The Infant Scalp Score: A Validated Tool to Stratify Risk of Traumatic Brain Injury in Infants With Isolated Scalp Hematoma

Sara A. Schutzman, MD[1,2], Lise E. Nigrovic, MD, MPH[1,2], and Rebekah Mannix, MD, MPH[1,2]

ABSTRACT

Objectives: The objective was to validate the previously derived Infant Scalp Score (ISS) that uses clinical signs in infants with isolated scalp hematoma (ISH) after head trauma to stratify risk for clinically important traumatic brain injury (ciTBI) or TBI on computed tomography (CT).

Methods: Using the publicly available Pediatric Emergency Care Applied Research Network TBI data set, we selected infants ≤ 1 year with GCS 14 to 15 who had ISH (defined as hematoma without other signs/symptoms of TBI). CT scans were obtained at the treating physician's discretion. We calculated ISS based on age, hematoma size, and location (range = 0–8) for each patient and calculated the sensitivity and specificity of the score for ciTBI and TBI on CT across a range of ISS cut-points.

Results: We included 1,289 infants ≤ 1 year of whom 462 (36%) had CT performed. Twelve had ciTBI and 59 had TBI on CT. An ISS cutoff ≥ 4 had sensitivity of 100% for ciTBI (95% confidence interval [CI] = 0.74 to 1.0) and TBI with specificity of 0.49 (95% CI = 0.46 to 0.51). An ISS cutoff of ≥5 had a sensitivity of 100% for ciTBI (95% CI = 0.74 to 1.0) and specificity of 0.68 (95% CI = 0.66 to 0.71), but missed three infants with TBI on CT (none of whom required intervention). The receiver operating characteristic curves for clinical score to detect ciTBI and TBI had areas under the curve of 0.916 and 0.807, respectively.

Conclusions: The ISS accurately stratified risk for ciTBI and TBI on CT in infants with ISH and is a useful tool to help guide clinical decision making.

Scalp swelling can be the only sign of traumatic brain injury (TBI) in many head-injured infants, and nonfrontal scalp hematoma was found to be one of six factors associated with a clinically important TBI (ciTBI) in the validated clinical prediction rule derived in the Pediatric Emergency Care Applied Research Network (PECARN) large multicenter cohort study of infants and children with minor head trauma.[1] However, most infants with a scalp hematoma will not have a clinically significant head injury. Risk stratification to determine who should have computed tomography (CT) imaging is of particular importance in these youngest patients because they are the most difficult to assess and also the most sensitive to the effects of ionizing radiation.[2,3]

Among young children with scalp hematoma, patient age, hematoma size, and hematoma location have each been associated with TBI. The previously

From the, [1]Division of Emergency Medicine, Boston Children's Hospital, and the, [2]Department of Pediatrics, Harvard Medical School, Boston, MA.
Received January 10, 2020; revision received June 23, 2020; accepted July 11, 2020.
The authors have no relevant financial information or potential conflicts to disclose.
Author contributions: SAS and RM were responsible for the project design; RM was responsible for data abstraction; SAS and RM were responsible for data analysis and interpretation; SAS drafted the original manuscript; all authors contributed substantially to its revision; SS takes responsibility for the paper as a whole; and all authors have read and approved the final manuscript as submitted.
Supervising Editor: Robert Cloutier, MD.
Address for correspondence and reprints: Sara Schutzman, MD; e-mail: sara.schutzman@childrens.harvard.edu.
ACADEMIC EMERGENCY MEDICINE 2020;00:0:1–6

doi: 10.1111/acem.14087
ISSN 1553-2712

derived Scalp Score (range = 0–8) combined these predictors to stratify risk of skull fracture and TBI and was validated in a prospective cohort of 203 head-injured patients younger than 2 years with blunt minor head trauma presenting to a single emergency department (ED).[4,5] A planned subanalysis of the PECARN data set for 2,998 children younger than 2 years with isolated scalp hematoma (ISH) found that these same variables as well as mechanism of injury were associated with TBI;[6] however, the presence or absence of individual predictors is less informative for an individual patient's specific risk and provides more limited guidance about need for imaging than a composite score that incorporates multiple predictors. Prior studies of scalp hematoma as a risk factor for TBI have included infants and children younger than 2 years of age; however, the risk of TBI in children age 1 to 2 years with ISH is very low.[4–7]

Our objective was to use the large publicly available PECARN TBI data set to determine the ability of the scalp score to identify infants younger than 1 year with ISH who have ciTBI and TBI on CT with the goal of enabling clinicians to better determine which infants can safely forgo imaging, thus limiting unnecessary radiation exposure.

