

Isolated Linear Skull Fractures in Children With Blunt Head Trauma

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abstract

BACKGROUND AND OBJECTIVE: Children and adolescents with minor blunt head trauma and isolated skull fractures are often admitted to the hospital. The objective of this study was to describe the injury circumstances and frequency of clinically important neurologic complications among children with minor blunt head trauma and isolated linear skull fractures.

METHODS: This study was a planned secondary analysis of a large prospective cohort study in children <18 years old with blunt head trauma. Data were collected in 25 emergency departments. We analyzed patients with Glasgow Coma Scale scores of 14 or 15 and isolated linear skull fractures. We ascertained acute neurologic outcomes through clinical information collected during admission or via telephone or mail at least 1 week after the emergency department visit.

RESULTS: In the parent study, we enrolled 43 904 children (11 035 [25%] <2 years old). Of those with imaging studies, 350 had isolated linear skull fractures. Falls were the most common injury mechanism, accounting for 70% (81% for ages <2 years old). Of 201 hospitalized children, 42 had computed tomography or MRI repeated; 5 had new findings but none required neurosurgical intervention. Of 149 patients discharged from the hospital, 20 had repeated imaging, and none had new findings.

CONCLUSIONS: Children with minor blunt head trauma and isolated linear skull fractures are at very low risk of evolving other traumatic findings noted in subsequent imaging studies or requiring neurosurgical intervention. Hospital admission for neurologically normal children with isolated linear skull fractures after minor blunt head trauma for monitoring is typically unnecessary.

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WHAT'S KNOWN ON THIS SUBJECT: Many children with blunt head trauma and isolated skull fractures are admitted to the hospital. Several small studies suggest that children with simple isolated skull fractures are at very low risk of clinical deterioration.

WHAT THIS STUDY ADDS: In this large cohort of children with isolated linear skull fractures after minor blunt head trauma, none developed significant intracranial hemorrhages resulting in neurosurgical interventions. These children may be considered for emergency department discharge if neurologically normal.

Although blunt head trauma is common in children and adolescents, the highest rates of emergency department (ED) visits are among children 0 to 4 years old (~1000 per 100 000 annually).¹ Isolated skull fractures (defined by the lack of any other traumatic findings on cranial imaging) occur in a subset of these children. For older children and adults, the literature suggests that patients with isolated skull fractures can appropriately be managed as outpatients.²⁻⁴ For younger children, there are no clear guidelines for management and many are hospitalized for observation.

Population-based epidemiologic data demonstrate children in the first year of life have high rates of skull fractures when compared with all other children.⁵ Hospital data also show that head injuries resulting in admission to the hospital are relatively frequent in children aged 0 to 4 years (80 per 100 000 annually).¹ Several retrospective reports have shown that young children with isolated skull fractures generally have uncomplicated clinical courses, but these data have not been confirmed in a rigorous prospective study.⁶⁻⁹ Information about current practice patterns suggests that there is significant variation among institutions and many young children with isolated skull fractures are admitted to the hospital.¹⁰

The purpose of the current study was to determine (1) the incidence of neurologic deterioration resulting in neurosurgical intervention and (2) the incidence of traumatic findings on follow-up imaging studies among children <18 years old with isolated linear skull fractures managed in the ED. We hypothesized that children with isolated linear skull fractures and normal mental status in the ED would neither demonstrate clinical deterioration requiring neurosurgical intervention nor develop new intracranial findings if repeat imaging were performed.

METHODS

This study was a planned secondary analysis of a large prospective cohort study in children <18 years old with blunt head trauma, conducted in 25 EDs in the Pediatric Emergency Care Applied Research Network (PECARN) from June 2004 through September 2006. Study methods for the cohort study have been previously described,¹¹ and methods specific to the current subanalysis are described below.

