34.5)
Non-frontal scalp hematoma plus LOC ≥5 s	0/16 (0; 0–20.6)	1/14 (7.1; 0.2–33.9)
Non-frontal scalp hematoma plus palpable skull fracture	1/72 (1.4; 0–7.5)	15/53 (28.3; 16.8–42.3)
Non-frontal scalp hematoma plus not acting normally per parent	1/59 (1.7; 0–9.1)	6/29 (20.7; 8.0–39.7)
Non-frontal scalp hematoma plus severe mechanism of injury	7/233 (3.0; 1.2–6.1)	25/118 (21.2; 14.2–29.7)

ciTBI, Clinically important traumatic brain injury.
*Altered mental status defined as a pediatric GCS score of 14, agitation, sleepiness, or slow to respond.

head trauma received CT imaging selectively and had a very low prevalence of clinically important traumatic brain injuries, with no patients requiring neurosurgery. Clinicians obtained CTs for the minority of patients, though several patients had epidural, subdural, or nonspecified extra-axial hematomas identified. Factors independently associated with having traumatic brain injuries on CT in this population included younger age, larger and non-frontal location of the scalp hematomas, and severe mechanisms of injury.

Previous studies of similar populations corroborate the low prevalence of traumatic brain injuries requiring acute medical interventions; only rarely have investigators identified patients younger than 24 months with apparently isolated scalp hematomas who have had intracranial hematomas that received neurosurgical interventions.[7,9] As noted in previous studies, our data suggest that clinicians can use scalp hematoma characteristics to assist with clinical decisionmaking in regard to acute neuroimaging use for children younger than 24 months with isolated scalp hematomas after blunt head trauma.[7,8] Specifically, the combination of patient age, scalp hematoma size and location, and mechanism of injury served to identify children with a higher and lower prevalence of traumatic brain injuries on CT. Previous investigators developed and validated a score that combines patient age, hematoma size, and hematoma location to determine which patients with isolated scalp hematoma are at higher risk for traumatic brain injuries.[7,8] Our study corroborates and extends their findings in a substantially larger sample of patients with CTs, through use of clinically important traumatic brain injury as an outcome and through incorporation of mechanism of injury as a predictor.

Similar to previous investigations, infants younger than 3 months had a substantially higher prevalence of traumatic brain injuries on CT than infants in older age groups, and those aged 3 to 6 months remained at substantial risk, particularly with non-frontal and larger scalp hematomas.[6,7] Infants younger than 3 months with isolated scalp hematomas not infrequently had traumatic brain injuries on CT even with small or frontal scalp hematomas. These data are in agreement with previous data and recommendations to maintain a low threshold for neuroimaging in infants younger than 3 months with signs of scalp trauma.[14] Clinicians must remain cognizant, however, that this youngest population is also the most susceptible to the risks associated with the ionizing radiation of CT. At the time of ED presentation, identifying whether a scalp hematoma is truly "isolated" in an infant or potentially the result of abuse is difficult, emphasizing the importance of maintaining a low threshold for obtaining skull radiographs or cranial CT scans if there is a concern for child abuse (eg, inconsistencies in the history and physical examination).[14]

For children aged 3 to 24 months, isolated small scalp hematomas (defined in our study as <1 cm) were rarely associated with traumatic brain injury on CT, irrespective of scalp hematoma location. CT appears to not be generally warranted for children in this age group with isolated scalp hematomas of this size. In addition, isolated frontal scalp hematomas as a whole are associated with a lower prevalence of traumatic brain injuries on CT. Both small scalp hematoma size and frontal location have been identified by other investigators as low-risk indicators for skull fractures and traumatic brain injuries[7]; our study adds more information on the topic by more precisely assessing the prevalence in a substantially larger population.

Similar to previous investigations, children aged 3 to 12 months with isolated non-frontal scalp hematomas after blunt head trauma represent an intermediate risk group for traumatic brain injury on CT.[7,8] Within this age group, patients aged 3 to 6 months remain at substantial risk for traumatic brain injury on CT and clinically important traumatic brain injury. Furthermore, traumatic brain injuries on CT were also not uncommon in all age groups when the scalp hematomas were of medium or large size and either in the temporal or parietal regions. It should be reassuring, however, that clinicians evaluating patients in the current study did not obtain CTs for most patients older than 3 months with isolated scalp hematomas and none required neurosurgical intervention (whether imaged or not). This suggests that clinicians frequently and safely used alternative management strategies such as observation rather than obtain an immediate CT for many young children with isolated scalp hematomas.[15]

Finally, our data suggest that mechanism of injury is an important predictor of traumatic brain injury in children younger than 24 months with isolated scalp hematomas. Although the great number of potential mechanisms precludes precise categorization for every mechanism, we found that a severe mechanism, as defined in the parent PECARN study, independently increases the risk of traumatic brain injury in this

age group. Previous data similarly suggest that falls from greater heights increase the prevalence of skull fractures and traumatic brain injuries,[6,16] which suggests that clinicians should, at a minimum, closely observe children in the ED with isolated scalp hematomas after more severe mechanisms of injury.

In conclusion, in this large prospective cohort of young children with blunt head trauma, we found that isolated scalp hematomas (ie, without other symptoms or signs of brain injury) are common, yet were very uncommonly associated with traumatic brain injuries requiring an acute medical intervention, particularly neurosurgery. There was, however, concern for nonaccidental trauma in several children with traumatic brain injuries on CT. The data presented build on our previous study results and help to further identify children younger than 24 months who are at very low risk of clinically important traumatic brain injuries, for whom CT scan can be obviated or the decision to CT can be deferred until after a period of ED observation. The present study suggests that infants younger than 6 months with isolated scalp hematomas have a higher prevalence of clinically important traumatic brain injuries and traumatic brain injuries on CT than older infants. Those at particular risk include infants younger than 3 months with any scalp hematomas and older infants with larger temporal or parietal scalp hematomas. If a non-frontal scalp hematoma is present, specific factors such as older age, small hematoma size, and nonsevere mechanism of injury should be used by clinicians to identify groups of children for whom CT typically appears unnecessary.

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APPENDIX

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