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ORIGINAL ARTICLE

Missed intracranial injuries are rare in emergency departments using the PECARN head injury decision rules

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Abstract

Purpose The PECARN head trauma (HT) prediction rules have been developed to guide computed tomography–related decision-making for children with minor HT (mHT). There are currently limited data on the rate of unscheduled revisits to emergency departments (EDs), and initially missed intracranial injuries, in children with mHT initially assessed using the PECARN rules. This study aimed to fill this gap in knowledge.

Methods Clinical charts of children assessed for mHT over a 5-year period at two EDs that implemented the PECARN rules in Italy and France were reviewed retrospectively. Children who returned to EDs for mHT-related, or potentially related complaints, within 1 month of initial assessment were included.

Results The total number of children with mHT presenting for the first time to the EDs of both sites was 11,749. Overall, 180 (1.5%) unscheduled revisits to the EDs occurred for mHT-related or potentially related complaints. Twenty-three of these 180 patients underwent neuroimaging, and seven had an intracranial injury (including one ischemic stroke). Of these, three were hospitalized and none needed neurosurgery or intensive care.

Conclusion Unscheduled revisits for mHT in EDs using the PECARN rules were very uncommon. Initially missed intracranial injuries were rare, and none needed neurosurgery or intensive care.

Keywords Minor head trauma · Missed brain injury · Clinical predictive rule · Return visit

Introduction

Head trauma (HT) continues to be a major problem in pediatrics, representing one of the most common reasons for visits to the pediatric Emergency Department (ED) [1, 2]. The vast majority of HTs are mild in severity [1, 2]. They represent a major challenge with respect to the identification of intracranial injuries, which, although uncommon, may lead to a potentially fatal or poor outcome [2]. At the same time, clinicians have to carefully balance decision on performing computed tomography (CT) in these children, due to concerns about radiation exposure and subsequent iatrogenic cancer risk [3, 4], as well as the need for sedation in uncooperative children [5] and finally, the issue of CT-related costs.

To help clinicians with this challenging decision-making process research has focused on the development of high quality pediatric HT clinical decision rules. The age-based rules published in 2009 by the Pediatric Emergency Care Applied Research Network (PECARN) [6] for children younger and older than 2 years of age have since been validated in multiple settings, proving to be highly accurate in identifying children with clinically important traumatic brain injuries (ciTBIs) [6–9]. As well, it misses the fewest patients, when compared with other high-quality pediatric HT rules [8, 9]. The PECARN rules are currently used in many countries for the ED management of children with minor HT (mHT) [10–12].

Although a few studies have shown the benefit of implementing the PECARN rules in clinical practice, in terms

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of decreased CT use and increased staff satisfaction with their use [11–14], the actual long-term impact in terms of unscheduled ED return visit rates and initially missed ciTBIs in children with mHT remains poorly investigated.

Unscheduled ED return visits are used to reflect the quality of care on initial presentation in terms of correct diagnosis, treatment, and advice, although the family's decision to return to the ED may be based on other factors including parental anxiety or unavailability of pediatric-focused community services [15]. Although several studies have focused on return visits to the ED [15–23], limited data are available on the ED burden and on the outcome of unscheduled return visits following pediatric mHT, in settings where the PECARN rules have been implemented [24].

This study aimed to

(i) describe the frequency and reasons of unscheduled mHT-related return visits to the ED in the first month following initial assessment for mHT

(ii) to determine the frequency of missed intracranial injuries and ciTBIs in two European pediatric EDs that implemented the PECARN rules in clinical practice.

Methods

Study design and setting

We conducted a retrospective study of children with mHT presenting for evaluation at one of two pediatric EDs located in Padova (Italy) and Paris (France). The study was conducted over a 5-year period (between January 2011 and December 2015).

Padova Children's Hospital is a tertiary care academic hospital with approximately 25,000 pediatric ED visits per year of children younger than 15 years of age. Robert-Debré Children's Hospital in Paris is a tertiary care academic hospital, with a level 1 trauma center designation and an annual ED census of approximately 80,000 pediatric ED visits per year of children younger than 18 years of age.