METHODS

Study Design and Setting

Our study utilizes the publicly available PECARN TBI data set, collected during a prospective observational cohort study conducted at 25 PECARN centers between June 2004 and September 2006.[1] Full protocol details have been previously described. The institutional review board (IRB) approved study procedures at each participating center; our IRB determined that this secondary analysis was exempt from review.

Selection of Participants

The parent TBI study included a consecutive sample of children with Glasgow Coma Scale scores of 14 or 15 after blunt head trauma who presented to the ED within 24 hours of the initial injury. Patients with trivial head trauma mechanisms were excluded as well as those with penetrating trauma, preexisting neurologic disorders including brain tumors, ventricular shunts, bleeding disorders, or neuroimaging performed prior to study enrollment.

For this study we selected infants younger than 1 year of age with ISHs defined as scalp hematoma without other clinical findings on initial ED history and physical examination (Table 1), utilizing the PECARN "extensive" definition for ISH and adding "no bulging fontanel."[6] We did not include children missing any of the listed signs or symptoms because we could not be certain that the child had an ISH.

Table 1
Definition of ISHs for Children Younger Than 1 Year of Age (All of the Following)

No history of loss of consciousness.
Acting normally per parents/guardian
Pediatric GCS score of 15.
No signs of altered consciousness
No palpable skull fracture.
No signs of basilar fracture.
No neurologic deficits.
No vomiting after the head trauma.
No seizure after the head trauma.
No bulging fontanel.

GCS = Glasgow Coma Scale; ISH = isolated scalp hematoma.

Method of Measurement

A faculty or fellow physician performed a standardized history and physical examination at the time of initial evaluation and documented the findings on the study data form. Cranial CT scans were obtained at the discretion of the treating clinician. Physicians categorized scalp hematoma size as small (<1 cm or barely palpable), medium (1 to 3 cm), or large (>3 cm). As part of the TBI parent study, interobserver agreement of findings from patient history and physical examination was determined on a convenience sample of 4% of patients. Presence of scalp hematoma ($\kappa = 0.66$, 95% lower confidence limit [LCL] = 0.62), scalp hematoma location ($\kappa = 0.87$, 95% LCL = 0.79), and hematoma size ($\kappa = 0.74$, 95% LCL = 0.68) had substantial interobserver agreement.8

Follow-up

In the PECARN TBI study, study staff reviewed medical records of all hospitalized children and conducted standardized telephone interviews at least 7 days after the initial ED visit for children discharged without a CT performed (79% successfully contacted). For children who could not be contacted, study teams reviewed medical records, trauma registries, process improvement reports and morgue records to ensure identification of children with a ciTBI.

Scalp Score

We calculated the previously derived scalp score using patient age, hematoma size, and hematoma location for every subject (Table 2). Scalp scores ranged from 1 (lowest risk) to 8 (highest risk), since only infants

Table 2
Scalp Score

Risk Points	Patient Age (months)	Hematoma Size	Hematoma Location
0	>12	None	Frontal
1	6–11	Small	Occipital
2	3–5	Medium	Temporal/Parietal
3	0–2	Large	

younger than 1 year were included. For children with more than one scalp hematoma, we selected the one with highest score.

Outcome Measures

Our primary outcome was ciTBI and our secondary outcome was TBI on CT. For infants who did not have a cranial CT performed, clinical follow-up was used to assess for the presence or absence of the primary outcome. ciTBI was defined as death from TBI, requiring a neurosurgical procedure for TBI, intubation for at least 24 hours for TBI, or hospitalization for 2 or more nights for head trauma associated with TBI on CT. TBI on CT was defined as the presence of any intracranial bleeding, pneumocephalus, cerebral edema, skull fracture depressed by at least the thickness of the skull, or diastasis of the skull.

