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Should pediatric patients with isolated skull fractures be admitted, transferred, or discharged from the emergency department, and what are the economic consequences? Original series, systematic review of the literature, and a proposed admission protocol

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OBJECTIVE Pediatric head trauma is a common reason for emergency department (ED) referrals. Skull fractures are the most common imaging findings in the setting of pediatric trauma. Ample literature negates the necessity of hospitalization for neurologically intact children with isolated skull fractures (ISFs) and when nonaccidental injuries (NAIs) are not suspected. Despite this evidence, in many centers these children are still admitted for observation. The authors performed a retrospective analysis of the outcomes of children admitted with ISFs. A literature review of studies of children with ISFs was also performed. The objective of this study was to assess the necessity of admission of children with ISF.

METHODS A retrospective single-center analysis was performed, based on the electronic referral database of a tertiary pediatric hospital. Pediatric patients (< 18 years old) with a linear skull fracture on CT were included. Patients with additional traumatic intracranial findings on imaging (bleeding, pneumocephalus, edema, etc.) were excluded, as were patients with depressed, open, or displaced fractures. A systematic literature review of the Medline and PubMed databases was performed.

RESULTS Two hundred fifty-eight children met the criteria between 2019 and 2022. Eighty-one percent sustained a fall. Other mechanisms of injury included blunt-force trauma and road accidents, and 10.5% had an unclear mechanism. Most children had parietal fractures (56.3%), followed by occipital fractures and others. Sixteen percent suffered from chronic illnesses. No cases of growing skull fractures were noted. None of the children needed neurosurgical intervention. Moreover, none needed a follow-up CT scan. Three patients were transferred from a first-tier hospital to the authors' institution, none because of neurosurgical concerns. Other than these 3 patients, all other children were admitted to a pediatric ward for 24-hour observation and subsequently discharged. NAI was highly suspected in 7.1% of children (3/42) suffering from chronic illnesses as opposed to 1.4% (3/216) of healthy children. This difference was not statistically significant ($p = 0.056$). The literature review yielded 680 papers. After screening for relevance, language, etc., 8 original series with 5823 patients remained. One patient (0.017%) was operated on, but probably not for ISF. The cost difference between discharge from the ED and admission ranged between $520 and $4291 (US dollars). None of the children discharged from the ED returned for hospitalization.

CONCLUSIONS In this original cohort, none of the children had a change in management following their admission. None needed neurosurgical intervention. In children with linear ISFs, a short ED observation should be considered, followed by discharge based on neurological status. A proposed ED discharge protocol is presented.

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KEYWORDS admission protocol; nonaccidental injury; skull fractures; traumatic brain injury; trauma

ABBREVIATIONS ED = emergency department; EPR = electronic patient record; ER = emergency room; GCS = Glasgow Coma Scale; ISF = isolated skull fracture; NAI = nonaccidental injury; PECARN = Pediatric Emergency Care Applied Research Network; UK = United Kingdom.

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Head trauma is one of the most important causes of morbidity and mortality in the pediatric population.[1–6] However, many cases are mild traumatic brain injuries, with less than 1% needing neurosurgical intervention.[1,2,7] Skull fractures are the most common imaging findings in the setting of pediatric trauma, diagnosed in approximately 10% of the cases.[2,8,9]

There is ample literature that negates the necessity of hospitalization for neurologically intact children with isolated skull fractures (ISFs) and when nonaccidental injuries (NAIs) are not suspected.[2,3,8,10–12] Despite this evidence, in many centers across the world, these children are still admitted for observation and even transferred from primary care hospitals to tertiary centers with additional and perhaps unnecessary costs.[8,13,14] In this study, we analyzed the outcome of children with ISF admitted and/or transferred from first-tier facilities to a high-volume tertiary center. A review of the current literature was also conducted on admission and transfer of children with ISF, and an economic analysis was also performed to determine which patients might benefit from emergency department (ED) discharge/hospitalization.

Methods

Cohort Study

A retrospective cohort study was performed at a single tertiary pediatric center (Great Ormond Street Hospital for Children in London). The electronic patient record (EPR; a prospectively collected database) was used to access the records of all referrals made to the pediatric center from 2019 (prior to this date, there was no EPR system in place) to June 2022. Due to the unique nature of our medical center as a national center for a variety of pathologies, it does not contain an ED service. Referrals are received from regional hospitals in the designated catchment area. The decision to transfer a patient from the regional hospital to our center is based on the clinical decision of the neurosurgeon on call.