Selection of Participants

Eligible patients presented within 24 hours of injury and had cranial computed tomography (CT) scans or skull radiographs performed during their ED evaluation. All imaging was obtained at the discretion of the treating physicians. We excluded children with trivial injuries defined as surface-level falls or collisions with stationary objects from walking or running with no signs (other than abrasions/lacerations) or symptoms of head trauma. Children with trivial injury mechanisms who had headaches, vomiting, or scalp hematomas or other such signs or symptoms of head trauma were included. Children with Glasgow Coma Scale (GCS) scores <14 and those with signs of basilar skull fractures (retroauricular bruising, periorbital bruising, hemotympanum, cerebrospinal fluid otorrhea, or cerebrospinal fluid rhinorrhea) were excluded. Those with ED imaging showing intracranial injuries other than isolated linear skull fractures (ie, >1 fracture, basilar skull fractures, depressed skull fractures, extraaxial hematomas, subarachnoid or intraventricular hemorrhage, cerebral hemorrhage/contusion or edema, diffuse axonal hemorrhage, pneumocephalus, or traumatic diastasis) were excluded as well. Children were also excluded from analysis if they had comorbidities, including brain tumors, preexisting neurologic disorders complicating assessments, ventricular shunts, or

bleeding disorders. All children in the analytic cohort had isolated linear skull fractures.

Mechanisms of Injury, Clinical Histories and Symptoms, and Imaging

The treating physician recorded the mechanism of injury and clinical information by using a standardized case report form before receiving any information about imaging results. Mechanisms of injury included the following: occupant in a motor vehicle collision; pedestrian struck by a motor vehicle; bicycle rider struck by a motor vehicle; bicycle collision or fall; other wheeled transport crash (motor/nonmotor designated); fall to ground while either standing, walking, or running; walked or ran into a stationary object; fall from a height (distance estimated); fall down stairs; sports related; assault; head struck by moving object; and other.

Clinical information collected included history of loss of consciousness (LOC; with estimated duration in seconds/minutes), posttraumatic seizure, amnesia, headache, vomiting, dizziness, and parent perception of general appearance (ie, whether patient was behaving normally). Physicians recorded the following physical examination findings relevant to head trauma: GCS score, other signs of altered mental status, signs of basilar skull fracture, palpable skull fractures, scalp hematoma, neurologic deficits, and suspected alcohol or drug intoxication. We defined neurologically normal as a GCS score of 15 and no other signs of altered mental status (eg, agitated, having repetitive questions in the ED, sleepy, or being slow to respond). Other documented clinical information included lacerations, abrasions, or hematomas of the head or neck and other noncranial trauma. We recorded the final dictated attending radiologist report as the imaging result. A study radiologist (S.W.-G.)

adjudicated any nonconclusive interpretations. To identify children with potentially missed traumatic brain injuries, research coordinators performed standardized telephone interviews with guardians of patients discharged from the ED between 7 and 90 days after the ED visit using a standardized survey instrument. Medical records and imaging results were obtained if a child with a missed traumatic brain injury was suggested at follow-up. If the research coordinator failed to reach the guardian for telephone follow-up, we reviewed the medical records, process improvement records, trauma registries, and county morgue reports to ensure that we did not miss any patients with clinically important traumatic brain injuries.¹¹

Outcome Measures

The main outcomes of interest were new traumatic findings on subsequent cranial CT or MRI, if performed, and neurologic deterioration resulting in neurosurgical intervention (eg, craniotomy, ventricular drainage). Children with no repeated neuroimaging and no follow-up information suggestive of neurologic complications were assumed to be without intracranial injuries.

Analysis

We reported the study population using descriptive statistics of counts, percentages, and 95% confidence intervals (CIs) as appropriate. We stratified our reporting into the following age groups: (1) <2 years old and (2) 2 to 17 years old (ie, until their 18th birthday). We determined the rates of new traumatic findings on repeat imaging (if performed) and neurosurgical interventions among children with isolated linear skull fractures present on initial imaging in the ED. We used the Wilson method to generate 95% CIs for proportions and performed comparisons of proportions using the χ^2 test. We considered *P* values <.05 to be

