EDITOR'S CHOICE

Application of the CHALICE clinical prediction rule for intracranial injury in children outside the UK: impact on head CT rate

Louise Crowe,[1–3] Vicki Anderson,[1–3] Franz E Babl[1–3]

[1]University of Melbourne, Melbourne, Australia
[2]Critical Care and Neurosciences, Murdoch Childrens Research Institute, Melbourne, Australia
[3]Royal Children's Hospital, Melbourne, Australia

Correspondence to
Louise Crowe, Murdoch Childrens Research Institute, Flemington Road, Parkville, Victoria 3052, Australia; louise.crowe@mcri.edu.au

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ABSTRACT

Objective The children's head injury algorithm for the prediction of important clinical events (CHALICE) is one of the strongest clinical prediction rules for the management of children with head injuries. The authors set out to determine the impact of this rule on the proportion of head injured patients receiving a CT scan in a major Australian paediatric emergency department.
Design Retrospective cohort study.
Setting Tertiary paediatric hospital emergency department in Australia (67 000 patients/year).
Patients All head injured patients presenting to the emergency department in 2004.
Main outcome measures Actual proportion of head injured patients receiving a CT scan compared with the proportion had the CHALICE algorithm been applied.
Results There were 1091 head injuries of all severities during the study period. 18% of head injured patients had a Glasgow Coma Scale <15, 19% a CT scan and 1.4% neurosurgical intervention. Application of the CHALICE algorithm would result in 46% receiving a CT scan. 303 patients who fit CHALICE criteria did not have a CT scan. These patients were managed with admission for observation or discharge and head injury instructions. Only five of these (1.6% or 0.5% of total head injuries) received a CT scan on representation for ongoing symptoms, four of which showed abnormalities on CT scan.
Conclusions Application of the CHALICE rule to this non-UK dataset would double the proportion of CT scans, with an apparent small gain in delayed pick-up of CT abnormalities. The role of expectant observation in hospital or at home needs to be defined.

What is already known on this topic

- CT of the head enables rapid diagnosis of intracranial abnormalities but is associated with radiation- and sedation-associated risks and considerable cost.
- The children's head injury algorithm for the prediction of important clinical events (CHALICE) head injury management algorithm has been developed to guide clinicians whether to scan a patient or not.

What this study adds

- For the first time, the CHALICE rule has been retrospectively applied outside of the derivation sites at an Australian paediatric hospital.
- Implementing the CHALICE rule would double the number of CT scans.
- Less than 3% of patients who fit the CHALICE rule and did not receive a CT scan represented for further treatment.

INTRODUCTION

Head injuries in children present a common management dilemma in emergency departments. CT provides rapid and definitive identification of any intracranial injuries and helps guide subsequent management, including possible neurosurgical intervention. Results are potentially reassuring to parents and may reduce unnecessary admissions. CT scans also have negative implications, particularly in children, including radiation-[1] and sedation-associated risks,[2 3] and they have resource implications.[4]

Several studies have developed evidence-based clinical prediction rules to identify which children are at high risk of intracranial complications and should therefore receive a cranial CT scan.[5] A recent review of clinical prediction rules identified eight such rules with considerable variation in study populations, methodological quality and performance.[5] Two clinical decision rules[6 7] were of high quality and performance.[5] One of these, the children's head injury algorithm for the prediction of important clinical events (CHALICE) rule, had been prospectively derived in a large multicentre UK based study.[6] CHALICE requires patients to receive a CT scan if any of a set of specified historical, examination and mechanism variables are identified. The CHALICE rule was derived with a sensitivity of 98% (95% CI 96% to 100%) and a specificity of 87% (95% CI 86% to 87%) to predict clinically significant head injury and a CT rate of 14%.[6]

However, CHALICE has not been validated in different populations.[5] This would be important as baseline proportions of children with head injury receiving CT scans vary from country to country. Although CT proportions are difficult to compare based on different study populations, referral patterns and study periods examined, CT proportions in the UK seem lower than elsewhere. The 10 emergency departments in the UK where CHALICE was derived had a baseline CT proportion of 3.3%.[6] A report from another UK site reported a CT proportion of 4.4%.[8] CT proportions in the USA,[9] Canada[10] and Australia[11 12] are generally reported to be higher than in the UK, although large intracountry variation has also been reported. A Canadian study of similar paediatric emergency departments showed large variation in the use of CT, ranging 6% to 26% across different hospitals.[10] In addition, CT proportions change over time; Canadian data showed an increase in the CT proportion from 15% in 1995 to 53% in 2005.[10 13]

We set out to apply the CHALICE rule in a large Australian paediatric emergency department. Our aim was to compare the baseline CT proportion with the proportion if the rule had been applied.

