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ORIGINAL CONTRIBUTION

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Abstract

Objectives: Minor head trauma accounts for a significant proportion of pediatric emergency department (ED) visits. In children younger than 24 months, scalp hematomas are thought to be associated with the presence of intracranial injury (ICI). We investigated which scalp hematoma characteristics were associated with increased odds of ICI in children less than 17 years who presented to the ED following minor head injury and whether an underlying linear skull fracture may explain this relationship.

Methods: This was a secondary analysis of 3,866 patients enrolled in the Canadian Assessment of Tomography of Childhood Head Injury (CATCH) study. Information about scalp hematoma presence (yes/no), location (frontal, temporal/parietal, occipital), and size (small and localized, large and boggy) was collected by emergency physicians using a structured data collection form. ICI was defined as the presence of an acute brain lesion on computed tomography. Logistic regression analyses were adjusted for age, sex, dangerous injury mechanism, irritability on examination, suspected open or depressed skull fracture, and clinical signs of basal skull fracture.

Results: ICI was present in 159 (4.1%) patients. The presence of a scalp hematoma (n = 1,189) in any location was associated with significantly greater odds of ICI (odds ratio [OR] = 4.4, 95% confidence interval [CI] = 3.06 to 6.02), particularly for those located in temporal/parietal (OR = 6.0, 95% CI = 3.9 to 9.3) and occipital regions (OR = 5.6, 95% CI = 3.5 to 8.9). Both small and localized and large and boggy hematomas were significantly associated with ICI, although larger hematomas conferred larger odds (OR = 9.9, 95% CI = 6.3 to 15.5). Although the presence of a scalp hematoma was associated with greater odds of ICI in all age groups, odds were greatest in children aged 0 to 6 months (OR = 13.5, 95% CI = 1.5 to 119.3). Linear skull fractures were present in 156 (4.0%) patients. Of the 111 patients with scalp hematoma and ICI, 57 (51%) patients had a linear skull fracture and 54 (49%) did not. The association between scalp hematoma and ICI attenuated but remained significant after excluding patients with linear skull fracture (OR = 3.3, 95% CI = 2.1 to 5.1).

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Conclusions: Large and boggy and nonfrontal scalp hematomas had the strongest association with the presence of ICI in this large pediatric cohort. Although children 0 to 6 months of age were at highest odds, the presence of a scalp hematoma also independently increased the odds of ICI in older children and adolescents. The presence of a linear skull fracture only partially explained this relation, indicating that ruling out a skull fracture beneath a hematoma does not obviate the risk of intracranial pathology.

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Traumatic head injuries are a frequent cause of visits to the emergency department (ED).[1] In Canada, over 150,000 ED visits for closed head injury occur annually in patients under 19 years of age.[1] Despite their frequency, ED physicians investigating children with head injuries still struggle to identify which children require imaging for traumatic brain injuries, while balancing radiation risks resulting from the overuse of computed tomography (CT).[2–5] One of the risks associated with radiation exposure from CT scans in childhood is the subsequent development of leukemia and brain tumors, which is estimated to triple with cumulative doses of 50–60 mGy.[6] In the past decade, various trials[7–11] have aimed to derive and validate pediatric clinical decision rules to reduce the levels of imaging in children presenting with head injury, while at the same time preventing any missed cases of intracranial injury (ICI).

One of the clinical features often used as a predictive sign for the presence of ICI in children with head injury is the presence of a scalp hematoma.[12–15] Four large, prospectively derived pediatric algorithms examining the need for neuroimaging following head injury all included the presence of a scalp hematoma.[7–10] Studies that have investigated the independent association between scalp hematomas and ICI are, however, scarce and at times contradictory. Some significant limitations include retrospective study designs[16] and methodologic issues such as small sample sizes and few positive CTs.[14–18] It is generally agreed that scalp hematomas in the temporal/parietal or occipital regions confer the greatest risk for ICI,[10,13,15,19,20] as do scalp hematomas of larger size.[13,15,21] With regard to age, children aged 0–6 months seem to be at highest risk of ICI when a scalp hematoma is present.[12,14,16] However, since most studies have been limited to children aged 0–24 months,[4,9,10,14,16,18,19] the clinical significance of a scalp hematoma in children older than 24 months presenting after blunt head trauma remains unclear.