The PECARN mHT rules were implemented in June 2010 and November 2010 in the ED of Padova [11] and Robert-Debré Children's Hospital, respectively.

Study population

Inclusion criteria We included children younger than 15 years presenting to the ED of Padova and younger than 18 years of age presenting to the ED of Paris, who returned to the ED for complaints related, or potentially related, to the head trauma, within 1 month of their initial assessment for their mHT (see "Definitions") index case.

Exclusion criteria We excluded children who were found to have an intracranial injury detected on neuroimaging when performed at the time of initial assessment, scheduled return visits, return visits for a new trauma, and patients who left before being seen at the return visit and for whom clinical data were not available.

Definitions

mHT: minor head trauma, a head trauma with a Glasgow Coma Scale (GCS) score ≥ 14 at initial presentation.

ciTBI: clinically important traumatic brain injury defined as death from traumatic brain injury, neurosurgery, intubation for more than 24 h for traumatic brain injury, or hospital admission of two nights or more associated with traumatic brain injury on CT.

mHT-related complaints: complaints obviously related to mHT, such as evolution of external injuries to the head (e.g., enlargement of scalp hematoma).

mHT potentially related complaints: nausea/vomiting, headache, abnormal behavior (as per parents), balance problems, drowsiness, fatigue/low energy/feeling slowed down, neurological symptoms, sleeping troubles, visual problems, difficulty in concentrating, and difficulty in remembering things.

Additional symptoms: symptoms not related to mHT, namely fever, diarrhea, abdominal pain.

Data sources and collection

At the pediatric ED of Padova study, patients were identified by searching the electronic medical record database for the keywords "head trauma," "head injury," "concussion," "laceration to head," in the field "final diagnosis." At the pediatric ED of Paris, patients were searched within the electronic medical record by a query for head trauma–related diagnoses "G443," "S000," "S10," "S04," "S05," "S06," "S09," "S099," "S091," "S007," "S008," "S009," "S097," and "T000" in the field "final diagnosis." Search for a return visit to the ED was performed by using administrative data (surname, name, and date of birth). Search strategies differed between the two study centers based on the different electronic medical records systems in use.

We developed a clinical report form and piloted it on 50 medical records to optimize data capture and collection. Trained research staff, who were not blinded to the study objectives, extracted data on demographics, clinical characteristics, timing of ED return visit, signs/symptoms determining return visit, management, disposition, and outcome. We followed published guidelines for quality chart review in emergency medicine [25]. Ambiguous data were discussed and reviewed with two senior investigators (LDD and LT).

The study was approved by the Ethics Committee at both centers.

Statistical analysis

Categorical variables are reported as percentages. Continuous variables are described using medians and interquartile ranges (IQR). We performed comparisons between groups by means of Chi-squared tests for categorical variables. Parameters displaying $p < 0.05$ were considered statistically significant. Data were entered into an Excel database and were analyzed using Stata (version 13.1, StataCorp, College Station, Texas, USA).

Results

During the 5-year study period, a total of 502,478 pediatric patients presented to the study EDs. Of these, 11,967 (2.4%) were assessed for a HT of any severity, while 11,749 (2.3%) presented a mHT based on the study definition. Two-hundred fifty-three (2.2%) patients with a mHT returned to the EDs within a month of their initial assessment. Seventy-three of these patients either did not meet inclusion criteria or met exclusion criteria, leaving 180 (1.5%) patients who returned to the ED for an unscheduled return visit for complaints related or potentially related to the mHT (Fig. 1).