Primary Data Analysis

First, we used descriptive statistics to describe the study population. Next, we calculated the rates of imaging, TBI, and ciTBI by score. We then constructed receiver operator characteristic curves for the Infant Scalp Score (ISS) to detect TBI and ciTBI. Confidence intervals (CIs) around test statistics were derived using the method of Clopper and Pearson for binomials. Statistical analyses were performed using Stata v 14 (StataCorp).

RESULTS

Characteristics of Study Subjects

Of the 43,904 children enrolled in the parent study 1,289 infants younger than 1 year met the definition of ISH. Clinical characteristics and disposition for infants with an ISH are described in Table 3.

Main Results

1,289/5,441 (24%) infants < 1 year had an ISH of whom 462 (36%) had cranial CT performed. Of these, 12 (2.6% of imaged and 0.9% of entire group) had a ciTBI and 59 (12.7% of imaged and 4.6% of the entire group) had a positive CT. The rate of obtaining a cranial CT, TBI, and ciTBI increased with higher scalp scores (Table 4).

No infant with an ISH and a scalp score < 5 had a ciTBI and no infant with an ISH and a scalp score < 4 had TBI on CT. Scores higher than these indicated

Table 3
Characteristics of Children Younger Than 1 year

	Total Patients With ISH (*n* = 1,289)	Patients With ISH Who Had CT (*n* = 462)
Age (months)		
<3	193 (15.0)	132 (28.6)
3–6	239 (18.5)	116 (25.1)
6–12	857 (66.5)	214 (46.3)
Male	703 (54.5)	251 (54.3)
Scalp score		
1	22 (1.7)	5 (1.1)
2	165 (12.8)	17 (3.7)
3	433 (33.6)	84 (18.2)
4	252 (19.6)	87 (18.8)
5	205 (15.9)	99 (21.4)
6	116 (9.0)	84 (18.2)
7	73 (5.7)	64 (13.9)
8	23 (1.8)	22 (4.8)
Disposition		
Home	1,186 (92.0)	361 (78.1)
OR	0	0
Admit–general	54 (4.2)	54 (11.7)
Admit–short-stay	24 (1.9)	23 (5.0)
ICU	17 (1.3)	17 (3.7)
Transferred/other	8 (0.6)	7 (1.5)
Death in ED	0	0

Data are reported as *n* (%).
ICU = intensive care unit; ISH = isolated scalp hematoma; OR = odds ratio.

Table 4
Rates of Imaging, TBI, and ciTBI by Score

Score	*N* = 1,289	CT Performed (*n* = 462)	CT With TBI (*n* = 59)	ciTBI (*n* = 12)
1	22 (1.7)	5 (1.1)	0	0
2	165 (12.8)	17 (3.7)	0	0
3	433 (33.6)	84 (18.2)	0	0
4	252 (19.6)	87 (18.8)	3 (5.1)	0
5	205 (15.9)	99 (21.4)	8 (13.6)	2 (16.7)
6	116 (9.0)	84 (18.2)	20 (33.9)	3 (25.0)
7	73 (5.7)	64 (13.9)	18 (30.5)	4 (33.3)
8	23 (1.8)	22 (4.8)	10 (17.0)	3 (25.0)

ciTBI = clinically important traumatic brain injury; TBI = traumatic brain injury.

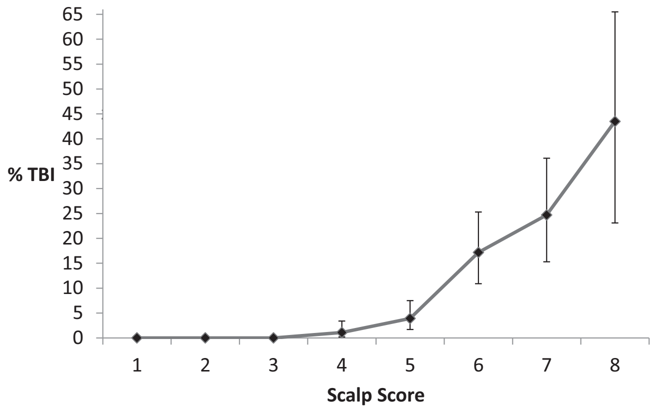

Figure 1. TBI by scalp score. TBI = traumatic brain injury.

increasingly higher risk for complications (Figures 1 and 2). The sensitivity and specificity for detecting ciTBI and TBI at various clinical score cutoffs are described graphically in receiver operating characteristic curves (Figures 3 and 4). The areas under the curve for ciTBI and TBI are 0.916 and 0.807, respectively.