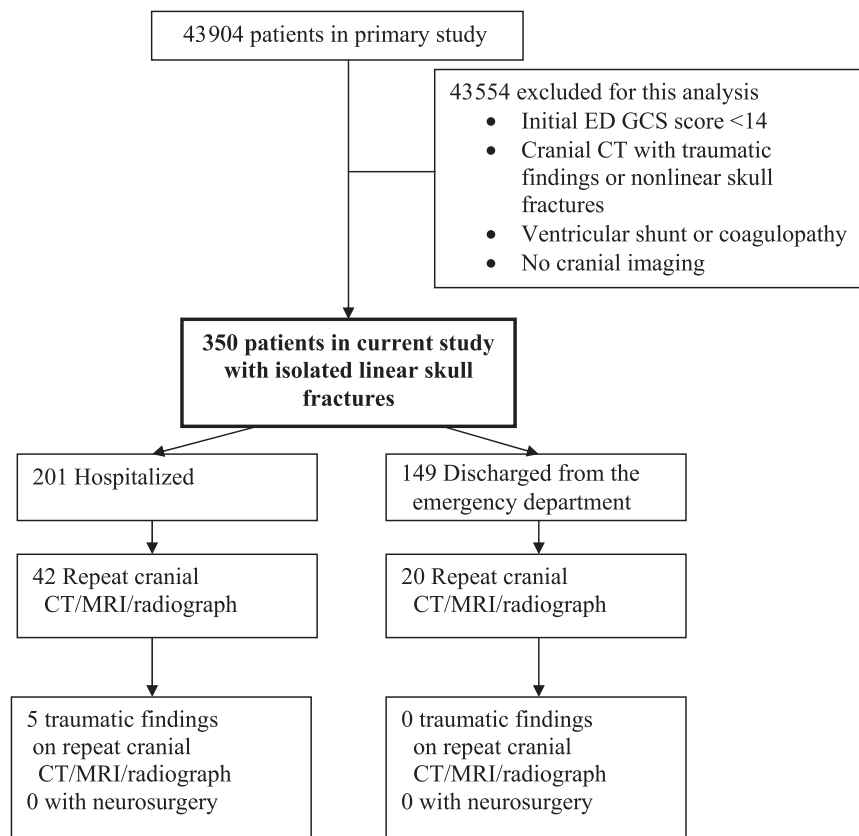
significant. We performed the data analysis by using SAS statistical software, version 9.2 (Cary, NC), and Stata statistical software (release 12.0; College Station, TX).

RESULTS

In the parent study we enrolled 43 904 (77%) of 57 030 eligible patients; 11 035 (25%) were younger than 2 years old. Figure shows information about the patients enrolled in the parent study and the current subanalysis, all of whom had GCS scores of 14 or 15. A total of 350 children with head trauma and isolated linear skull fractures identified on cranial imaging were included in the current subanalysis; 310 were identified by CT scans, 10 were identified on plain skull radiographs (with normal CT scans),

and 30 had both CT and a skull radiograph that showed the fracture. In the parent study, cranial CT scans were obtained for 14 969 patients, of whom 780 (5.2%; 95% CI: 4.9%–5.6%) had visible traumatic brain injuries.

The median age of children with isolated skull fractures was 10 months old. Two hundred twenty-two (63%) of the 350 children were younger than 2 years old, and 128 were 2 to 17 years old. Two hundred eight (59%) were boys. The initial GCS scores were 15 in 297 children (85%). Injury mechanisms for children with isolated linear skull fractures in each age group are shown in Table 1. Falls were the most common injury mechanism, particularly among younger children. Most falls were from low heights, including falls to the ground that



FIGURE

Study patient flow. Among the patients discharged from the ED, 79% were reached by telephone or mail survey. For the remainder, we reviewed the medical records, process improvement records, trauma registries, and morgue records to identify children with missed injuries.