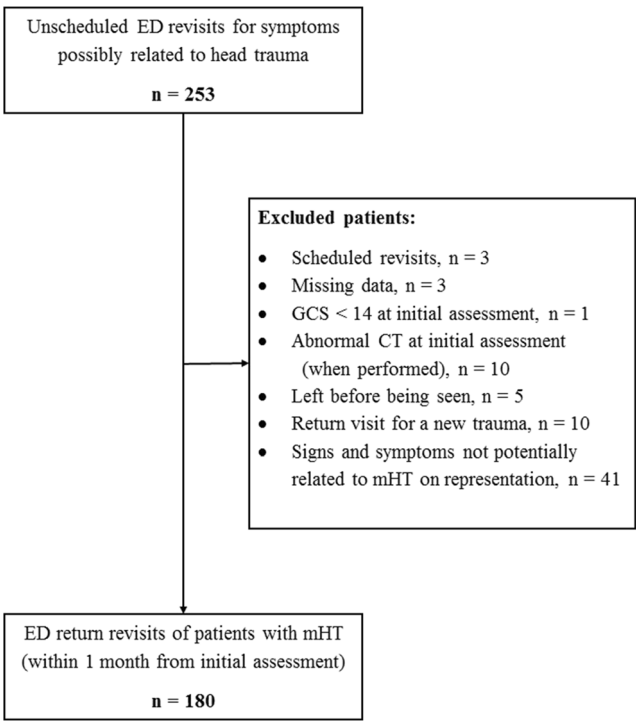

Fig. 1 Flow chart of patient selection. *Abbreviations*: ED = emergency department, GCS = Glasgow Coma Scale; CT = computed tomography; mHT = minor head trauma

The clinical characteristics of study patients, their management, and their disposition at the time of their initial ED assessment are reported in Table 1. The median age of the study population was 2.9 years of age. The most frequent mechanism of trauma was falls, followed by being struck by an high impact object. The GCS score at initial assessment was 15 for all patients; half of them were asymptomatic, while vomiting and headache were the most common symptoms at initial

Table 1 Clinical characteristics, management, and disposition of patients with minor head trauma at initial presentation in the emergency department

		Total $n = 180$
Sex M, *n* (%)		111 (61.7%)
Age, median (IQR)		2.9 (5.3)
Hours since injury, median (IQR)		2.0 (3.5)
Mechanism of injury, *n* (%)		
Falls		111 (61.7%)
Head struck by high impact object		24 (13.3%)
Walked into stationary object		17 (9.4%)
Road traffic accidents		15 (8.3%)
Sport-related		9 (5.0%)
Other		1 (0.6%)
Unknown (unwitnessed)		3 (1.7%)
Symptoms, *n* (%)		
Asymptomatic		89 (49.4%)
Vomit		48 (26.7%)
Headache		39 (21.7%)
Abnormal behavior (as per parents)		28 (15.6%)
Loss of consciousness		11 (6.1%)
Dizziness		6 (3.3%)
Post-traumatic amnesia		2 (1.1%)
Post-traumatic seizures		1 (0.6%)
Other symptoms		30 (16.7%)
Physical findings, *n* (%)		
GCS 15		180 (100%)
Altered mental status		2 (1.1%)
Signs of base skull fracture		1 (0.6%)
Palpable skull fracture		2 (1.1%)
Scalp hematoma		67 (37.2%)
Location	Isolated frontal	33 (49.3%)
	Other location	33 (49.3%)
	Unknown	1 (1.5%)
Consistency	Boggy	21 (31.3%)
	Firm	21 (31.3%)
	Unknown	25 (37.3%)
Focal neurological signs		0 (0%)
Intoxication		0 (0%)
Associated extracranial injuries		28 (15.6%)
Imaging, *n* (%)		
Head CT scan		15 (8.3%)
Disposition, *n* (%)		
Discharge within 4 h from ED assessment		134 (74.4%)
ED observation unit (4–24 h)		46 (25.6%)

M male, *IQR* interquartile range, *GCS* Glasgow Coma Scale, *CT* computed tomography, *h* hours, *ED* emergency department

Table 2 Clinical characteristics, management, and disposition of patients with minor head trauma at re-presentation to the emergency department