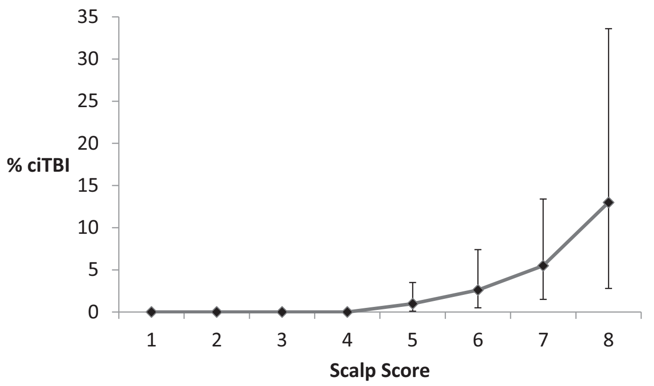

Figure 2. Clinically important TBI by scalp score. TBI = traumatic brain injury.

Using a scalp score cutoff of ≥4 to obtain a cranial CT, no TBI and no ciTBI would be missed; however, 669 of 1,289 (52%) patients would have been imaged. Using a cutoff of ≥5, no infants with ciTBI and three with TBI would have been missed, but only 417 of 1,289 (32%) would have imaged.

The three patients with a scalp score of 4 who had TBI on CT were as follows: 1) a 1-month-old with cerebral hemorrhage, 2) a 1-month-old with an extraaxial hematoma, and 3) a 5-month-old with epidural hematoma and skull fracture. Sizes of the intracranial hemorrhages were not recorded. However, none of these infants required neurosurgery nor hospital admission more than 1 night.

DISCUSSION

The ISS reliably stratified the risk for both ciTBI and TBI on CT in a secondary analysis of more than 1,200 prospectively enrolled infants with an ISH after minor blunt head trauma included in the PECARN TBI study.

The clinician's goal is to identify infants and children with complications of head trauma while limiting cranial CT utilization, given concerns for both ionizing radiation exposure and resource utilization. The three highest-quality minor head trauma clinical prediction rules for children each include scalp hematoma as a predictor for TBI.[1,9,10] However, the overall incidence of TBI in infants with ISH is low and not all of these patients require imaging. In a secondary analysis of the PECARN TBI study of children < 2 years of age with an ISH, younger age, nonfrontal location

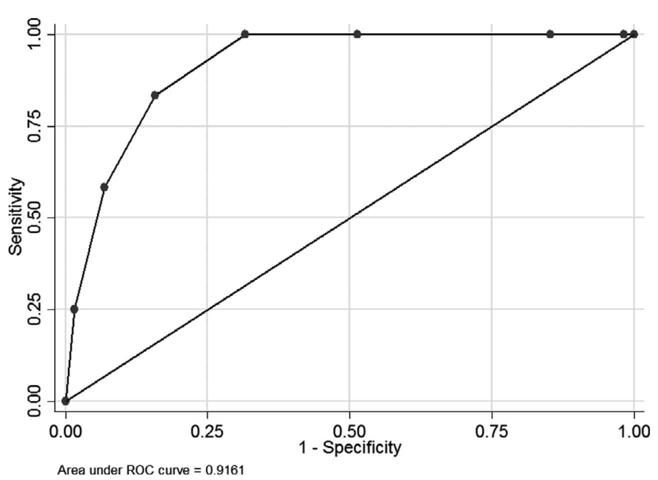

Figure 3. Receiver operating characteristic (ROC) curve for ISS to detect ciTBI. ISS = Infant Scalp Score; TBI = clinically important traumatic brain injury.