TABLE 1 Injury Mechanism by Age Group

	<2 Years Old (<i>n</i> = 222)	2–17 Years Old ^a (<i>n</i> = 128)
Falls (total) ^b	180 (81)	62 (48)
From standing, walking, or running	8 (4)	11 (9)
From height <3 feet	58 (26)	13 (10)
From height 3–5 feet	86 (39)	14 (11)
From height 6–10 feet	5 (2)	16 (13)
From height >10 feet	1 (0.5)	4 (3)
From unknown height	1 (0.5)	1 (1)
Down stairs		
≤5 stairs	8 (4)	1 (1)
≥6 stairs	12 (5)	2 (1.6)
Unknown number of stairs	1 (0.5)	0
Walked or ran into stationary object	1 (0.5)	3 (2)
Head struck by object, accidental	2 (1)	5 (4)
Head struck by object, assault	1 (0.5)	6 (5)
Bicycle collision or fall	1 (0.5)	7 (5)
Bicycle hit by motor vehicle	0	2 (1.6)
Other wheeled transport crash, motorized	0	5 (4)
Other wheeled transport crash, nonmotorized	1 (0.5)	1 (1)
Pedestrian struck by vehicle	2 (1)	10 (8)
Occupant in motor vehicle collision		
Restrained	2 (1)	4 (3)
Unrestrained	1 (0.5)	3 (2)
Restraint use not documented	1 (0.5)	2 (1.6)
Sports related	0	5 (4)
Other mechanism	18 (8)	12 (9)
Unknown mechanism	12 (5)	1 (1)

Data are presented as *n* (%).

^a Until 18th birthday.

^b Fall versus other injury mechanism by age group, *P* < .01.

occurred when children were standing, walking, or running. Falls down stairs were a more frequent mechanism among children <2 years old versus those who were ≥2 years old (*P* < .01).

There were differences in patient histories and physical examination findings by age group. The frequency of histories of LOC differed significantly between the <2-year-old group (8 of 197; 4%) and the older group (37 of 115; 32%) (*P* < .001), as did histories of vomiting (age <2 years [29 of 217; 13%] versus age 2 to 17 years [54 of 127; 43%]; *P* < .001). Children <2 years old (183 of 222; 82%) more often had scalp hematomas compared with those aged 2 to 17 years (82 of 128; 64%) (*P* < .001).

There were 201 children admitted to the hospital (Fig, Table 2). Among children <2 years old, the parental description that the child was not acting normally was significantly

associated with admission (admitted, 33%; 95% CI: 24%–41%; discharged, 16%; 95% CI: 8%–23%; *P* < .01). There were no other significant differences in history or physical findings between children admitted and those discharged from the ED among children <2 years old. For children aged 2 to 17 years, vomiting was significantly associated with admission (admitted, 53%; 95% CI: 41%–64%; discharged, 26%; 95% CI: 14%–40%; *P* < .01); there were no other history or physical findings associated with disposition.

Of the 201 children hospitalized, 42 had repeat imaging studies performed and 5 showed evolution of (new) traumatic findings. These included the following: (1) a 1-month-old with a fall from <3 feet with an initial head CT reading of a left parietal skull fracture and a subsequent CT with a small subdural hematoma, (2) a 2-year-old who fell down >15 stairs who had an

initial CT scan revealing a large right parietal skull fracture and a subsequent CT with an extraaxial hematoma, (3) a 2-year-old with a fall from <3 feet with an occipital fracture with a subsequent CT showing a cerebral contusion, (4) an 11-year-old involved in a skateboard crash with an occipital fracture with a subsequent CT showing punctate intracranial hemorrhages, and (5) a 15-year-old involved in an assault with an initial head CT showing an occipital fracture and a subsequent CT showing small parenchymal hemorrhages. None of these patients required neurosurgery (Table 3). The 95% CI around the observed event rate of 0 in 350 is 0% to 1%. Among the 149 children with isolated linear skull fractures who were discharged home from the ED (Fig), 20 had repeat cranial imaging after discharge; no additional traumatic findings were detected on any of these imaging studies. There were no significant differences between the age cohorts in the proportion of children discharged to home from the ED. Telephone or mail follow-up was successful for 79% of patients who were discharged from the ED, and the rest had the other follow-up procedures, which included medical record review, process improvement record review, trauma registry review, and morgue record review. None of the patients with isolated linear skull fractures in the ED who were discharged to home had subsequent neurologic deterioration.