The primary endpoint was the necessity for neurosurgical intervention. The secondary endpoint was the request for transport by the neurosurgical team due to a neurosurgical cause. Pediatric patients (< 18 years of age) were included if they sustained a linear skull fracture as evidenced on a CT scan at the time of injury. Head CT scans were performed by the local referring hospitals when indicated.[15,16]

Patients were excluded if additional traumatic intracranial findings were found on imaging, such as intracranial bleeding, pneumocephalus, edema, and depressed, open, or displaced fractures. A subgaleal or subcutaneous hematoma was not a cause for exclusion.

Notes were reviewed on the EPR to record the mechanism of the injury, timing and location of the fracture, and any additional injuries sustained. NAI concerns of the referring hospital were collected, as well as if there were any complications or follow-up imaging required.

Systematic Review of the Literature

The literature review was performed in accordance with the PRISMA guidelines and checklist. The outcome sought out was the necessity for neurosurgical intervention in ISFs. Additional data were collected regarding hospitalization/ED discharge, economic consequences, and NAI. The literature search of children with ISFs was performed using the Medline and PubMed databases. Original papers between the years 2000 and 2022 in the English language were included. We excluded papers not addressing the topic, papers not involving pediatric patients, review papers, and papers that included radiological findings other than ISF without subgrouping. Search words included pediatric age (infant, child, etc.), linear fracture, admission, emergency room (ER, ED, etc.), and skull/brain CT/imaging. The screening process was conducted by two reviewers separately (I.B.Z., G.I.). Biases or limitations of each article were noted during the data collection process. Data on included and excluded papers, and on factors within these papers, were summarized using Microsoft Word and PowerPoint.

Statistical Analysis

Descriptive statistics were used for summarizing and presenting the data. The link between two categorical variables was tested using the chi-square test and/or Fisher's exact test. Calculations of statistical significance were determined with a confidence interval of 95% and an alpha level of 0.05. Ethical approval for the study was waived by the medical center's ethics committee due to the retrospective anonymous nature of the study.

Results

Cohort Study

A total of 258 children met the inclusion criteria from 2019 to 2022. The average patient age at presentation was 5 years (range 2 months to 17 years). The minimum follow-up period was 3 months (maximum 3 years). Table 1 outlines the demographic features of the study participants.

Need for Intervention

Of the 258 children with linear skull fractures, all but 1 were fully conscious (Glasgow Coma Scale [GCS] score of 15) at the time of referral. The one exception was a patient who underwent intubation and sedation due to postictal aspiration pneumonia. No patient deteriorated neurologically during admission, and none underwent a follow-up CT scan. No patient underwent neurosurgical intervention. Of the current cohort, no cases of growing skull fracture or sinus venous thrombosis were noted.

Three children were transferred from the first-tier hospital to our tertiary pediatric center, although they were not found to require any neurosurgical intervention. One child with learning disabilities involved in a road traffic accident was transferred due to difficulty performing a routine neurological examination in the referring hospital. The second child had a seizure that caused the fall. He was then intubated due to aspiration and was transferred because of lack of facilities in the referring hospital due to the COVID-19 pandemic. The third child was transferred for observation due to his underlying preinjury epilepsy

TABLE 1. Demographic features

Variable	Value (%)
No. of pts	258 (100.0)
Male sex	172 (66.7)
Children w/ chronic illness	42 (16.3)
Children referred from hospitals w/ no adult or pediatric neurosurgical facilities	201 (77.9)
Mean age at presentation ± SD, yrs	5.21 ± 3.87

Pt = patient.

for neurological observation and adjustment of medical treatment following a fall from height. Apart from these 3 children, the remaining children (n = 255/258) were admitted to the pediatric wards in their first-tier hospitals where they were observed for 24 hours and subsequently discharged with no further neurosurgical follow-up needed (follow-up was recommended to be conducted at the referring hospital).

Mechanism of Injury

Of the various mechanisms of injury reported in the current cohort, falls were the most common, accounting for 81% of the mechanisms reported. This was followed by blunt-force trauma, road accidents, and finally, mechanisms that were not clearly described (Fig. 1).

Fracture Location

Of the various fracture locations, the most common location was parietal fractures, accounting for more than half of the children (n = 130/231, 56.3%) in our cohort. This was followed by occipital fractures (n = 51/231, 22.1%), frontal and temporal fractures (n = 20/231, 8.7% each), and skull-base fractures (n = 10/231, 4.3%; Fig. 2).

