Diagnostic Testing for Acute Head Injury in Children: When Are Head Computed Tomography and Skull Radiographs Indicated?

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ABSTRACT. *Objective.* **Despite the frequent occurrence of head injury in children, there is no agreement about clinical screening criteria that indicate the need for imaging studies. This study was undertaken to provide information relevant to the choice of imaging modalities in children with acute head trauma.**

Methodology. **A prospective cohort of 322 children seeking care consecutively in an urban pediatric emergency department for nontrivial head injury was assembled. Skull radiographs, head computed tomography, and data forms including mechanism of injury, symptoms, and physical findings were completed for each child.**

Results. **Intracranial injury occurred in 27 children (8%), whereas 50 (16%) had skull fractures. Of those with intracranial injury, 16 (59%) had normal mental status and no focal abnormalities, and 1 of those 16 required surgery for evacuation of an epidural hematoma. Six (38%) of the 16 were younger than 1 year, 5 of whom had scalp contusion or hematoma without other symptoms. Findings not significantly associated with intracranial injury were scalp contusion, laceration, hematoma, abrasion, headache, vomiting, seizure, drowsiness, amnesia, and loss of consciousness for less than 5 minutes. Findings associated with intracranial injury were skull fracture, signs of a basilar skull fracture, loss of consciousness for more than 5 minutes, altered mental status, and focal neurologic abnormality.**

Conclusions. **Intracranial injury may occur with few or subtle signs and symptoms, especially in infants younger than 1 year. The relative risk for intracranial injury is increased almost fourfold in the presence of a skull fracture, although the absence of a skull fracture does not rule out intracranial injury. The significance of nonsurgical intracranial injury in neurologically normal children needs further study.** *Pediatrics* **1997;99(5). URL: http://www.pediatrics.org/cgi/content/full/99/5/e11;** ***brain injuries, head injuries, skull fractures, computed tomography, radiography.***

ABBREVIATIONS. CT, computed tomography; OR, odds ratio; GCS, Glasgow Coma Scale.

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Brain injury is the leading cause of death and disability in pediatric trauma victims.[1–4] Head injuries in children account for 250 000 hospital admissions each year, whereas nearly 5 million children present to hospital emergency departments seeking evaluation and care of head injuries.[5,6] The morbidity and mortality associated with significant intracranial injury may be ameliorated by early diagnosis and treatment.[7–10]

Despite the frequent occurrence of head injury in children, diagnostic strategies differ among individuals and institutions. Skull radiographs have been used as part of the evaluation for children with head trauma, yet their value remains controversial.[11–13] Head computed tomography (CT) has become the diagnostic method of choice for identification of intracranial disorders in patients with head trauma.[14] However, CT is expensive, not always readily available, sometimes requires sedation of the patient, and always requires skilled interpretation. A defined set of clinical screening criteria for the evaluation of head injury does not exist for children but would be valuable in the decision-making process.

Few prospective studies have addressed radiographic diagnosis of head trauma exclusively in children. These prospective studies have examined the value of imaging in a series of patients selected for head CT on the basis of unspecified criteria.[15,16] The purpose of this study was to evaluate clinical features associated with head injury that impact the decision to obtain imaging studies using prospective data collection and predetermined selection criteria.

METHODS

A prospective cohort of children with mild, moderate, and severe nonpenetrating head injuries received standardized evaluation to collect consistent, relevant clinical information in the form of patient history, physical examination, and imaging studies. This protocol was approved by the institutional review board at Washington University School of Medicine. From May 1 to October 31, 1993, data were collected prospectively about children seeking care in the emergency department at St Louis Children's Hospital for nontrivial head injury.[17] All patients younger than 18 years who presented to the emergency department with histories or physical findings of nontrivial head injury were eligible for the study. Children with penetrating injuries to the head were excluded from the study.

Patients with nontrivial head injuries were defined as children of any age who had symptoms related to head injury such as headache, amnesia, vomiting, drowsiness, loss of consciousness, seizure, and dizziness or significant physical findings, including altered mental status, neurologic deficit, and altered surface anatomy. A scalp laceration, contusion, or abrasion was considered a significant physical finding only in infants younger than 12

months; a scalp hematoma was considered a significant finding in children younger than 24 months.

Children with trivial head injuries (those without symptoms or significant physical examination findings) were not included in the study. In previous studies, scalp abrasions, lacerations, contusions, and hematomas as the only physical findings in older children and adults have not been associated with intracranial injury.[5,18] Children younger than 1 year, however, often have been excluded in prior studies examining clinical features predictive of intracranial injury. In addition, one study has suggested that scalp hematomas in children younger than 2 years may be predictive for serious injury.[19] For this reason, children younger than 1 year with any alterations in surface anatomy as their only findings were included in our study. Furthermore, children between the ages of 12 and 24 months with scalp hematomas as their only findings were included.