DISCUSSION

In this large prospective study, we demonstrated that children with minor blunt head trauma and isolated linear skull fractures demonstrated on cranial imaging obtained in the ED are at very low risk of neurologic deterioration resulting in a neurosurgical procedure. Although 5 of 350 patients had subsequent imaging that revealed new intracranial findings, none were managed with

TABLE 2 History and Physical Examination Findings by Age Group: Admitted Versus Discharged

	<2 Years Old		2–17 Years Old ^a	
	Admitted (n = 120)	Discharged (n = 102)	Admitted (n = 81)	Discharged (n = 47)
History of LOC	5/104 (5)	3/93 (3)	26/71 (37)	11/44 (25)
Headache ^b	—	—	38/52 (73)	26/39 (67)
History of vomiting	16/117 (14)	13/100 (13)	42/80 (53)	12/47 (26)
>2 times	4 (3)	2 (2)	22 (27)	9 (19)
Dizziness ^b	—	—	11/43 (26)	5/35 (14)
Posttraumatic seizure	2/115 (2)	0/99 (0)	2/80 (3)	3/46 (7)
Posttraumatic amnesia ^b	—	—	15/46 (33)	6/34 (18)
GCS of 15	97 (81)	93 (91)	65 (80)	42 (89)
Altered mental status ^c	39/119 (33)	15 (15)	41/80 (51)	15 (32)
Not acting normally per parent	37/113 (33)	15/96 (16)	32/71 (45)	17/45 (38)
Palpable skull fracture or unclear exam	35/119 (29)	26 (25)	6 (7)	6 (13)
Scalp hematoma	95 (79)	88 (86)	54 (67)	28 (60)
Small (<1 cm, barely palpable)	11 (9)	7 (7)	5 (6)	4 (9)
Medium (1–3 cm)	38 (32)	41 (40)	28 (35)	11 (23)
Large (>3 cm)	41 (34)	38 (37)	17 (21)	12 (26)
Undocumented size	5 (4)	2 (2)	4 (5)	1 (2)
Frontal	11 (9)	10 (10)	12 (15)	9 (19)
Occipital	15 (13)	22 (22)	23 (28)	9 (19)
Temporal/parietal	68 (57)	56 (55)	16 (20)	10 (21)
Undocumented location	1 (1)	0	3 (4)	0
Neurologic deficit	2/116 (2)	0/100 (0)	1/80 (1)	1/46 (2)

Data are presented as n (%). Symptoms and signs based on the time of initial ED evaluation; denominators were provided in each cell if some data were not available.

^a Until 18th birthday.

^b Headache, dizziness, and posttraumatic amnesia not assessed in preverbal patients (n = 120).

^c Any versus none.

neurosurgery. The data suggest that hospitalization for monitoring and ongoing neurologic examinations is not necessary for most children with isolated linear skull fractures and normal mental status examinations after minor blunt head trauma. With very uncommon exceptions, children of all ages meeting these criteria can safely be managed at home with a reliable caretaker.

Previous research evaluating the need for hospital admission among children with minor blunt head

trauma and isolated linear skull fractures has been limited by the small numbers studied in single centers, use of retrospective designs, or analysis of administrative databases that are less useful for identifying complications.^{6–10,12–14} The prospective design and large sample size of the current study enabled us to report the risk of deterioration and need for neurosurgical intervention with precision. The data also include a large number of children <2 years old in whom skull fractures are

common and mental status assessment may be difficult, resulting in greater uncertainty about the optimal management strategy.

Our data about the height of a fall are notable for the number of fractures associated with falls from low heights, particularly in younger children. Among those <2 years old, falls from <3 feet, including surface falls, were the mechanisms of injury for 30% of those diagnosed with skull fractures. Other reports have similarly documented fractures resulting from low-height falls in children <2 years old.^{7,15,16}

Fractures resulting from falls involving stairs were also more common among children <2 years old (9% of injury mechanisms) and were infrequent in the older age cohort. This frequency is somewhat lower than the 30% reported for a similar age cohort, likely reflecting data source differences.⁷

History and physical examination findings differed in children <2 years old compared with the older cohort.

TABLE 3 Outcome Measures

Variable	<2 Years Old (n = 222)	2–17 Years Old ^a (n = 128)
ED disposition		
Home	102 (46)	47 (37)
Neurosurgery	0 (0)	0 (0)
Repeat imaging		
CT	27 ^b (12)	27 ^c (21)
Radiograph	6 (3)	1 (1)
MRI	0 (0)	2 (2)

Data are presented as n (%). All 5 patients listed in footnotes b and c with evolution of new CT findings were hospitalized.