	Total $n = 180$
Hours since initial assessment, median (IQR)	37.5 (52.0)
Symptoms, *n* (%)	
Clearly or potentially related to head trauma	
Nausea/vomit	121 (67.2%)
Headache	52 (28.9%)
Abnormal behavior (as per parents)	19 (10.6%)
Balance problems	18 (10.0%)
Drowsiness	12 (6.7%)
Evolution of external injuries to the head*	12 (6.7%)
Fatigue/low energy/feeling slowed down	11 (6.1%)
Neurologic symptoms	8 (4.4%)
Sleeping troubles	6 (3.3%)
Difficulty concentrating	3 (1.7%)
Visual problems	3 (1.7%)
Difficulty remembering things	1 (0.6%)
Additional symptoms	
Fever	28 (15.6%)
Diarrhea	26 (14.4%)
Abdominal pain	7 (3.9%)
Physical findings, *n* (%)	
GCS 15	180 (100%)
Altered mental status	2 (1.1%)
Palpable skull fracture	3 (1.7%)
Scalp hematoma	32 (17.8%)
Focal neurological signs	4 (2.2%)
Imaging, *n* (%)	
Head CT scan	23 (12.8%)
Abnormal findings	7 (30.4%)
Head X-ray	1 (0.6%)
Abnormal findings	1 (100%)
Disposition, *n* (%)	
Discharge within 4 h from ED assessment	136 (75.6%)
ED observation unit (4–24 h)	37 (20.6%)
Admission to the ward	7^ (3.9%)
Diagnosis, *n* (%)	
Head trauma–related complaints	97 (53.9%)
Gastroenteritis	44 (24.4%)
Minor infection	10 (5.6%)
Physiological evolution of external signs of trauma	10 (5.6%)
Abnormal cranial/intracranial imaging	8 (4.4%)
Other	11 (6.1%)

Note: Eight patients returned to the emergency department more than once for head trauma related signs and symptoms—only signs and symptoms at the first return visit are reported in the table

M male, *IQR* interquartile range, *GCS* Glasgow Coma Scale, *CT* computed tomography, *h* hours, *ED* emergency department

* Enlargement of previously noted scalp hematoma, change in consistency of the hematoma

^ Six patients were observed for ≤ 24 h in ED before admission to the ward

assessment. Nearly 40% presented with a scalp hematoma. Fifteen (8.3%) patients had normal findings on head CT scan. The majority of patients were discharged home within 4 h of assessment.

The reasons for the return visit, timing since initial visit, clinical findings, ED management, and disposition at time of the unscheduled revisit are reported in Table 2 for the overall sample of 180 patients. Supplementary Table S1 (Online Resource) presents stratified data by age group (≤ 2 years; 2 ≤ 10 years; > 10 years). All patients had a GCS score of 15 on representation with revisits occurring within 72 h since initial assessment for 81.1% of patients (median = 37.5 h). For the overall sample of 180 patients, the most frequent complaints at representation were nausea/vomiting (67.2%), headache (28.9%), abnormal behavior (10.6%), and balance problems (10%) (Table 2). Overall, 27.2% of patients presented one or more additional symptoms, namely fever, diarrhea, and abdominal pain. Younger children were significantly more likely to present nausea/vomit, abnormal behavior as per parents, diarrhea and abdominal pain than the older children (Table S1; Online Resource). In contrast, older children, were more likely to present headache, balance problems, neurological symptoms, visual problems, and difficulty in concentrating (Table S1; Online Resource).

