Traumatic brain injury in young children with isolated scalp haematoma

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ABSTRACT

Objective: Despite high-quality paediatric head trauma clinical prediction rules the management of otherwise asymptomatic young children with scalp haematomas (SH) can be difficult. We determined the risk of intracranial injury when SH is the only predictor variable using definitions from the Pediatric Emergency Care Applied Research Network (PECARN) and Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE) head trauma rules.

Design: Planned secondary analysis of a multicentre prospective observational study.

Setting: Ten Emergency Departments in Australia and New Zealand.

Patients: Children <2 years with head trauma (n=5,237).

Interventions: We used the PECARN (any non-frontal haematoma) and CHALICE (>5 cm haematoma in any region of the head) rule-based definition of isolated SH in both children <1 year and <2 years.

Main Outcome measures: Clinically important traumatic brain injury (ciTBI, i.e. death, neurosurgery, intubation >24 hours, or positive computed tomography scan in association with hospitalization ≥2 nights for TBI).

Results: In children <1 year with isolated SH as per PECARN rule, the risk of ciTBI was 0.0% (0/109; 95% confidence interval (CI) 0.0-3.3%); in those with isolated SH as defined by the CHALICE it was 20.0% (7/35; 95%CI 8.4-36.9%) with one patient requiring neurosurgery. Results for children <2 years and when using rule specific outcomes were similar.

Conclusions: In young children with SH as an isolated finding after head trauma, use of the definitions of both rules will aid clinicians in determining the level of risk of ciTBI, and therefore in deciding whether to do a CT scan.

INTRODUCTION

Minor head trauma is a common reason for childhood emergency department (ED) visits.[1,2] Children <2 years of age represent 25%-50% of these, and often have no symptoms or signs of intracranial injury other than scalp haematomas (SHs).[3-5] Many clinical prediction rules include SH as a predictor of intracranial injury.[6-9] The three highest quality rules on paediatric head trauma, all include SH, although with different definitions and characteristics.[10]

The Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE) includes SHs >5 cm in children <1 year as a predictor of clinically significant intracranial injury (csII) defined as death, neurosurgery or marked abnormality on computed tomography (CT) resulting from head injury.[11] The Pediatric Emergency Care Applied Research Network (PECARN) head injury rule for children <2 years, demonstrated children with isolated non-frontal SH to be at intermediate risk of clinically important traumatic brain injury (ciTBI), a composite outcome encompassing death, need for neurosurgery, intubation for >24 hours due to TBI or admission for ≥2 nights.[5] "Large, boggy scalp haematoma" is a predictor variable in the Canadian Assessment of Tomography for Childhood Head Injury (CATCH) rule.[12] However, due to strict inclusion criteria of the derivation study (the rule applies only to children who have one or more other symptoms), this does not present the same dilemma for clinicians when present in isolation.

Both the PECARN and CHALICE rules are widely used in different settings,[4,13-15] and where SH is the only identified predictor in a young child, clinicians may be faced with the challenge of deciding whether to do an immediate CT scan, or observe first, recognising that the young brain is more sensitive to damage from

ionizing radiation.[16] The eligibility criteria, predictors and outcome of the PECARN and CHALICE rules are reported in *Supplementary* Table.

The aim of this study was to determine the risk of ciTBI and TBI on CT in young children with isolated SH, according to the PECARN and CHALICE definitions, using the large prospective database from the Australasian Paediatric Head Injury Rule Study (APHIRST).[3,17]

METHODS

Study design

This was a secondary analysis of young children with isolated SH (all other rule-based predictor variables absent), using data from a prospective observational cohort study conducted in ten paediatric EDs in Australia and New Zealand between April 2011 and November 2014.[3,17] All EDs are members of the Paediatric Research in Emergency Departments International Collaborative (PREDICT) research network.[18] Full details of the parent study methods have been previously described.[3,17]

The study was approved by the institutional ethics committees at each site. We obtained informed verbal consent from parents/guardians apart from instances of significant life-threatening or fatal injuries where ethics committees granted a waiver of consent. The study was registered with the Australian New Zealand Clinical Trials Registry, ACTRN12614000463673.