METHOD

Study design

This was a retrospective cohort study examining application of the CHALICE head injury prediction rule to children with head injuries attending a paediatric emergency department. The study was approved as an audit by the hospital ethics committee.

Study setting and population

The study was conducted in the emergency department of the Royal Children's Hospital (RCH), Melbourne, Australia. The emergency department deals with 67 000 patients/year. RCH is the only paediatric trauma centre in the state of Victoria and serves a population of around 1.5 million children. Published head injury guidelines at RCH (http://www.rch.org.au/clinicalguide/cpg.cfm?doc_id=5177#assessment) group patients into minor, moderate and severe head injury based on a number of more or less detailed definitions of length of loss of consciousness (LOC) at time of injury, current mental status, emesis, headache, size of scalp haematoma and other factors. For moderate head injuries, management options include observation in the emergency department or ward with reassessment depending on neurological changes and further vomiting, CT scan and neurosurgical consultation. Skull x-rays are not a management option. Key decision points in the guidelines refer to discussion with senior medical staff.

Study protocol

Cases were identified though a search of the computerised emergency department database for the following discharge codes of the International Classification of Diseases 10th revision (ICD-10): 'fracture of skull and facial bones' (S02.0–2.9), 'sprain and strain of joints and ligaments of other and unspecified parts of the head' (S03.5), 'intracranial injury' (S06.0–6.9), 'crushing injury of the head' (S07.0–7.9), 'traumatic amputation of part of the head' (S08.0–8.9) and 'other and unspecified injuries of the head' (S09.0–9.9).[14]

In order to also capture head injured patients who were discharge coded under a non-head injury code, we searched the emergency department database of triage notes and discharge codes for open wounds to the head. Due to the variable nature of injuries relevant to this code, injuries coded ICD-10 code 'open wounds of the head' (S01.7–7.9)[14] were included in the study if they matched the following criteria: Glasgow Coma Scale (GCS)[15] alteration from 15, reporting common head injury symptoms (eg, confusion, vomiting),[16] mechanism of injury associated with head injury (fall from a height greater than 0.9 m or involved in a motor vehicle accident),[17] arrival by ambulance or admission to hospital.

In order to determine representation and later diagnosis of intracranial injury in identified cases, we also analysed any future emergency department visits, admissions and cranial imaging in all identified patients.

The medical records for all identified cases were manually abstracted and reviewed. Chart review was undertaken after piloting a data abstraction form and previously suggested guidelines for quality chart reviews were followed.[18] The data were extracted from the medical record by a professional researcher with epidemiology qualifications and a portion (25%) of records were randomly selected and reviewed by a second researcher. Inter-rater agreement for all variables was 98%. Detailed information was collected on child's age, gender, suburb of residence, mechanism of injury, type of activity, location, symptoms, diagnostic investigations and clinical treatment and management. All children 16 years and under who were seen in the emergency department from January to December 2004 (12 months) following a head injury were reviewed, with the data collected between 2006 and 2007. The CHALICE criteria were applied by one researcher and any cases where queries arose were reviewed by the panel of three authors. The abnormal drowsiness criterion was difficult to assess retrospectively as it relied on documented clinical judgement. To overcome this, we only included drowsiness as fitting CHALICE criteria when another criterion was also met.

Outcome measures

The proportion of head injuries receiving a CT scan was the primary outcome measure. The projected proportion of head CT scans based on the CHALICE rule[6] (box 1) was calculated. Historical, examination and mechanism findings based on CHALICE criteria, GCS scores, CT findings and neurosurgical intervention were also determined.

Data analysis

All data were entered into an Excel software database (Microsoft, Redmond, Washington, USA). Median values are reported as median with IQR. Key proportions are presented with 95% CI. Statistical calculations were performed in Stata 9.0 (Stata, College Station, Texas, USA).