Nonaccidental Injury

NAI was suspected as the underlying cause of injury in 6 (2.3%) of the 258 children with reported linear skull fractures. NAIs are usually suspected when some of the following factors exist: delays in seeking care, unknown mechanism of injury, injury inconsistent with reported mechanism, changing history upon questioning, injuries in other areas of the body, complex skull fracture, previous traumatic history, and prior involvement of child protective services.[8,17,18] Pediatric/safeguarding teams are highly involved in making these assessments, which are routinely performed in young children in the United Kingdom (UK).

When trying to ascertain a common denominator for children suffering from NAI, we found 3 (2 with epilepsy and 1 with learning disabilities) of 42 children bearing chronic conditions/illnesses with a diagnosis of NAI (7.1%), as opposed to only 1.4% (3/216) of children without chronic conditions. Fisher's exact test between the groups yielded a p value of 0.056, which was not statistically significant. However, it does show a trend toward more cases of NAI in children with chronic conditions.

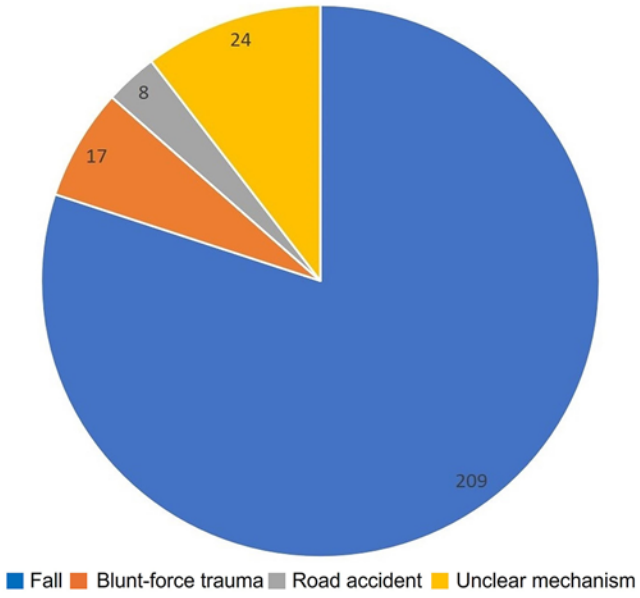

FIG. 1. Pie chart showing the four mechanisms of injury and the number of patients with each mechanism in the study cohort of 258 patients. Figure is available in color online only.

Systematic Literature Review

The initial literature search produced 680 articles. After screening for nonrelevant papers (papers not addressing the general topic, i.e., fractures or hemorrhages in other locations, other pediatric illnesses, nonpediatric patients, papers reporting skull radiographs, etc.), papers not in English, and duplicates, 48 papers remained. After

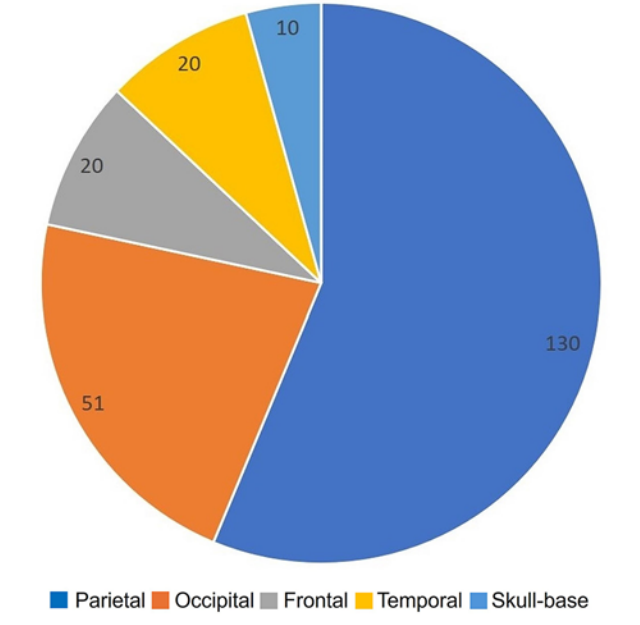

FIG. 2. Pie chart showing the location of skull fractures and the number of patients in each location. Figure is available in color online only.