Selection of study subjects

From the parent APHIRST study dataset we selected patients <2 years and limited to those who met the definitions of isolated SH according to PECARN and

CHALICE.

Definitions

PECARN isolated SH: children <2 years, presenting within 24 hours of sustaining a blunt head trauma with no PECARN predictors other than non-frontal (parietal, temporal or occipital) SH (Table 1).

CHALICE isolated SH: children <1 year old with scalp swelling >5 cm and no other CHALICE predictors (Table 1).

To overcome difficulties in comparing rules with different inclusion, exclusion and outcome criteria, and to provide more meaningful data for clinicians, we primarily applied the definitions of isolated SH of both rules, independent of age, to all children <2 years and then to children <1 year of age. In the primary analysis for both definitions, we excluded children with penetrating trauma, known brain tumours, pre-existing neurologic disorders, ventricular shunts, bleeding disorders, suspected child abuse,[19] or neuroimaging undertaken prior to arrival at the study ED.

Study procedures

Patients were enrolled by the treating ED clinician who collected predictive clinical data prior to neuroimaging. ED and hospital management data were recorded and telephone follow-up was done within 90 days of injury to assess for ciTBI or csII not diagnosed at the time of initial assessment for patients who did not have neuroimaging.

To identify and exclude possible cases of suspected child abuse among our population, we searched the study database for answers to relevant questions contained in the case report forms (CRF). While the patient was in the ED clinicians were asked on the CRF “Do you suspect non-accidental injury (Physical abuse of a child, not other assault)?”

Clinicians reported the SH according to size and location in 4 anatomic

regions (frontal, parietal, temporal, and occipital). When more than one location was present the largest location component was documented. Clinicians reported the measure of the haematoma as a continuous variable. Use of a tape measure was not required.

All variables listed in the isolated SH definitions were explicitly included in the CRF and were collected prospectively before outcomes were known.

Outcome Measures

Our *primary outcome* was ciTBI.[5]

Our *secondary outcomes* were:

- TBI on CT: intracranial haemorrhage/contusion, cerebral oedema, traumatic infarction, diffuse axonal injury, shearing injury, sigmoid sinus thrombosis, midline shift of intracranial contents or signs of brain herniation, diastasis of the skull, pneumocephalus, skull fracture depressed by at least the width of the table of the skull;[5]
- csII: death as a result of head injury, need for neurosurgery or marked abnormality on CT (any new, acute, traumatic intracranial pathology as reported by consultant radiologist, including intracranial haematomas of any size, cerebral contusion, diffuse cerebral oedema and depressed skull fractures).[11]

We used senior radiologist reports to determine CT scan results and operative reports for patients who underwent neurosurgery.

Data analysis

Data were entered into Epidata (The Epidata Association, Odense, Denmark), and later REDCap,[20] and analyzed using Stata 15.1 (Statacorp, College Station, Texas, USA).

To ensure our analysis only included patients with isolated SH, we excluded patients with missing data for any of other rule predictors.

We used descriptive statistics to summarise our data. Frequencies and proportions, or means and standard deviations were presented for demographic, injury and clinical variables. We reported 95% confidence intervals (CIs) for the prevalence of the study outcomes for children <2 years and those <1 year of age.

RESULTS

In the APHIRST study, we enrolled 22,524 (77.0%) of 29,433 potentially eligible patients. After excluding patients lost to follow up, re-presentations, missing Glasgow Coma Scale values, or meeting exclusion criteria for the present study, 19,527 patients were analysed. Of these, 5,237 (26.8%) were <2 years and 2,260 (11.6%) were <1 year of age (Figure 1).

In children <2 years, 241 (4.6%) met the PECARN definition of isolated SH, and 63 (1.2%) met the modified CHALICE definition expanded to include children up to 2 years. In the subgroup of children <1 year, 109 (4.8%) met the PECARN isolated SH definition and 35 (1.6%) the original CHALICE age definition.