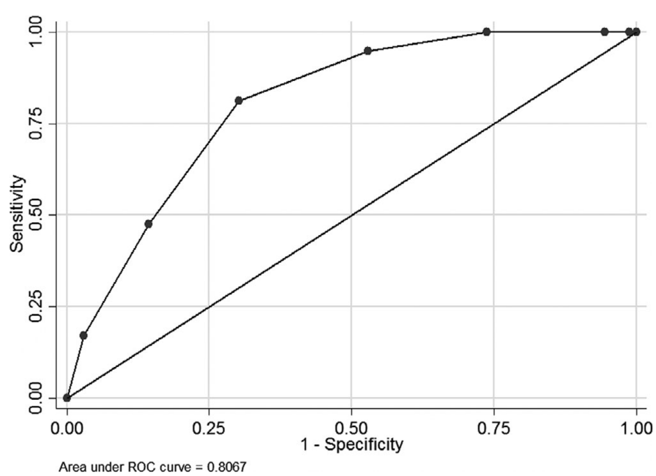

Figure 4. Receiver operating characteristic (ROC) curve for ISS to detect TBI on CT. ISS = Infant Scalp Score; TBI = traumatic brain injury.

and larger hematoma size location as well as mechanism of injury were each associated with higher risk of TBI; however, each predictor in isolation gives limited guidance regarding an individual infant's specific risk.[6] A more recent study compared PECARN and CHALICE prediction rules for risk of ciTBI/TBI in infants with ISH using a large prospective cohort of head-injured children enrolled in EDs located in Australia and New Zealand.[11] Using the PECARN rule the risk of ciTBI in infants younger than 1 year with ISH was 0% (95% CI = 0.3% to 3.3%), compared with 20% (95% CI = 8.4% to 36.9) using the CHALICE prediction rule. However, for the PECARN analysis the numbers were low (109 infants) and 12.5% had TBI on CT. Additionally, only overall risk for ciTBI and TBI on CT were reported without more granular analysis of specific predictors.

The scalp score, similar to other scoring systems (e.g., the Pediatric Appendicitis Score), combines predictor variables in a multivariate model to more precisely risk stratify head-injured infants.[12] Although the PECARN secondary analysis identified similar individual risk factors for ciTBI and TBI as the scalp score (as well as mechanism of injury), it does not provide the clinician with the specific risk for any one patient. The scalp score is a convenient tool that provides a quantified risk of ciTBI/TBI for any head-injured infant with ISH, better enabling the clinician to make informed decisions about the need for cranial CT.

Despite high-quality predictive models, the rates of cranial CT for head-injured children have remained constant in many settings. A recent study using the National Hospital Ambulatory Care Medical Survey, a database of nationally representative ED visits, found no decrease in CT use for head trauma from 2007 to 2015, spanning the time before and after the PECARN publication.[13] Although overall rates for children younger than 2 years were lower than older children, rates over time were not reported by age group. The scalp score further refines recommendations for infants with ISH, which account for 24% of head-injured infants in this age group. Using the scalp score, a validated tool providing specific risk for complications, might enable and encourage clinicians (many of whom are uncomfortable assessing preverbal infants) to forego cranial CT for lower risk patients, a desirable goal in patients at highest risk for sequelae from ionizing radiation. Of note, in the PECARN study 107 CTs (23% of all CTs obtained for infants with ISH) were in low-risk infants with a scalp score of 3 or less. Further refined recommendations are of particular value in this group as observation prior to CT decision-making, a powerful strategy for the management of many head-injured children, is of more limited utility for infants with ISH as the hematoma will not resolve during observation.[14]

We calculated the scalp score's predictive ability for both ciTBI as well as TBI to inform clinical decision making for both. The long-term clinical impact of TBI on CT that does not require an acute intervention has not been established as long-term follow-up studies of these infants are lacking. Regardless of need for intervention, clinicians and caregivers may be reluctant to miss a young infant's TBI on CT as its importance with respect to developmental and neurocognitive sequelae is unclear.