Twenty-three (12.8%) of the 180 patients underwent head CT. In this subgroup of 23 patients, the most commonly reported symptoms were nausea and vomiting ($n = 13$), headache ($n = 7$), and balance problems ($n = 5$). With respect to signs, seven patients presented a non-frontal scalp hematoma and two patients had a palpable skull fracture. The number of symptoms/signs reported for each patient varied between zero and four. Seven patients who underwent head CT showed abnormal findings, including an isolated skull fracture, five intracranial injuries, and a stroke (Table 3). Some of these CT scan images are included in Fig. 2 as exemplary cases. A cranial X-ray was performed in one patient, and this demonstrated a skull fracture. A CT scan was not performed in this patient. None of these patients had undergone neuroimaging at the index visit nor had they been observed for more than 24 h at initial assessment. Patients' complaints at return visit included headache and vomiting, and/or development or enlargement of a scalp hematoma. The patient with a stroke finding on CT underwent a magnetic resonance imaging scan (Fig. 2 e and f) that confirmed the diagnosis of thalamic arterial ischemic stroke. She was a 5-year-3-month-old girl who initially presented with headache following a fall to the ground from standing; she was discharged home after less than 12 h of observation in the ED. The patient returned 24 h later for paresis of the right side of her body, persistent limb paresthesia and limping. After excluding this patient, the cases classified as ciTBI were two, as they met the criterion of hospitalization for two or more nights. None of the seven patients with abnormal CT results required neurosurgery or admission to the pediatric intensive care unit.

Table 3 Characteristics, management, and outcomes of patients with abnormal neuroimaging at re-presentation

PN	Age (years)	Sex	Mechanism of injury	CT performed at initial assessment	Symptoms/signs at initial assessment	Disposition at initial assessment	Time of representation	Physical findings and symptoms at representation	Injuries on neuroimaging (cranial CT)	Disposition at representation	Neurosurgery	Final diagnosis
1	0.4	M	Fall from height	No	Asymptomatic, frontal scalp hematoma	Observation > 12 h ≤ 24 h	48 h	Frontal boggy scalp hematoma, palpable skull fracture	Frontal fracture with small subdural hematoma	Observation	No	Intracranial traumatic lesion
2	0.8	M	Fall from height	No	Asymptomatic	Observation > 4 h ≤ 12 h	24 h	Non-frontal boggy scalp hematoma, palpable skull fracture, irritability	Isolated skull fracture	Observation	No	Isolated skull fracture
3	1.9	M	Fall from ground level	No	Asymptomatic, frontal scalp hematoma	Discharge ≤ 4 h	48 h	Nausea/vomiting	Small right frontal hemorrhagic lesion	Observation	No	Intracranial traumatic lesion
4	3.7	M	Head struck by high impact object	No	Headache, vomit, walking refusal, non-frontal scalp hematoma	Observation > 4 h ≤ 12 h	24 h	Non-frontal scalp hematoma, headache/balance problems	Occipital fracture with extradural hematoma	Admission (5 days)	No	Intracranial traumatic lesion
5	5.3	F	Fall from ground level	No	Headache	Observation > 4 h ≤ 12 h	24 h	Neurological focal signs—limp, paresis of right side of the body, paresthesia right superior limb	Left thalamic ischemic lesion	Admission (25 days)	No	Stroke
6	5.6	M	Fall from height	No	Acting abnormally, altered mental status, non-frontal scalp hematoma	Discharge ≤ 4 h	2 h	Nausea/vomiting	Small right temporal hemorrhagic lesion (3 mm)	Observation	No	Intracranial traumatic lesion
7	6.7	F	Sport-related	No	Headache, non-frontal scalp hematoma	Observation > 12 h ≤ 24 h	20 h	Non-frontal scalp hematoma, headache, fatigue	Temporal fracture with small subdural and epidural hematoma	Admission (2 days)	No	Intracranial traumatic lesion

PN patient number, *M* male, *F* female, *CT* computed tomography, *h* hours, *Obs* observation, *d* days