Clinical characteristics of children meeting the PECARN and CHALICE definitions of isolated SH in both age groups are reported in Table 2. Very young infants (<3 m) represented approximately 10% of cases. The most common injury mechanism was falls. Differences in SH location and size are strictly related to the rule-based definition of isolated SH.

Primary outcome

The risk of ciTBI in children <2 years with PECARN isolated SH was 0.0% (0/241; 95%CI 0.0-1.5%), and 12.7% (8/63; 95%CI 5.6-23.5%), with one patient requiring neurosurgery, when using the CHALICE definition.

When restricting the analysis to children <1 year the risk of ciTBI was 0.0% (0/109; 95%CI 0.0-3.3%) in children meeting the PECARN isolated SH definition and 20.0% (7/35; 95%CI 8.4-36.9%) in those meeting the CHALICE definition, with one patient requiring neurosurgery.

Secondary outcomes

A TBI on CT was present in 10% (1/10; 95%CI 0.3-44.5%) of patients <2 years with PECARN isolated SH and in 42.9% (12/28; 95%CI 24.5-62.8%) of patients with CHALICE isolated SH. In children <1 year a TBI on CT was found in 12.5% (1/8; 95%CI 0.3-52.7%) of patients with PECARN isolated SH and in 50% (10/20; 95%CI 27.2-72.8%) of those with CHALICE isolated SH.

When using the CHALICE outcome of csII in children <2 years the risk was 0.4% (1/241; 95%CI 0.0-2.3%) and 19.1% (12/63; 95%CI 10.2-30.9%) for the PECARN and CHALICE definition of isolated SH respectively. In children <1 year the risk was 0.9% (1/109; 95%CI 0.0-5.0%) for the PECARN definition and 28.6% (10/35; 95%CI 14.6-46.3%) for the CHALICE definition.

Table 3 describes the frequency of the primary and secondary outcomes, as well as disposition, for children meeting the isolated SH definitions according to each rule in both age groups.

A detailed description of children with ciTBI and csII in children <2 years using both definitions of isolated SH is reported in Table 4.

DISCUSSION

In this secondary analysis focusing on young children with isolated SH according to the PECARN and CHALICE rule definitions, we found that the

prevalence of ciTBI was extremely low in children meeting the PECARN definition, but substantial for children meeting the CHALICE definition. Our results corroborate the findings of the recent PECARN sub-analysis on isolated SH,[21] which reported a risk of ciTBI of 0.4% (95%CI, 0.2%-0.7%), and a risk of TBI on CT of 8.8% (95%CI 6.6%-11.4%).

We provide the first data on the risk of ciTBI and csII in children meeting the CHALICE isolated SH definition. Data from the original CHALICE study showed 12% of csII in the overall group of children with SH, while data on SH as an isolated predictor were not reported.[11] Our findings of a much higher risk of ciTBI or csII in children with CHALICE isolated SH compared with PECARN isolated SH are not surprising considering that the CHALICE rule was developed to identify patients at high risk of significant intracranial injury, where one positive predictor is sufficient to recommend CT scan.[11] In addition, the CHALICE definition includes a large SH size (>5 cm) and a younger age (<1 year), which have been shown to be independently associated with intracranial injury. The PECARN sub-analysis, consistent with other studies, found that younger patient age, increased SH size, non-frontal SH location, and severe injury mechanism were independently associated with TBI on CT.[6,21-23] In children meeting the CHALICE definition of isolated SH, the frequency of ciTBI/csII clearly supports the performance of CT scan.

When looking at the subgroup of patients with TBI on CT, patients with CHALICE isolated SH did not meet the PECARN isolated SH definition because of co-existing PECARN positive predictors, namely “palpable skull fracture” (on digital inspection, or unclear on the basis of swelling or distortion of the scalp, as per PECARN study), “severe mechanism of injury” (which includes a much lower height threshold for falls, of 3 feet versus 3 metres in CHALICE) or “not acting normally per parent”.[5,11]

Consistent with the PECARN study, our TBI definition excluded isolated

uncomplicated skull fracture on CT. As reported by a recent meta-analysis, the presence of these fractures in isolation confers an extremely low risk of emergency neurosurgery, delayed hemorrhage or death.[24] Regardless of the need for acute intervention though, clinicians may be reluctant to miss a TBI on CT as their importance with respect to neurocognitive and development sequelae is unclear.