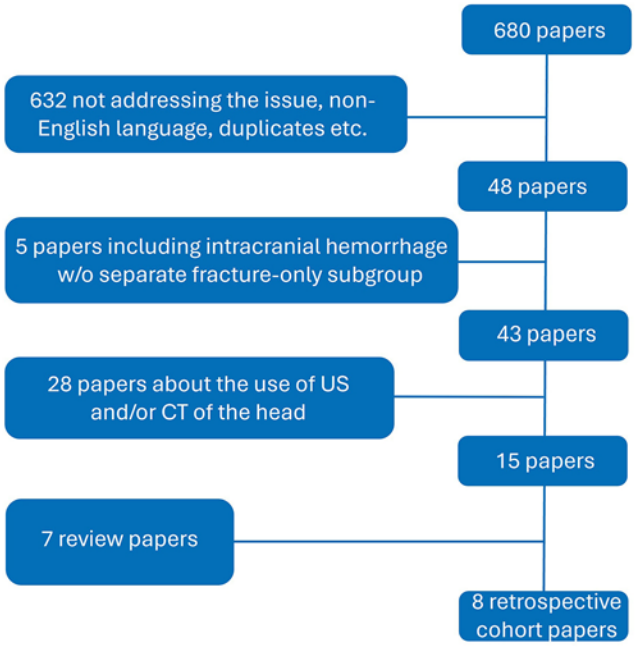

FIG. 3. Flowchart showing the initial literature screening. US = ultrasound. Figure is available in color online only.

further screening (Fig. 3) of patients with other imaging findings such as intracranial hemorrhage, papers addressing the issue of imaging modalities, and review papers, 8 original papers remained.[2,3,5,10–12,14,19] A summary of the papers is presented in Table 2.

A total of 5823 patients were assessed. All studies were retrospective, although some were based on prospectively collected data (as was our study), which might introduce a selection bias. Another possible source of this bias is that only 1 study stated that imaging was performed according to a preset protocol (Pediatric Emergency Care Applied Research Network [PECARN]).[19] One study stated that imaging was conducted at the discretion of ER doctors,[10] and the rest did not comment on this aspect.[2,3,5,11,12,14] Apart from 1 paper with a subsection on ISF,[3] the rest of the studies involved ISF only. All papers reported operative outcome.

Outcome

Of the 5823 patients evaluated, only 1 (0.017%) was operated on for a meningeal tear. This patient was from a multicenter study taken from a large database.[3] The authors stated that it was not possible to obtain more details and it was probably not an ISF. With the exception of this case, none of the children were operated on in the acute phase (although in some papers, children returned at a later stage for an operation for a growing skull fracture). In all studies but one, the majority of children were admitted for observation. None of the children who were discharged from the ED needed neurosurgical intervention, and none returned for hospitalization.

Nonaccidental Injury

Three papers reported suspicion or confirmation of NAI.[3,5,14] The percentage of confirmed NAI cases ranged between 1% and 11%. In the study by Mannix et al., it was stated in the context of NAI that 6% of the children younger than 18 months had additional fractures on skeletal radiography.[3]

TABLE 2. Literature review

Authors & Year	No of Pts	ISF Only	% of Pts Operated on (ISF)	% of Pts Discharged From ED	Recommendation for Discharge From ED*
Reuveni-Salzman et al., 2016[2]	222	Yes	0	0	Children w/ ISF may be considered for discharge from the ED
Mannix et al., 2013[3]	3915	Yes	Possible 0.02†	22	A shorter period of observation rather than admission could be considered for many pts w/ ISF
Arrey et al., 2015[5]	326	Yes	0	17	Hospitalization is not necessary for many children w/ nondisplaced ISF
Powell et al., 2015[10]	350	Yes	0	42.5	Children w/ ISF & normal neurology can safely be managed at home
Rollins et al., 2011[11]	235	Yes	0	24.7	Pts presenting w/ GCS scores of 15 & an ISF can be safely discharged from the ED
Blackwood et al., 2016[12]	71	Yes	0	22.5	Pts w/ ISF can be discharged safely from the ED w/o inpatient observation
White et al., 2016[14]	438	Yes	0	0	Not discussed
Tunik et al., 2016[19]	266	No‡	0	60	Children w/ isolated basilar skull fractures are candidates for discharge from the ED

All studies were retrospective. No patients had a negative outcome from ED discharge.
* Studies that recommend ED discharge do so for children with normal neurological examinations, no safeguard concerns, and to the care of adult competent caretakers.
† The study stated that the reason for the operation in the 1 patient who had undergone surgery was a meningeal tear; it was stated that it was possible that the child did not have an ISF.
‡ The study included patients with hemorrhage, but there was a subcategory of ISF within the study that is described in the table.