The primary objective of this study was to investigate whether scalp hematoma presence, location, and size were associated with ICI in children aged 0 through 16 years presenting to the ED following minor head trauma and to determine whether this relationship differed with patient age. In addition, we examined whether an underlying linear skull fracture may account for the relation between scalp hematomas and ICI. We hypothesized that scalp hematomas in temporal/parietal or occipital regions and of large and boggy size would be associated with an increased risk of ICI, particularly in children less than 6 months of age, and that underlying linear skull fractures might account for this relationship.

METHODS

Study Design

This was a secondary analysis using data from the Canadian Assessment of Tomography for Childhood Head Injury (CATCH) study, a multicenter, prospective cohort study in children presenting to the ED with minor head injury between July 2001 and November 2005. The CATCH study was approved by the ethics committee of each participating institution, and written consent was obtained from all participants.

Study Setting and Population

The primary aim of the CATCH study was to develop a clinical prediction rule for the use of CT in children presenting to the ED with acute minor head injury. This study included patients (0 through 16 years) presenting consecutively to the ED with minor head injury at 10 participating Canadian pediatric teaching hospitals. The rationale and full methodology of the CATCH study were described previously.[8] In brief, eligible patients were those with 1) blunt trauma to the head resulting in witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (at least two episodes 15 minutes apart), or persistent irritability in the ED (for children less than 24 months of age); 2) initial score on the Glasgow Coma Scale (GCS) ≥13; and 3) injury within the past 24 hours. Patients were excluded if they had obvious penetrating skull injury or depressed fracture, acute focal neurologic deficits, developmental delay, or head injury secondary to suspected child abuse or were previously enrolled in the same study. Patients who were presenting for reassessment of head injury and those with confirmed pregnancy were also excluded.

Study Protocol

All patients were assessed in the ED by staff physicians certified in pediatrics, emergency medicine, or family medicine or by supervised residents (in their second year of training or above). Physician assessors were trained on evaluating patients for 26 standardized, a priori selected clinical predictor variables from the history, general examination, and neurologic status, including information on presence of hematoma of the scalp (yes/no), hematoma size ("small and localized," defined as 1–3 cm; or "large and boggy," defined as > 3 cm and boggy in texture on palpation) and location (frontal, parietal, temporal, occipital, or other, such as face or neck) to standardize data form completion. We considered frontal, parietal, temporal, or occipital hematoma as true scalp hematoma and excluded hematomas on the face. Structured data collection sheets were completed prior to CT scans. When feasible, each patient was assessed independently by a second emergency physician to allow determination of interobserver agreement ($n = 333$; inter-rater agreement for hematoma presence, $\kappa = 0.61$, 95% confidence interval [CI] = 0.52 to 0.70; size $\kappa = 0.70$, 95% CI = 0.51 to 0.88).

Outcome Measurement

The primary outcome measure was the presence of ICI, which was defined as CT findings of either intracranial hemorrhage or contusion, cerebral edema, pneumocephalus, traumatic infarct, diffuse axonal injury, or depressed skull fracture (i.e., skull fractures depressed past the inner table).[8] Nondepressed skull fractures (including linear skull fractures, i.e., fractures transversing the full thickness of the skull from outer to inner table) and basal skull fractures (i.e., fractures in the floor of the cranial vault) were not considered ICI. Outcome measure definitions were determined a priori at a national study meeting in 2001 that included input from three academic pediatric neurosurgeons. CT scans were interpreted by blinded staff radiologists. Because not all patients routinely underwent CT, those who did not undergo imaging were classified as having no clinically important ICI if they met all of the following explicit criteria at 14 days, as determined during a structured telephone interview: absent or mild headache, absent memory or concentration problems, absent seizure or focal motor symptoms, and return to usual daily activities. Patients not meeting these criteria returned for clinical reassessment and CT. Patients who did not undergo CT and who could not be reached for follow-up were excluded from the analysis.