While previous guidelines recommended skull x-rays in children with isolated SH, based on evidence showing the association between skull fracture and TBI, other studies have shown that up to 50% of TBI can occur in the absence of a skull fracture.[9,22,25-28] Point of care ultrasound is increasingly replacing skull x-rays for the identification of skull fractures in children with traumatic SHs, showing a good accuracy for fractures identification compared with CT scan.[29,30] In addition, this test is not invasive, has no radiation, and allows to define the characteristics of a fracture (depressed or complex).[29]However, its role as a screening tool to risk-stratify patients for TBI in the era of high quality head injury prediction rules remains to be clarified. On the other hand, clinicians may also be reluctant to miss a skull fracture, as its detection assists in informing families on prevention of re-injury, as the skull surrounding a fracture is at risk of further trauma.[31]

The results of our study must be interpreted in light of some limitations. Clinicians obtained CT scans in few patients, with selection bias likely toward those with a more concerning clinical presentation. This bias would be expected to inflate the prevalence of TBI on CT, and hence the actual prevalence of TBI on CT in patients with isolated SHs is likely lower than reported in our study. In addition, the low number of patients who underwent CT scan led to wide confidence intervals. However, we had complete verification for the more significant outcomes, ciTBI and csII for all patients who did not undergo a CT at initial assessment.

In our study we excluded patients with suspected non-accidental injury, as

the PECARN rule does not apply to these children and suspicion of non-accidental injury is an independent CHALICE predictor.[11,19] We specifically asked in our CRF whether children were suspected victims of non-accidental injury. Although children with suspected abuse rarely present with isolated SH as a the only sign, specific hints from the history and physical examination should always be taken into account in the comprehensive assessment of head injured children.[32] These children should be viewed as entities, which are different from those with accidental injury.

Our study also has strengths. We have for the first time compared the risk of TBI on CT as well as ciTBI in children meeting the definitions of isolated SH of two high-quality widely used clinical prediction rules.[4,13,14] Our analysis included only complete data, as we excluded all patients who had at least one missing predictor, as we could not ensure the patient unquestionably met the isolated SH definition.

CONCLUSIONS

The risk of ciTBI in young children with SH as the sole predictor significantly differs based on the rule used, being very low in children meeting the PECARN definition of isolated SH, but substantial in those meeting the CHALICE definition.

While children meeting the PECARN definition of isolated SH can safely be observed, those meeting the CHALICE definition warrant a CT scan. The use of the definitions of both rules will aid clinicians in determining the level of risk of ciTBI, and therefore in deciding whether to do a CT scan.

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Figure 1. Flow-chart of study patient selection

APHIRST: Australasian Paediatric Head Injury Rule Study; CHALICE: Children's Head Injury Algorithm for the Prediction of Important Clinical Events; CT: computed tomography; GCS: Glasgow coma scale; PECARN: Pediatric Emergency Care Applied Research Network; MRI: magnetic resonance imaging; SH: scalp haematoma

What is already known on this topic

- Young children with isolated scalp haematoma (SH) following head trauma pose a clinical challenge with respect to neuroimaging versus observation
- The presence of a SH, although differently defined, is a common predictor of high quality paediatric head injury clinical prediction rules
- The risk of intracranial complications has not been described and compared in young children meeting the isolated SH definition according to different rules

What this study adds

- The risk of intracranial complications in young children with SH as the sole rule predictor significantly differs based on the rule used
- It is very low in children meeting the PECARN definition of isolated SH, but substantial in those meeting the CHALICE definition
- While children meeting the PECARN definition of isolated SH can safely be observed, those meeting the CHALICE definition warrant a CT scan

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Table 1 – Definitions of isolated scalp haematomas according to the PECARN and CHALICE rules.