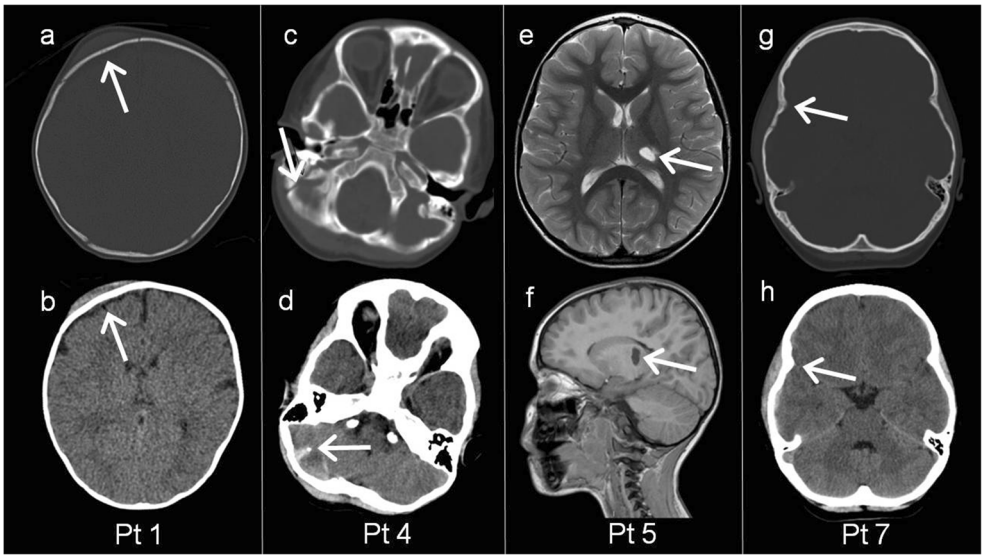

Fig. 2 Abnormal neuroimaging findings at re-presentation. CT scan images of patients 1 (**a**, **b**), 4 (**c**, **d**), and 7 (**g**, **h**), and T2-weighted (**e**) and 3D SENSE (**f**) MRI images of patient 5, obtained at re-presentation. White arrows indicate injury location. Patient details are reported in Table 3. *Abbreviation*: Pt = patient

Discussion

Our study showed that unscheduled pediatric ED revisits following an initial assessment for a mHT in EDs that implemented the PECARN rules were very infrequent and initially missed ciTBIs were rare. Furthermore, none of the children identified to have abnormal neuroimaging findings at the time of return visit required neurosurgery or admission to the intensive care unit. These findings corroborate the clinical validity of the PECARN head injury decision rule.

The percentage of overall mHT-related unscheduled revisits over a period of 5 years at two tertiary-level European pediatric EDs was lower than that reported in a recent study conducted in Israel (1.5% versus 4.5%) [22]. However, the Israeli study specifically focused on adolescents who were diagnosed with a concussion at the time of initial assessment, and did not refer to the implementation of the PECARN rules. A single center quality improvement project that implemented the PECARN TBI rules in the USA reported a slightly higher percentage of return visits (3%) within 72 h of initial ED evaluation over a 54-month period including both pre- and post-implementation phases [24]. None of the return visits required hospitalization. While in the North American study the mean CT rate decreased from 21 to 9% during the study period thanks to targeted quality improvement interventions, the mean CT rate was less than 10% in the EDs participating in the current study during the whole study period.

In our study, most children who represented to the ED were younger than 10 years of age. The majority of return visits occurred within 72 h and were due to nausea/vomit and headache. This may differ from the North American setting where the majority of pediatric patients seeking medical care following a mHT are preadolescents or adolescents sustaining a concussion, which may result in persistent post-concussion symptoms and possible need for clinical reassessment [26, 27]. In our study, the differences in sport practice (with contact sports such as American football, hockey, and rugby practiced less often), in access to primary care, as well as the lower age limit to access a pediatric ED may explain the young age of patients returning to the ED following a mHT. However, in the subgroup of patients older than 10 years of age the percentage of head trauma–related complaints, namely, post-concussive symptoms, was significantly higher compared with the younger age groups. While children of different age groups may experience different symptoms, the more developed expressive and language skills of older children allow them to better define their symptoms and help the clinician in making the diagnosis of post-concussive symptoms. Although validated tools are available to make the diagnosis of post-concussive symptoms in younger children, these were not available and used in clinical practice at the time the study was conducted [28]. In our study, the diagnosis of head trauma–related complaints in the younger age groups were attributed to head trauma by the treating clinicians when the symptoms, such as nausea/vomiting, abnormal behaviors as per parents, headache, and somnolence could not be attributed to other causes.