Data Analysis

Categorical baseline variables were reported by counts and corresponding percentages. Due to departures from normality, continuous variables were summarized by medians and interquartile ranges. Differences in baseline characteristics between children with and without scalp hematoma were assessed using Wilcoxon two-sample test for continuous variables and chi-square or Fisher's exact test for categorical variables. Multivariate logistic regression analysis was used to investigate whether scalp hematoma presence, location, and size were associated with the presence of ICI. Associations were adjusted for age, sex, dangerous injury mechanism, irritability on examination, and presence of any sign of basal skull fracture (from the original CATCH predictor variables). Model covariates were a priori selected based on clinical relevance and existing literature.[8,14,19] Age was categorized into three clinically relevant risk groups based on previous literature: 0 to <6, 6 to <24, and ≥24 months (reference category). A direct model building strategy was used, since there are no a priori hypotheses about the order or relative importance of the selected variables.[22] Including 10 events per a priori selected covariate in the multivariate regression model,[22,23] a minimum of 60 ICI cases would be required. To enable comparison to previous literature presenting age-stratified results, we repeated the analyses in three clinically relevant age groups (0 to <6, 6 to <24, and ≥24 months). Finally, to examine whether associations between scalp hematoma and ICI were independent of an underlying linear skull fracture, analyses were repeated after excluding patients with a linear skull fracture on CT ($n = 156$). p-values < 0.05 were considered statistically significant. SPSS version 21.0 (SPSS, Inc.) was used to analyze our data.

RESULTS

During the CATCH derivation period 3,866 patients were enrolled; 2,043 (52.8%) underwent CT scanning, and 1,823 (47.2%) received the proxy outcome measure of a structured telephone interview at 14 days after discharge. Study characteristics between enrolled patients ($n = 3,866$) and patients who were eligible but not enrolled ($n = 2,178$), or who were excluded due to missing outcome measures ($n = 245$), did not significantly differ.[8] Of the 1,256 (32.5%) patients with a hematoma on physical examination 1,189 were located in frontal, parietal, temporal, or occipital regions ("scalp hematoma") and 67 elsewhere on the face or neck ("no scalp hematoma"). Patients with a scalp hematoma ($n = 1,189$) were significantly younger; were more likely to arrive by ambulance or be transferred from another hospital; more often had a history of dangerous injury mechanism, amnesia, and irritability; had greater suspicion of open or depressed skull fractures; had lower GCS scores; and more often had CT or skull radiography performed compared to those without ($n = 2,677$; Table 1). Loss of consciousness was significantly less common among patients with scalp hematoma compared to those without.

Scalp Hematoma and ICI

Of enrolled patients, 159 (4.1%) had ICI on CT, of whom 24 (0.6%) underwent neurologic intervention (craniotomy, elevation of skull fracture, monitoring of intracranial pressure, or endotracheal tube insertion for the treatment of head injury; intubation only, $n = 1$). Of those patients with a scalp hematoma, 111 (9.3%) had ICI on CT, with the most common injuries being epidural hematoma or a cerebral contusion (Table 2). Neurologic intervention was indicated in 14 (1.2%) patients. Results from multivariate regression analyses investigating the relationship between scalp hematoma (presence, location, and size) and ICI are summarized in Table 3 (full model, Data Supplement S1, available as supporting information in the online version of this paper). Compared to those without, patients with a scalp hematoma had a 4.4 times greater odds of ICI. When location was taken into account, presence of a scalp hematoma in any location was significantly associated with the occurrence of ICI, with the highest odds for temporal/parietal and occipital hematomas (Table 3; full model Data Supplement S1). When hematoma size was accounted for, patients with both small and localized and large and boggy scalp hematoma were at increased odds of ICI compared to those without scalp hematoma, with the highest odds for patients with large and boggy hematoma (Table 3; full model, Data Supplement S1).

Influence of Age on the Relation between Scalp Hematoma and ICI

Intracranial injury was more common in children with a scalp hematoma aged 0–6 months compared to older age categories (Table 4). Results from multivariate regression analyses investigating the relation between presence of scalp hematoma and ICI, stratified to age, are summarized in Table 4 (full model, Data Supplement S2, available as supporting information in the online version of this paper). Presence of a scalp hematoma was significantly associated with increased odds of ICI in all three age groups, with the highest odds in children aged 0 to <6 months (Table 4).