PECARN rule	CHALICE rule
No PECARN predictors other than parietal, temporal or occipital scalp hematoma	**No CHALICE predictors other than swelling > 5 cm**
Patient met all the following #	*Patient met all the following ##*
No LOC or LOC < 5s	No witnessed LOC > 5min
Acting normally per parent/guardian	No abnormal drowsiness
Pediatric GCS score of 15	No ≥ 3 vomits after head injury
No signs of altered mental status*	No suspicion of non-accidental injury
No palpaple skull fracture	Paediatric GCS score of 15
No severe mechanism of injury §	No suspicion of penetrating or depressed skull injury or tense fontanelle
	No signs of basilar fracture
	No focal neurology
	No severe mechanism of injury §§

predictors listed are those from the PECARN blunt head trauma prediction rule for children younger than 2 years. The list does not include one of the predictors, namely parietal, temporal, or occipital scalp haematomas, because these scalp haematomas are the focus of this study group.

* (e.g. sleepiness, agitation)

§ 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.

predictors listed are those from the CHALICE head trauma prediction rule. The list does not include one of the predictors, namely swelling > 5 cm.

§§ High-speed road traffic accident either as pedestrian, cyclist or occupant (defined as accident with speed >40 m/h); fall of > 3 m in height; high-speed injury from a projectile or an object

LOC, loss of consciousness; GCS, Glasgow Coma Scale

Table 2 – Characteristics of children meeting the PECARN and CHALICE definition of isolated SH according to age group

	Children younger than 2 years (n=5237)			
	PECARN isolated SH n=241		CHALICE isolated SH n=63	
Mean age, months (SD)	12.3	6.8	11.4	6.3
Age groups, n (%), months				
0-<3	24	10.0	5	7.9
3-<6	25	10.4	5	7.9
6-<12	60	24.9	25	39.7
12-<24	132	54.8	28	44.4
Male, n (%)	150	62.2	30	47.6
Mechanism of injury, n (%)				
Fall related	211	87.6	61	96.8
≤ 1 m	206	85.5	41	65.1
> 1 m	0	0.0	20	31.8
Unknown height	5	2.1	0	0.0
Fall down stairs	6	2.5	0	0.0
Object struck head accidental	0	0.0	0	0.0
Motor vehicle crash	5	2.1	0	0.0
Severe mechanism of injury n (%)#§	0	0.0	0	0.0
Scalp haematoma location n (%)				
Frontal	0	0.0	26	41.3
Temporal	53	22.0	10	15.9
Occipital	0	0.0	2	3.2
Parietal	125	51.9	5	7.9
Scalp haematoma size n (%)				
< 3 cm	164	68.1	0	0.0
3-5 cm	63	26.1	0	0.0
> 5 cm	6	2.5	63	100.0
	Children younger than 1 year (n=2260)			
	PECARN isolated SH n=109		CHALICE isolated SH n=35	
Mean age, months (SD)	5.7	3.4	6.7	3.2
Age groups, n (%), months				
0-<3	24	22.0	5	14.3
3-<6	25	22.9	5	14.3
6-<12	60	55.1	25	71.4
Male, n (%)	71	65.1	15	42.9
Mechanism of injury, n (%)				
Fall related	98	89.9	33	94.3
< 1 m	97	89.0	21	60.0
> 1 m	0	0.0	12	34.3
Unknown height	1	0.9	0	0.0
Fall down stairs	3	2.8	0	0.0

Object struck head accidental	0	0.0	0	0.0
Motor vehicle crash	2	1.8	0	0.0
Severe mechanism of injury n (%)#§	0	0.0	0	0.0
Scalp haematoma location n (%)				
Frontal	0	0.0	11	31.4
Temporal	25	22.9	7	20.0
Occipital	0	0.0	0	0.0
Parietal	47	43.1	3	8.6
Scalp haematoma size n (%)				
< 3 cm	67	61.5	0	0.0
3-5 cm	33	30.3	0	0.0
> 5 cm	5	4.6	35	100.0

Severe mechanism of injury as per PECARN rule: 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
§ Severe mechanism of injury as per CHALICE rule: High-speed road traffic accident either as pedestrian, cyclist or occupant (defined as accident with speed >40 m/h); fall of > 3 m in height; high-speed injury from a projectile or an object