RESULTS

A search for the specified ICD-10 codes and application of the rule identified 1091 cases, with two of these children dying after arrival. Twenty-six children had a CT scan at another hospital and were excluded from the dataset, leaving 1065 cases. Demographics and head injury details including CHALICE criteria presentations are displayed in table 1. Most children were from the Melbourne metropolitan area, were male and presented with a GCS of 15. Children were aged from 8 days to 16 years with a mean age of 5.1 years. Nineteen per cent of children (95% CI 17.1% to 21.9%) had a head CT scan. Abnormalities were found on CT scan in 73 patients (6.8%; 95% CI 5.4% to 8.5%) and intracranial abnormalities were found in 39 (3.6%; 95% CI 2.6% to 4.9%). Two children had skull x-rays. Fifteen children (1.4%; 95% CI 0.9% to 2.3%) underwent neurosurgical intervention (table 1).

The CHALICE rule[6] was applied to the dataset as shown in figure 1. Overall, 489 patients (45.8%; 95% CI 42.9% to 48.9%) fit the CHALICE rule and could have therefore received a CT scan. Most children met only one CHALICE criterion (259), followed by two criteria (188), three criteria (37) four criteria (4) and five criteria (1). The five most frequent criteria were

Box 1 The children's head injury algorithm for the prediction of important clinical events rule[6]

- A CT scan is required if any of the following criteria are present
  - History
    - Witnessed LOC of >5 min duration
    - History of amnesia (either antegrade or retrograde) of >5 min duration
    - Abnormal drowsiness (defined as drowsiness in excess of that expected by the examining doctor)
    - ≥3 vomits after head injury (a vomit is defined as a single discrete episode of vomiting)
    - Suspicion of NAI (defined as any suspicion of NAI by the examining doctor)
    - Seizure after head injury in a patient who has no history of epilepsy
  - Examination
    - GCS <14, or GCS <15 if <1 year old
    - Suspicion of penetrating or depressed skull injury or tense fontanelle
    - Sign of basal skull fracture (defined as evidence of blood or cerebrospinal fluid leakage from the ear or nose, panda eyes, Battle's sign, haemotympanum, facial crepitus or serious facial injury)
    - Positive focal neurology (defined as any focal neurology, including motor, sensory, coordination or reflex abnormality)
    - Presence of bruise, swelling or laceration >5 cm if <1 year old
- Mechanism
    - High-speed road traffic accident either as a pedestrian, cyclist or occupant (defined as accident with speed >40 m/h or 64 km/h)
    - Fall of >3 m in height
    - High-speed injury from a projectile or an object
  - GCS, Glasgow Coma Scale; LOC, loss of consciousness; NAI, non-accidental injury.

abnormal drowsiness, amnesia over 5 min, three or more discrete vomits, GCS <14 and GCS <15 in children under 12 months of age. Only 186 of the 489 (38.0%; 95% CI 33.7% to 42.5%) patients who fit the CHALICE rule underwent CT scanning. Figure 2 displays the outcomes of the 303 children who fit the CHALICE rule but did not have a CT scan: 34.7% were admitted for observation, none of whom received a subsequent CT scan, and 65.3% were discharged home with head injury instructions. Of these, seven (2.3% of CHALICE positive patients without CT, 95% CI 0.7% to 2.8%; or 0.8% of all head injured patients, 95% CI 0.4% to 1.6%) represented for ongoing symptoms (in addition to four for wound care), of whom five (1.6% of CHALICE positive patients without CT, 95% CI 0.5% to 3.8%; or 0.7% of all head injured patients, 95% CI 0.3% to 1.0%) had a CT scan for ongoing symptoms. Four of these five (1.3% of CHALICE positive patients without CT, 95% CI 0.4% to 3.6%; or 0.4% of all head injured patients, 95% CI 0.1% to 1.0%) had abnormalities on CT scanning (two children had skull fractures, one had a skull fracture and extradural haematoma and one had cerebral swelling). Two of these five children were admitted to hospital and none required neurosurgical intervention. One child represented for new onset seizures after the head injury.

The two children who died did fit CHALICE criteria in each category, that is history, examination and mechanism. CT scans indicated cerebral oedema.

Of the children who received a CT scan during acute admission, 16 required sedation so that scan could be carried out. Projecting this proportion to the 303 patients who fit CHALICE criteria and did not receive a CT scan, would have required an additional 26 sedations.

Of the 576 patients who did not fit CHALICE criteria, 21 (21 of 576; 3.6%) had CT scans. Of these 21 patients, eight had an abnormal CT scan (six children were positive for abnormality as defined by the CHALICE rule). Of these eight children, one child required neurosurgical intervention (see table 2), six children were admitted and followed-up by neurosurgery and one child was discharged home with head injury instructions and followed-up with neurosurgery. The causes of head injuries and the symptoms were varied and are listed in table 2.