Table 1
Baseline Characteristics of Children With and Without Scalp Hematoma (N = 3,866)

	Patients With Scalp Hematoma (n = 1,189)	Patients Without Scalp Hematoma (n = 2,677)	p-value
Age (mo)*	8.3 (4.1–12.7)	10.5 (5.5–13.9)	<0.001
0 to <6	47 (4)	37 (1)	
6 to <24	75 (6)	118 (4)	
≥24	1,067 (90)	2,522 (94)	
Sex, male	771 (65)	1,734 (65)	0.97
Arrived by ambulance	491 (41)	985 (37)	0.01
Transferred from other hospital	234 (20)	431 (16)	0.01
Dangerous injury mechanism†	391 (31)	584 (22)	<0.001
Loss of consciousness (witnessed)	360 (30)	907 (34)	0.03
Disorientation or confusion (witnessed)	624 (53)	1,456 (54)	0.28
Amnesia	405 (34)	779 (29)	0.002
Worsening headache	193 (16)	430 (16)	0.89
Repeated vomiting	505 (43)	1,077 (40)	0.20
Irritability	195 (16)	224 (8)	<0.001
Initial GCS score			
15	1,047 (88)	2,442 (91)	0.01
14	105 (9)	177 (7)	
13	37 (3)	58 (2)	
GCS score < 15 two hours postinjury	109 (9)	123 (5)	<0.001
Suspected open or depressed skull fracture	119 (10)	24 (0.9)	<0.001
Any signs of basal skull fracture	41 (3)	49 (2)	<0.001
CT of head performed	759 (64)	1,284 (48)	<0.001
Skull radiography performed	106 (9)	76 (3)	<0.001
CT and skull radiography performed	63 (5.3)	32 (1.2)	<0.001

Data are reported as number (%).
CT = computed tomography; GCS = Glasgow Coma Scale.
*Median (interquartile range).
†Dangerous mechanism defined as motor vehicle crash, fall from elevation of ≥3 feet (91 cm) or five stairs, or fall from bicycle with no helmet.

Presence of a Linear Skull Fracture

In total, 156 patients had a linear skull fracture, of whom 122 (78.2%) had a scalp hematoma and 34 (21.8%) did not (Table 2). Of the 111 patients with scalp hematoma and ICI, 57 (51%) patients had a linear skull fracture and 54 (49%) did not.

After excluding patients with a linear skull fracture on CT (n = 156), associations of scalp hematoma with ICI attenuated but remained statistically significant (Table 5; full model, Data Supplement S3, available as supporting information in the online version of this paper). Scalp hematoma in any location remained associated with increased odds of ICI, with highest odds for temporal/parietal and occipital hematomas. Both small and localized and large and boggy hematoma remained associated with increased odds of ICI.

DISCUSSION

In this large cohort of children aged 0–16 years presenting to the ED following minor head trauma, the presence of a scalp hematoma on physical examination was significantly associated with an increased odds of ICI. While ICI rates were highest in children with a scalp hematoma aged 0–6 months, the presence of a scalp hematoma put all age groups at increased odds of ICI. The presence of an underlying linear skull

Table 2
The Presence of ICI on CT in Children With and Without Scalp Hematoma (N = 3,866)

	Patients With Scalp Hematoma (n = 1,189)	Patients Without Scalp Hematoma (n = 2,677)	p-value
Acute brain lesion*	111 (9.3)	48 (1.8)	<0.001
Epidural hematoma	37 (3.1)	18 (0.7)	<0.001
Cerebral contusion	33 (2.8)	8 (0.3)	<0.001
Pneumocephalus	26 (2.2)	12 (0.4)	<0.001
Subdural hematoma	26 (2.2)	6 (0.2)	<0.001
Depressed skull fracture	25 (2.1)	3 (0.1)	<0.001
Subarachnoid hemorrhage	10 (0.8)	9 (0.3)	0.05
Intracerebral hematoma	6 (0.5)	4 (0.2)	0.08
Diffuse cerebral edema	4 (0.3)	2 (0.1)	0.08
Extra-axial hematoma (undifferentiated)	2 (0.2)	4 (0.2)	0.10
Cerebellar hematoma	3 (0.3)	0	0.03
Intraventricular hemorrhage	1 (0.1)	0	0.31
Linear skull fracture on CT	122 (10.3)	34 (1.3)	<0.001
Neurologic intervention	14 (1.2)	10 (0.4)	0.01
Death secondary to head injury	0	0	

Data are reported as number (%).
CT = computed tomography; ICI = intracranial injury.
*Some patients had more than one lesion.