Most of the unscheduled return visits for mHT occurred within 72 h of initial assessment (81.1%), with 70% occurring within 48 h. All patients who were eventually diagnosed with an intracranial injury re-attended the ED within 48 h of initial assessment. None of these patients had a head CT scan at the index visit. The CT rate in patients who returned was slightly higher (12.8%) compared with the study centers usual CT rates for initial presentations. After the first 24 h following trauma, decision-making on neuroimaging is no longer supported by the PECARN rules, which were developed for children presenting within 24 h of their mHT. Recent evidence has shown that a ciTBI

may occur in 0.8% of delayed presentations (> 24 h) for mHT and that suspicion of depressed skull fracture and non-frontal scalp hematoma were significantly associated with both ciTBI and the presence of intracranial injury on CT [29]. In our study, two of the 23 patients who underwent CT scan at time of the return visit had a palpable skull fracture on physical examination and seven had a non-frontal scalp hematoma.

It should be noted that one of the patients with abnormal CT finding in our study was found to have a thalamic arterial stroke, which was confirmed by magnetic resonance imaging. She returned for right limp and hemiparesis. It is important to remember that head trauma, although rarely, could be the consequence of a central nervous system or cardiac condition rather than a primary event. This seemed the case for our patient, after a detailed review of the history of her injury.

Limitations

The results of our study should be interpreted in light of its limitations. First, the retrospective design limits the accuracy of data collection. Although a very sensitive search strategy was used to identify return visits for mHT in the electronic medical record systems, these were different in the study sites and the possibility exists that some records could have been missed by our search. Recommended strategies for retrospective data abstraction in emergency medicine were used to limit subjective interpretation and maximize accuracy of data collected from medical record review [25]. However, medical charts report unstructured information collected from the treating clinicians and some signs/symptoms may have not been reported.

While some of the patients initially assessed for mHT at the study centers could have gone to a different center and have been eventually diagnosed with an intracranial injury, we believe this could have been very unlikely to occur as both study centers are referral centers and parents are given detailed instructions on when to return to the same ED following their initial assessment for a mHT.

The lack of patient follow-up could have also affected the final diagnoses received on return visit, as it cannot be excluded that patients diagnosed with post-traumatic vomiting or headache could have in fact been attributed to an infectious cause. However, this does not change the main findings of our study.

Conclusions

Unscheduled return visits to pediatric EDs using the PECARN head injury decision rules are very uncommon and mostly involved children younger than 10 years of age. They mainly returned within 72 h due to nausea/vomiting and headache. Missed ciTBIs were rare and none required neurosurgery or hospitalization in the intensive care unit.

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Author contribution Conceptualization: Silvia Bressan, Liviana Da Dalt; methodology: Silvia Bressan, Liviana Da Dalt, Luigi Titomanlio; formal analysis and investigation: Silvia Bressan, Marta Arpone; writing—original draft preparation: Silvia Bressan, Marta Arpone, Liviana Da Dalt; writing—review and editing: Silvia Bressan, Paola Berlese, Marta Arpone, Ivan Steiner, Luigi Titomanlio, Liviana Da Dalt; resources: not applicable; supervision: Liviana Da Da Dalt, Ivan Steiner, Luigi Titomanlio.

Data availability The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval The study was approved by the Ethics Committee of the University Hospital of Padova and of the Robert Debré Hospital in Paris.

Consent to participate Waiver of participants' informed consent was approved by the study center's Ethics Committees, this being a retrospective study.

Consent for publication No identifiable data are included in our study.

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