DISCUSSION

In this Australian dataset, head injured children received CT scans six times more frequently than the average for children at the 10 UK derivation sites for the CHALICE rule (19% vs 3%).[6] The mean age in the study group was similar to that in the original CHALICE study. Application of the rule would have doubled the proportion of CT scans to 46%. Although some studies of the implementation of head injury decision rules have reported a marked increase in the number of CT scans that should have been performed,[8 19 20] this is the first study to have done this for the CHALICE rule.

Patients who fit the CHALICE rule and did not receive a CT scan were either admitted for observation or discharged with head injury instructions after a period of observation in the emergency department. Ninety-eight per cent of these patients ultimately did not represent or require further investigation and therefore most likely did not require the CT scan as indicated by the CHALICE rule. However, five patients who did fit CHALICE criteria and did not receive a CT scan represented with ongoing symptoms, and subsequently all these children received a CT scan. Four of the five CT scans were abnormal: one child subsequently developed a seizure disorder but none of these children required neurosurgical intervention. These data provide some support for the sensitivity of the CHALICE rule. The head injury guidelines at RCH (http://www.rch.org.au/clinicalguide/cpg.cfm?doc_id=5177#assessment) focus on observation with reassessment and senior staff input for possible moderately severe injuries. This decision making process based on 'clinical judgement' is difficult to capture in a strict algorithm or describe with fixed criteria. The example would be a toddler who fulfilled one or more CHALICE criteria but is now running about the department.

Table 1 Demographics, key findings based on CHALICE criteria, GCS, CT findings and neurosurgical intervention (n=1065)

Variable		Patients	
		N	%
Demographics	Gender (male)	673	63.1
	Age (years)	Mean 5.1 years Median 3.0 years	Range 8 days to 16 years 10 months
	Metropolitan address	1001	93.9
Head injury outcomes	GCS=15	869	81.6
	GCS=14	114	10.7
	GCS ≤13	82	7.7
	Deaths	2	0.2
	Admission rate	309	29.0
CT scanning carried out		207	19.4
CT positive findings*	Skull fracture only (non-depressed)	34	3.2
	Depressed skull fracture	6	0.6
	Skull fracture and intracranial injury	16	1.2
	Intracranial injury breakdown		
	Contusion	11	1.0
	Epidural haematoma	5	0.5
	Intraparietal haemorrhage	6	0.6
	Tympanic membrane rupture	1	0.1
	Cerebral oedema	3	0.3
	Subarachnoid haematoma	1	0.1
	Subdural haematoma	13	1.2
Skull x-ray carried out		2	0.2
Skull x-ray findings	Skull fracture	1	0.1
Neurosurgical intervention†	Craniotomy	7	0.7
	Elevation of fracture	6	0.6
	Insertion of drainage	5	0.5
CHALICE criteria‡	LOC >5 min	20	1.7
	Amnesia >5 min	92	8.7
	Abnormal drowsiness	193	18.1
	≥3 Vomits	77	7.2
	Suspicion of NAI	30	2.8
	Seizure (no epilepsy)	28	2.6
	GCS <14	70	6.6
	GCS <15 and <12 months	63	5.9
	Suspect penetrating/depressed skull	5	0.5
	Signs of basilar skull fracture	9	0.8
	Focal neurology	34	3.2
	Bruise >5 cm	28	2.6
	High-speed accident	59	5.5
	Fall >3 m	25	2.3
	High-speed injury from projectile	27	2.5

*CT findings – some patients had more than one intracranial injury.
†Neurosurgical intervention – some patients had more than one procedure.
‡For details see figure 1.
CHALICE, children's head injury algorithm for the prediction of important clinical events; GCS, Glasgow Coma Scale; LOC, loss of consciousness; NAI, non-accidental injury.

While CT scans are generally available and accessible in the Australian setting, an increase in scanning rates based on the CHALICE rule would have a number of sequelae, including increased radiation exposure, more sedation use and a possible impact on hospital resources. Radiation exposure through CT scans has increasingly been recognised as problematic in terms of the increase in lifetime risk of fatal cancer, in particular in children.[1 21 22] The ALARA (as low as reasonably achievable) concept should be applied whenever possible.[21 22] Based on the sedation requirements for the patients who had actually been scanned in this sample and extrapolated, 26 more sedations would have been required to manage these children. While fewer patients might have been admitted for observation if a CT scan had ruled out an intracranial injury, the financial implications in our setting are not clear. In the tax payer funded Australian hospital system, public patients are not charged for CT scans or for hospital admissions and public patient cost can only be estimated at ~AUS$200 for admissions or for CT scans (based on private patient charges, personal communication, and information from the imaging and finance departments at RCH). Parental anxiety due to a patient not being scanned (missed injury) or being scanned (radiation risks) or disruption to family life through a hospital admission are difficult to quantify.