Table 3
Multivariate Logistic Regression Analyses Investigating the Relation Between Scalp Hematoma Presence, Location, and Size and the Presence of ICI (N = 3,866)

	ICI		
	AOR (95% CI)	p-value	Overall Model Fit*
Scalp hematoma presence (n = 1,189)	4.40 (3.06–6.02)	<0.001	248.38 (<0.001)
Scalp hematoma location (n = 1,189)			
Frontal (n = 467)	2.10 (1.20–3.67)	0.009	265.18 (<0.001)
Temporal/parietal (n = 387)	6.02 (3.90–9.28)	<0.001	
Occipital (n = 335)	5.58 (3.50–8.88)	<0.001	
Scalp hematoma size (n = 1,182)†			
Small and localized (n = 940)	2.98 (1.98–4.49)	<0.001	276.46 (<0.001)
Large and boggy (n = 242)	9.87 (6.29–15.50)	<0.001	

Models adjusted for age, sex, dangerous injury mechanism, irritability on examination in patients < 24 months of age, and presence of any sign of basal skull fracture.
AOR = adjusted odds ratio; ICI = intracranial injury.
*Goodness-of-fit test, defined as likelihood ratio test or chi-square (p-value).
†Hematoma size was unknown for seven patients.

Table 4
Multivariate Logistic Regression Analyses Investigating the Relation Between the Presence of Scalp Hematoma and ICI, Stratified to Age (N = 3,866)

		Intracranial injury		
	n (%)	AOR (95% CI)	p-value	Overall Model Fit*
Patients aged 0 to < 6 mo (n = 84)	15 (17.9)			16.93 (0.002)
Scalp hematoma (n = 47)	14 (29.8)	13.49 (1.53–119.33)	0.02	
Patients aged 6 to < 24 mo (n = 193)	8 (4.1)			18.61 (0.001)
Scalp hematoma (n = 75)	7 (9.3)	9.72 (1.13–84.04)	0.04	
Patients aged ≥ 24 mo (n = 3,589)	136 (3.8)			196.64 (<0.001)
Scalp hematoma (n = 1,067)	90 (8.4)	4.10 (2.81–5.99)	<0.001	

Models adjusted for sex, dangerous injury mechanism, irritability on examination in patients < 24 months of age, and presence of any sign of basal skull fracture.
AOR = adjusted odds ratio; ICI = intracranial injury.
*Goodness-of-fit test, defined as likelihood ratio test or chi-square (p-value).

Table 5
Multivariate Logistic Regression Analyses Investigating the Relation Between Scalp Hematoma Presence, Location, and Size and the Presence of ICI in Patients Without a Linear Skull Fracture (n = 3,710)

	ICI		
	AOR (95% CI)	p-value	Overall Model Fit*
Scalp hematoma presence (n = 1,067)	3.26 (2.10–5.06)	<0.001	99.50 (<0.001)
Scalp hematoma location (n = 1,067)			
Frontal (n = 451)	2.13 (1.12–4.03)	0.02	103.68 (<0.001)
Temporal/parietal (n = 326)	4.05 (2.31–7.11)	<0.001	
Occipital (n = 290)	4.02 (2.21–7.32)	<0.001	
Scalp hematoma size (n = 1,067)†			
Small and localized (n = 882)	2.09 (1.25–3.50)	0.005	120.54 (<0.001)
Large and boggy (n = 178)	8.55 (4.89–14.93)	<0.001	

Models adjusted for age, sex, dangerous injury mechanism, irritability on examination in patients < 24 months of age, and presence of any sign of basal skull fracture.
AOR = adjusted odds ratio; ICI = intracranial injury.
*Goodness-of-fit test, defined as likelihood ratio test or chi-square (p-value).
†Hematoma size was unknown for seven patients.

fracture only partially explained the increased odds of ICI in children with a scalp hematoma. Our findings underline the importance of the presence of a scalp hematoma on physical examination in any child under the age of 17 years presenting to the ED following minor head injury and suggest that close monitoring is warranted, particularly for hematomas located in nonfrontal regions and of large and boggy size.

To our knowledge, this is the largest study investigating the relationship between scalp hematoma and ICI in symptomatic children of wide age range presenting to the ED following minor head injury. The ICI rate of 9.3% in children with a scalp hematoma is comparable to rates of 6%–9% reported in similar patient populations with either postinjury symptoms or GCS scores of 13–15 following minor head trauma.[9,11,24] Our data support previous findings that scalp hematoma in nonfrontal regions[10,13,15,19,20] and of large and boggy size confer the greatest odds of ICI following minor head trauma in childhood.[13,15] Contrary to some studies,[7,10,13–15,19] we found that scalp hematomas in frontal location and of smaller size were also related to increased odds of ICI, although to a lesser extent than previously noted regions and larger-sized hematomas. This discrepancy may be partially explained by our sample size, higher number of outcome events, and wider age distribution.