Economic Consequences

Six articles addressed the issue of economic consequences associated with ISF.[2,3,5,11,12,14] The cost difference between discharging patients from the ED and admitting them ranged between $520 and $4291 (US dollars). One paper by White et al. addressed only the issue of transfer of 438 patients with ISF from a first-tier to a third-tier medical center.[14] Transfer by ambulance cost $3467.5, while transfer by helicopter cost $11,569. None of these patients required a neurosurgical operation.

Transfer

Three papers addressed the issue of transfer of patients from peripheral hospitals to referral centers.[5,11,14] All proposed ED discharge for children with ISF and normal neurology, assuming no "red flags" are raised. In the study by Arrey et al.,[5] it was stated that none of the patients had any neurological deficits at the time of admission, and none required neurosurgical intervention, but this study did not address transfer patients alone. It did state, however, that many times the reason for transfer was the lack of confidence of the physicians in the referring centers, and there may be a need for further educating these physicians to avoid unnecessary transfers.

Skull Base Fractures

One paper specifically addressed the issue of skull base fractures.[19] In this paper by Tunik et al., only patients who had basilar fractures associated with other imaging findings were operated on. None of the ISFs in the skull base needed neurosurgical intervention. None of the patients who were discharged from the ED had acute adverse outcomes.

Discussion

In this retrospective cohort study, 258 children were evaluated following a minor head injury with an ISF on CT. As noted above, none of the children in this cohort underwent neurosurgical intervention. Three patients were transferred from a first-tier hospital to a tertiary center, none of them due to a neurosurgical cause. When examining the literature, the findings are similar, with only 1 case operated on from almost 6000 patients, and probably not due to an ISF.[2,3,5,10–12,14,19] Other meta-analyses and review studies have shown similar data.[6,8,17,20] Furthermore, hospitalization for neurologically intact children seems unnecessary and should be reserved for symptomatic children, suspicion of NAI, or children living in rural areas or with unreliable caregivers.[2,3,5]

None of the children in our series underwent follow-up CT scans during their 24-hour observation due to lack of clinical deterioration. In 1 meta-analysis, this issue was assessed with the recommendation of not performing routine CT scans during observation of children with ISF.[8]

NAI was the cause of the fracture in 2.3% of our patients. This result demonstrates that the actual rate of NAI cases is quite low, and after initial screening in the ED and once red flags are filtered, the vast majority of children will not fall into this category.[8] There appeared to be a higher percentage of NAI cases in children with chronic conditions, although this was not statistically significant. Perhaps this finding is due to the difficult psychological aspects of living with a child bearing a chronic disease. The importance of safeguarding/pediatric teams assessing for NAI, however, cannot be overstated as missing this diagnosis can have profound consequences.

We did not assess economic consequences in our original series, but when considering the relevant literature, the economic gain from ED discharge is significant.[2,3,5,11,12] Moreover, it appears that transfer of these children to a tertiary center for neurosurgical evaluation is unnecessary.[11,14] Similar to our study, some of the transfers in other studies were due to lack of pediatric resources (such as a pediatric intensive care unit) in the referring centers.[11]

As operative concerns of children with isolated linear fractures in the acute period seem unlikely, reasons for admission for observation may include NAI concerns and workup as well as positive symptomatology, such as a GCS score < 15 or an abnormal neurological examination. Another possible reason for admission is uncontrollable emesis. If the child is vomiting continuously and a concern arises about oral fluid intake, this may constitute another reason for admission. Other specific patient-oriented issues may obligate admission, such as adjusting the levels of antiepileptic drugs.

As a result of our original series and the literature review, we have constructed a protocol for the ED management of children with ISF (Fig. 4). This protocol has already been implemented in the center (Schneider Children's Medical Center of Israel) of one author (I.B.Z.).

Limitations of the Study

Our original series is retrospective in nature. All the papers found in the literature review are also retrospective, which may introduce a selection bias and limit the strength of our conclusions. Moreover, only two sources of information were used; however, the large number of children assessed in total (nearly 6000 patients), with all papers arriving at the same conclusions, generates more confidence in our conclusions. The registry is composed of children referred to our medical center, which might create a selection bias because there might have been children admitted to the local hospital without our knowledge. Nonetheless, it is obligatory to seek a neurosurgical consultation for skull fractures in the UK, so this would be unlikely. Moreover, if this did occur, it would mean the child was probably doing extremely well and not in need of neurosurgical care. We did not assess these children long term due to the way the system is organized in the territory of the tertiary center, but the purpose of this study was not to address the issue of long-term outcome of children with ISF, only their short-term management.