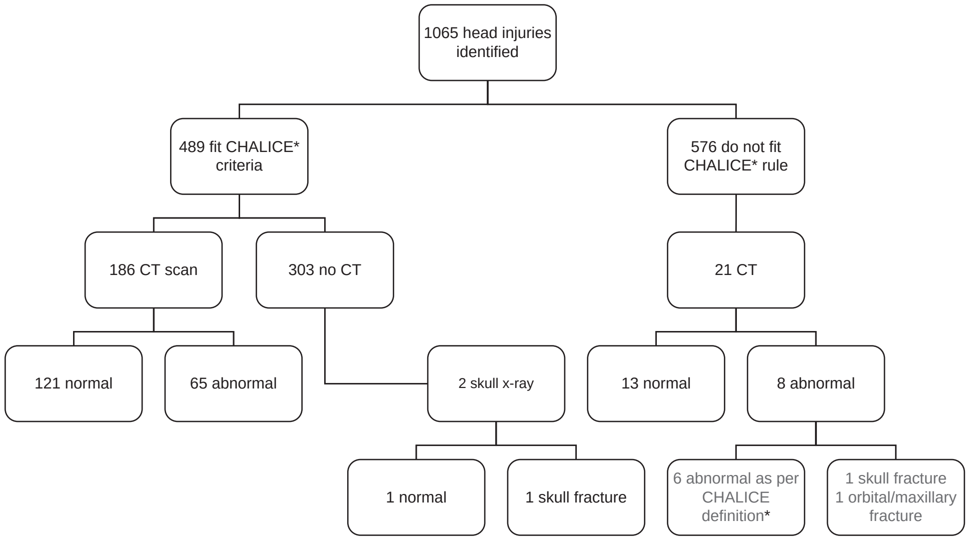

Figure 1 Application of the children's head injury algorithm for the prediction of important clinical events (CHALICE) decision rule to the dataset. *For the CHALICE rule and definition see box 1 and the Methods section.

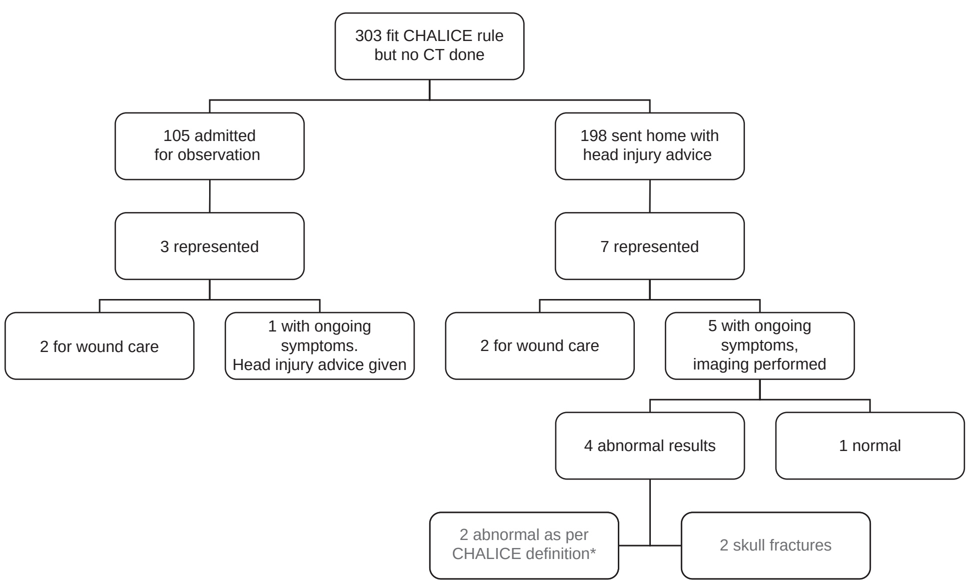

Figure 2 Outcome of children who met children's head injury algorithm for the prediction of important clinical events (CHALICE) rule but did not receive a CT scan. *For the CHALICE rule and definitions see box 1 and the Methods section.