Research on scalp hematoma and ICI to date has almost exclusively focused on children younger than 24 months of age.[4,9,10,14,16,18,19] This may be partially due to the fact that clinical assessment is more difficult in children under the age of 2 years, infants with ICI are frequently asymptomatic, and skull fractures or ICI may occur despite relatively minor trauma.[12,25] Interpretations from studies in older pediatric populations are further limited by unstandardized or broad definitions of scalp injuries.[7,11,26,27] One prospective study in 1,666 children aged 0–18 years identified scalp hematoma as a predictor for the need of CT imaging following blunt head trauma in children both younger and older than 3 years,[24] but did not investigate the independent relationship between scalp hematoma and ICI. While our data do confirm that ICI rates are highest in children younger than 6 months of age presenting with a scalp hematoma following minor head trauma,[12,14,16,28] the presence of a scalp hematoma also significantly increased the odds of ICI in older age categories.

A potential mechanism by which a scalp hematoma may be associated with an increased risk of ICI is the presence of an underlying linear skull fracture. Presence of a scalp hematoma significantly increases the likelihood of a linear skull fracture,[13,15] which in turn is a strong indicator for ICI.[12,18,21] In our cohort, 57/111 (51%) children with a scalp hematoma and ICI had an underlying linear skull fracture on CT. When children with a linear skull fracture were excluded from the analysis, scalp hematomas remained associated with increased odds of ICI, although the strength of the relation was slightly attenuated, suggesting that other factors may play a role. This is important, as noninvasive imaging techniques such as point-of-care ultrasound are increasingly used in pediatric emergency medicine and have shown promise in the identification of linear skull fractures in children with scalp hematoma following head injury.[29,30] As 54/111 (49%) of our population with a scalp hematoma had ICI in the absence of a linear skull fracture, a significant proportion of children with intracranial pathology would be missed if clinicians would solely rely upon the presence or absence of a linear skull fracture to determine the need for head imaging.

LIMITATIONS

We acknowledge some potential limitations of this study. For ethical reasons, not all enrolled children underwent CT to determine the presence of ICI. A structured and validated telephone interview at 14 days after discharge was used as a proxy outcome measure in participants without neuroimaging. This may have led to an underestimation of the rate of intracranial injuries as clinically silent radiographic changes may have been missed. In addition, we defined ICI as any intracranial hemorrhage or contusion on CT. As no consensus on the significance of relatively small CT abnormalities in children currently exists, this definition was decided upon in consultation with three Canadian academic pediatric neurosurgeons. Further, despite our large sample size the number of children below 6 and 24 months of age was relatively low, thus decreasing the statistical power and contributing to relatively large CIs. Finally, since eligible children only included those presenting to a pediatric ED with witnessed loss of consciousness, amnesia, disorientation, persistent vomiting, or irritability following mild head injury, our findings may not be generalizable to the entire pediatric population, specifically asymptomatic children. Despite these limitations, the size and nature of our data set provide valuable information about hematomas and the wide age range of our population increases understanding of the risks associated with a scalp hematoma in older children.

CONCLUSIONS

In this large cohort of children aged 0 through 16 years presenting to the ED following mild head injury, we found that the presence of a scalp hematoma, particularly in nonfrontal regions and of large and boggy size, was associated with an increased odds of intracranial injury. Our findings also indicate that clinical concern is not only warranted in children younger than 24 months, but also in older children and adolescents. An underlying linear skull fracture may contribute to the increased odds of intracranial injury in children with a scalp hematoma following minor head injury, but cannot solely be relied upon when determining the need for additional neuroimaging, clinical monitoring, or the risk of intracranial injury in the pediatric population.

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Supporting Information

The following supporting information is available in the online version of this paper:

Data Supplement S1. Multivariate logistic regression analyses investigating the relation between scalp hematoma presence, location, and size, and the presence of intracranial injury (N = 3866).

Data Supplement S2. Multivariate logistic regression analyses investigating the relation between the presence of scalp hematoma and intracranial injury, stratified to age (N = 3866).

Data Supplement S3. Multivariate logistic regression analyses investigating the relation between scalp hematoma presence, location, and size, and the presence of intracranial injury in patients *without a linear skull fracture* (n = 3710).