It is important to note that because the score is a composite, a given score may represent a heterogeneous population (e.g., a "6" could represent a 1-month-old with a medium occipital hematoma or a 7-month-old with a large parietal hematoma). It is possible that their risks are not identical; however, the score performed well taking all of these variables into consideration.

It would be possible to make a more specific rule (e.g., adding in mechanism, having a higher score for age < 3 months); however, it would be a tradeoff with the rule's ease of use. Given the performance of the current rule, we chose to not alter it so as to maintain a user-friendly rule for clinicians.

The scalp score was not designed to be applied to, nor should it be used for, head-injured infants for whom nonaccidental trauma is a concern. Studies have shown that abused infants with TBI may have no signs or symptoms of head trauma and the PECARN clinical prediction rule was less sensitive for identifying ciTBI in physically abused young children.[15,16] Treating clinicians must maintain a high level of clinical suspicion for nonaccidental trauma when caring for young head-injured infants.

LIMITATIONS

Our study has several limitations. First, the patient data were obtained from the publicly available PECARN head trauma data set; therefore, assessment of more granular data was limited. Additionally, infants who did not undergo CT may have had an unrecognized TBI on CT. However, all infants had standardized clinical follow-up and none were reported to have a TBI or ciTBI diagnosed after the index ED encounter.

CONCLUSIONS

The previously described scalp score accurately stratified the risk of clinically important traumatic brain injury and traumatic brain injury on computed tomography in infants with an isolated scalp hematoma. This score can aid clinicians to better determine which infants with an isolated scalp hematoma should have a cranial computed tomography to avoid missing clinically important traumatic brain injury or traumatic brain injury while avoiding unnecessary ionizing radiation exposure for low-risk infants.

References

1. Kuppermann N, Holmes JF, Dayan JF, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective study. Lancet 2009;374:1160–70.
2. Mathews JD, Forsythe AV, Brady A, et al. Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. BMJ 2013;346:f2360.
3. Goodman TR, Mustafa A, Rowe E. Pediatric CT radiation exposure: where we were, and where we are now. Pediatric Radiol 2019;49:469–78.
4. Greenes DS, Schutzman SA. Clinical significance of scalp abnormalities in asymptomatic head-injured infants. Pediatr Emerg Care 2001;17:88–92.
5. Bin SS, Schutzman SA, Greenes DS. Validation of a clinical score to predict skull fracture in head-injured infants. Pediatr Emerg Care 2010;26:633–9.
6. Dayan PS, Holmes JF, Schutzman S, et al. Risk of traumatic brain injuries in children younger than 24 months with isolated scalp hematomas. Ann Emerg Med 2014;64:153–62.
7. Burns EC, Grool AM, Klassen TP, et al. Scalp hematoma characteristics associated with intracranial injury in pediatric minor head injury. Acad Emerg Med 2016;23:576–83.
8. Gorelick MH, Atabaki SM, Loyle J, et al. Interobserver agreement in assessment of clinical variables in children with blunt head trauma. Acad Emerg Med 2008;15:812–28.
9. Osmond MH, Klassen TP, Wells GA, et al. CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury. CMAJ 2010;182:341–8.
10. Dunning J, Daly JP, Lomas JP, et al. Derivation of the children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children. Arch Dis Child 2006;91:885–91.
11. Bressan S, Kochar A, Oakley E, et al. Traumatic brain injury in young children with isolated scalp haematoma. Arch Dis Child 2019;104:664–9.
12. Samuel M. Pediatric appendicitis score. J Pediatr Surg 2002;37:877–81.
13. Burstein BB, Upton JE, Terra FT, Neuman MI. Use of CT for head trauma: 2007–2015. Pediatrics 2018;142:e20180814.
14. Nigrovic LE, Schunk JE, Foerster A, et al. The effect of observation on cranial computed tomography utilization for children after blunt head trauma. Pediatrics 2011;127:1067–73.
15. Ide K, Uematsu S, Tetsuhara K, et al. External validation of the PECARN head trauma prediction rules in Japan. Acad Emerg Med 2017;24:308–14.
16. Rubin DM, Christian CW, Bilaniuk LT, et al. Occult head injury in high-risk abused children. Pediatrics 2003;111:1382–6.