^a Until 18th birthday.

^b Includes 1-month-old with left parietal skull fracture, new finding of small subdural hematoma.

^c Includes 2-year-old with right parietal skull fracture, new finding of extraaxial hematoma; 2-year-old with occipital fracture, new finding of cerebral contusion; 11-year-old with occipital fracture, new finding of punctate intracranial hemorrhages; 15-year-old with occipital fracture, new finding of small parenchymal hemorrhage.

Only 4% of children <2 years old had a reported history of LOC and 13% had histories of vomiting, which is significantly less frequent than observed among the older children. These data suggest that young children with isolated skull fractures may lack clinical symptoms typically associated with head trauma and observed in older children. Although scalp hematomas were common among younger children, their accuracy for predicting intracranial injuries, including fractures, has been shown to be limited.^{7,15,17}

Consensus guidelines suggest that children <2 years old with isolated simple skull fractures and no associated intracranial injuries on CT can be considered for ED discharge.¹⁸ This strategy has also been advocated for older children.¹³ National data from children's hospitals suggest that most children with isolated skull fractures are admitted to the hospital.¹⁰ Two retrospective single-center studies including children with isolated skull fractures suggested that those with presenting GCS scores of 15 and isolated skull fractures can safely be discharged from the ED.^{8,9} The current study adds to this literature and strengthens the previously published consensus guidelines because it includes a large sample of children of all ages from multiple centers with prospective follow-up. In the data we report, the 95% CI around the rate of neurosurgery, 0 in 350, was 0% to 1%. The collection of additional prospective data among children with isolated linear skull fractures would be useful to more precisely define the rate of neurosurgery, although a prospective study larger than the current study is unlikely to be conducted. It is important that all children with head trauma be discharged to a reliable caretaker and have clear return-for-care criteria. However, because the rate of potential complications is quite low, these data may help to change hospital admission patterns at institutions in which management is more conservative.

This study had some limitations. Because head CTs were obtained at the discretion of the treating physicians, many patients enrolled in the parent study were not imaged. Because it was likely that higher-risk patients received neuroimaging, our reported prevalence of findings on CT is likely higher than that for the general population of children with minor blunt head trauma. In addition, most patients who had skull fractures identified on the CT scans performed in the ED did not have a second CT scan, so it is possible that there were additional traumatic findings that were missed. Nonetheless, by means of detailed follow-up procedures, we identified no patients who required neurosurgical intervention among any of the patients, and no patients discharged from the ED experienced neurologic deterioration. Therefore, the clinical importance of identifying additional traumatic findings by imaging is not clear. Although follow-up was completed for most patients, it is possible that some children who were lost to follow-up had traumatic findings managed at a hospital that was not involved in the study. Because the PECARN sites are the primary trauma centers of the region, however, this is unlikely. We did not assess long-term neurocognitive function in study patients because the goal of this study was to assess for acute outcomes. However, brain injuries may occur despite normal head CT or MRI scans; therefore, for some, follow-up for postconcussive symptoms is likely needed. Management decisions, including admission and follow-up imaging, may be affected by clinicians' concerns about possible child abuse. Although information about assault was collected in the ED, information specific to suspicion about child abuse was not collected from inpatient records in this study. Often there is uncertainty in differentiating accidental from inflicted injury at the time of the initial evaluation in the ED, so patients with child abuse may have been underreported here. It is

incumbent on physicians to ascertain that there is a clear and rational history of the injury event and to complete a careful physical examination.

CONCLUSIONS

Children with minor blunt head trauma, initial ED GCS scores of 14 or 15, and isolated linear skull fractures are at very low risk of clinical deterioration and need for neurosurgical intervention. New findings on follow-up CT or MRI scans are rare. Our data suggest that neurologically normal children with isolated linear skull fractures after minor blunt head trauma do not typically warrant inpatient observation and can safely be discharged from the hospital after ED evaluation to reliable caretakers and a safe environment with strict discharge instructions and return precautions.

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