When comparing the data of patients in this study and CHALICE derivation site data, at RCH, in terms of history variables for the CHALICE rule (see box 1), such as amnesia over 5 min, drowsiness, more than three discrete vomits, suspicion of non-accidental injury and seizure were higher for our group. At examination, our group had lower GCS, fewer positive focal neurology signs and less presence of bruise in children under 1 year. Regarding mechanism, high-speed road traffic accident and falls over 3 m were also higher in our group. Our dataset had lower levels of basal skull fracture.

Based on the retrospective study design, there are a number of questions regarding the reliability and validity of our findings. Ideally this study would have been conducted prospectively and CHALICE criteria would have been elicited at the time of the emergency department visit. At CHALICE sites, doctors were specifically trained to complete study proformas.[6] Although the recommendations for optimal chart review[18] were followed except for abstractor blinding, the main concern based on the retrospective nature of this study is that information may not have been recorded or may have been under-reported. CHALICE positive patients were likely more reliably identified (eg, a recorded statement of loss of consciousness of more than 5 min) as compared to CHALICE negative patients who received a CT scan (eg, additional vomiting may not have been recorded). Patients in the CHALICE derivation study were followed by phone call to detect any subsequent complications.[6] We were only able to determine if patients represented or had a subsequent CT scan at our centre; however, as the only paediatric major trauma service in the state of Victoria, it is likely that patients with external findings subsequently detected at outside hospitals would have been referred to RCH. We also excluded patients who had a CT scan prior to referral to RCH as initial triage notes were sometimes incomplete and the focus of this study was on the

Table 2 CT and skull x-rays performed on children who did not fit CHALICE rule*

Case number	Age (years)	Injury cause/symptoms	Result	Neurosurgery?
1	15	Persistent headache a week later	Normal	
2	15	GCS=15 on arrival but GCS=13 in ambulance, brief LOC, 2 discrete vomits	Normal	
3	14	GCS=14 on arrival, brief LOC, fell off ride-on-mower	Normal	
4	11	Fell 2 m, had brief LOC	Normal	
5	9	Fell 1.25 m from tree to concrete with brief LOC	Normal	
6	7	Fell off bike, brief LOC, bruise on head	Normal	
7	7	Previously had a tumour, has missing bone flap, hit it when fell over	Normal	
8	6	Vomit <3 times, headache, fell off trampoline	Normal	
9	2	Headache, lump on head	Normal	
10	14	GCS=15 on arrival, LOC of 4 min, fell off horse	normal	
11	14	GCS=15 on arrival, LOC for 3 min, agitated, fell playing football	Normal	
12	10	Headache, drowsy, dizzy, fell off shoulders	Normal	
13	11	Vomit <3 times, fell from tree <3 m	Normal	
14	11	Fell 2 m, brief LOC	Skull fracture	No
15	9	GCS=15, vomited once, mild headache, fell and hit head on concrete	Small left occipital contusion	No
16	15	Playing AFL, vomited once, brief LOC, headache, nausea	Orbital and maxillary fractures	No
17	3	Fell 1 m onto tiles, had headache, boggy swelling	Skull fracture and contusion	No
18	10	GCS=15 on arrival, previously GCS=14 in ambulance, brief LOC	Subdural haematoma	No
19	7	Fell off bike wearing helmet, lump on head	Skull fracture, small haematoma	No
20	7	On admission GCS=15, previously 13, irritable, fell off bike, no helmet	Small subgaleal haemorrhage and parietal haemorrhagic contusion	Yes, repair of anterior fossa and dura tear
21	2	Lump on head	Haematoma parietal	No

*See box 1 for definition.
AFL, Australian Football League; CHALICE, children's head injury algorithm for the prediction of important clinical events; GCS, Glasgow Coma Scale; LOC, loss of consciousness

decision making process at our institution. Finally, due to the retrospective methodology, it is possible that some patients were admitted for reasons not primarily related to neurological observation.

CONCLUSION

Implementation of the CHALICE clinical prediction rule would cause an increase in the number of CT scans. Although the CHALICE rule would have identified a very small number of additional cases with abnormal CT scans, based on our clinical set-up the majority of CT scans would have been unnecessary with resultant radiation exposure and the possible need for sedation of the child. The value of the CHALICE rule is acknowledged, but the role of expectant observation and senior staff review needs to be clarified.

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Competing interests None.

Ethics approval This study was conducted with the approval of the Royal Children's Hospital Ethics Committee.

Provenance and peer review Not commissioned; externally peer reviewed.

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