Table 3 – Study outcomes and dispositions according to age group

	Children younger than 2 years (n=5237)			
	PECARN isolated SH n=241		CHALICE isolated SH n=63	
CT performed n (%)	10	4.2	28	44.4
CT findings n (%)				
TBI on CT	1	0.4	12	19.1
Isolated skull fracture	8	3.3	10	15.9
ciTBI	0	0.0	8	12.7
csII	1	0.4	12	19.1
Neurosurgery	0	0.0	1	1.6
Disposition, n (%)				
Discharged home	195	80.9	38	60.3
SSU	39	16.2	7	11.1
Ward	9	3.7	18	28.6
Intensive care unit	0	0.0	0	0.0
	Children younger than 1 year (n=2260)			
	PECARN isolated SH n=109		CHALICE isolated SH n=35	
CT performed n (%)	8	7.3	20	57.1
CT findings n (%)				
TBI on CT	1	0.9	10	28.6
Isolated skull fracture	8	7.3	8	22.9
ciTBI	0	0.0	7	20.0
csII	1	0.9	10	28.6
Neurosurgery	0	0.0	1	2.9
Disposition, n (%)				
Discharged home	79	72.5	18	51.4
SSU	24	22.0	3	8.6
Ward	7	6.4	14	40.0
Intensive care unit	0	0.0	0	0.0

ciTBI: clinically important traumatic brain injury; csII: clinically significant intracranial injury; CT: computed tomography; SSU: short stay unit; TBI: traumatic brain injury

Table 4 – Clinical characteristics of children meeting the CHALICE and PECARN definition of isolated scalp haematoma who had a TBI on CT

Age (mo)	Reported injury Mechanism	SH Location	SH Size	CT findings	Skull fracture on CT	ciTBI	csII	Reason why PECARN definition not met
CHALICE rule								
0	Fall ≤1m	Parietal	> 5 cm	Intracranial hemorrhage	Yes	No	Yes	Palpable fracture
1	Fall >1m	Parietal	> 5 cm	Intracranial hemorrhage	Yes	Yes	Yes	Acting abnormally, Palpable fracture, Severe MOI
1	Fall >1m	Parietal	> 5 cm	Intracranial hemorrhage	Yes	Yes	Yes	Severe MOI
2	Fall >1m	Parietal	> 5 cm	Intracranial hemorrhage	Yes	Yes	Yes	Palpable fracture, Severe MOI
3	Fall >1m	Occipital	> 5 cm	Intracranial hemorrhage	Yes	Yes	Yes	Acting abnormally, Palpable fracture, Severe MOI
3	Fall >1m	Parietal	> 5 cm	Intracranial hemorrhage	Yes	Yes	Yes	Palpable fracture, Severe MOI
3#	Fall ≤1m	Temporal	> 5 cm	Intracranial hemorrhage	Yes	Yes	Yes	Palpable fracture
6	Fall ≤1m	Temporal	> 5 cm	Intracranial hemorrhage	Yes	Yes	Yes	Palpable fracture
8	Fall ≤1m	Parietal	> 5 cm	Intracranial hemorrhage	Yes	No	Yes	Palpable fracture
9	Fall >1m	Parietal	> 5 cm	Intracranial hemorrhage	Yes	No	Yes	Acting abnormally, Severe MOI
12	Fall ≤1m	Temporal	> 5 cm	Intracranial hemorrhage	Yes	Yes	Yes	Palpable fracture
17	Fall ≤1m	Parietal	> 5 cm	Intracranial hemorrhage	Yes	No	Yes	Palpable fracture
PECARN rule								
7	Struck by object	Occipital	> 5 cm	Diastasis, depressed fracture*	Yes	No	Yes	*Not applicable*

This child needed surgical evacuation of an epidural hematoma
*(By at least one width of the skull)
ciTBI: clinically important traumatic brain injury; csII: clinically significant intracranial injury; CT: computed tomography; MOI: mechanism of injury; TBI: traumatic brain injury