Conclusions

In children suffering from an ISF, who are neurologically intact, discharge from the ED after a short observation period may be considered. An ED management

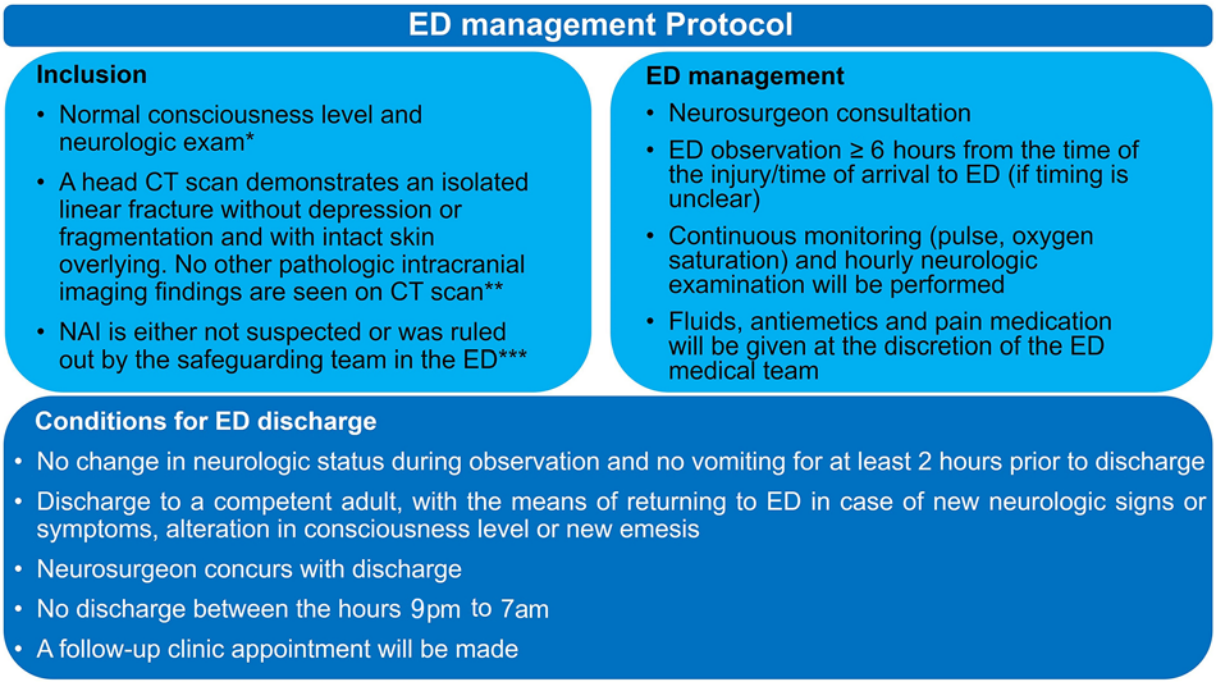

FIG. 4. ED management protocol for children with ISFs. *As well as without clinical suspicion of a CSF leak and without other significant injuries or chronic illnesses. **CT scan was performed according to the PECARN criteria. Other findings might include, but are not limited to, pneumocephalus, intracranial hemorrhage, brain edema, suspected sinus vein thrombosis, or CSF leak. ***NAI is particularly considered in the following situations: delays in seeking care, unknown mechanism of injury, injury inconsistent with reported mechanism, altering history upon questioning, injuries in other areas of the body, complex skull fracture, previous traumatic history, and prior involvement of child protective services. Figure is available in color online only.

protocol is proposed. Further prospective study will be important to assess this protocol.

Acknowledgments

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Ben Zvi. Acquisition of data: Imtiaz. Analysis and interpretation of data: Ben Zvi. Drafting the article: Ben Zvi, Imtiaz, Piper. Critically revising the article: Ben Zvi, Piper, Tisdall. Reviewed submitted version of manuscript: Piper, Tisdall. Approved the final version of the manuscript on behalf of all authors: Ben Zvi. Statistical analysis: Ben Zvi, Imtiaz. Administrative/technical/material support: Piper. Study supervision: Piper, Tisdall.

Supplemental Information

Previous Presentations

An abstract of the original cohort study was presented as an oral presentation at the 48th International Society for Pediatric Neurosurgery meeting in Singapore, December 6–10, 2022.

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