The emergency physician who evaluated the patient completed a standard data collection form at the time of the visit. The survey questions included demographic and identification information, injury history information (mechanism of injury, use of safety devices, and patient symptoms after the injury), and pertinent findings on the general and neurologic examinations. Suspicion of alcohol or drug use and suspicion of nonaccidental injury were noted.

Each child underwent skull radiographs and head CT without contrast. The skull radiographs included both lateral views and Caldwell and Townes projections. The head CT slices were parallel to the orbitomeatal line. For children younger than 6 months, the slice thickness was 4 mm with a 4-mm table feed, whereas for those children 6 months or older, the slice thickness was 10 mm with an 8-mm feed. Both soft tissue and bone windows were obtained. Final interpretations were performed by an attending pediatric radiologist and neuroradiologist for the skull radiographs and the head CTs, respectively. The radiologists were not blinded to the clinical features.

Patient disposition from the emergency department was recorded. The medical records of admitted patients were reviewed to verify the initial diagnosis. The families of study patients who were discharged home from the emergency department were contacted by telephone 3 to 7 days later. The following questions were asked: "Is your child back to normal?"; "Has your child seen another physician since discharge?"; and "Do you have other concerns about your child's head injury?".

For data quality control purposes, a study investigator reviewed the charts of all patients who left the emergency department with diagnoses of head trauma and who were not entered into the study. The patient names and medical record numbers were obtained using an available listing of emergency department discharge diagnosis code summaries. The specific International Classification of Diseases, ninth revision, codes searched include 800.00 through 804.99 (skull fracture), 850.00 through 854.99 (brain injury), and 873.00 through 873.99 (open wound of scalp or face). The total number of patients seen for head trauma as well as the total number of patients who were eligible for study entry were tabulated.

The following statistical approaches were used to assess the association between intracranial disorder and the presence of potentially predictive clinical features. The χ^2 test was used to test the significance of the univariate association between clinical features and intracranial injury for categorical variables. When expected cell counts were less than five, P values were calculated using Fisher's exact test. The t test was used for calculations of the only continuous variable, age. All tests were two tailed. P values less than .05 were considered significant, and P values between .05 and .1 were considered to represent a trend. Multivariate analysis was used to determine the presence and strength of the association between multiple features and intracranial injury. A stepwise logistic regression analysis was performed with an entry criteria of $P < .2$. Variables that retained an association with intracranial injury with $P < .05$ were considered independent predictors of intracranial injury.

RESULTS

A total of 1201 children with head injury were seen in the emergency department during the 6-month data collection period, and 410 had nontrivial head injuries as described in "Methods." Data were collected on 321 patients. Eighty-nine patients were eligible but not entered into the study because of the unavailability of a study investigator. Children included in the study sample were similar to children who were eligible but not entered, except that the admission rate among the enrolled patients was greater than for nonenrolled patients (Table 1).

Fifty-nine percent of the study patients were male; 63% were African-American, 35% were white, and 1% were Asian. This compares with the total emergency department population (during the same year) of 54% male patients, 77% African-American patients, 22% white patients, and 1% others. The ages of the study patients ranged from 2 weeks to 17¾ years. Forty-two percent of the study patients were younger than 2 years, 48% were 2 to 12 years, and 10% were 12 to 18 years. This compares with the total emergency department population of 36% younger than 2 years, 50% 2 to 12 years, and 14% 12 to 18 years. A fall was the mechanism of injury in more than half of the patients. (Fig 1). Seventy-four percent of the patients were discharged home from the emergency department, 19% were admitted to general care, and 7% were admitted to intensive care. One child died as a result of severe pulmonary injury after having been struck by a motor vehicle.

Ninety-eight percent of all study children underwent head CT, whereas 89% received skull radiographs. The seven children who did not receive head CTs were well at follow-up within 1 week after discharge from the emergency department. These seven patients were excluded from further data analysis. Children with more severe head injuries who were rapidly transferred to the operating room or intensive care unit were less likely to receive skull radiographs. The omission of the 35 skull radiographs may have led to an underreporting of skull fractures in this study.

Discrepancies between skull radiographs and head CT in identifying the presence of a linear skull fracture occurred in 10 cases. In 8 children, the skull radiographs demonstrated linear fractures, whereas the CT did not. Conversely, in 2 children, head CT showed linear skull fractures, whereas the skull radiographs did not. In 2 additional cases, discrepancies occurred regarding whether a fracture was depressed. A depressed skull fracture was noted on one patient's skull radiographs but not on the head CT. Another child's head CT report described a depressed skull fracture, whereas the skull radiographs did not. Both are listed as children with depressed

TABLE 1. Demographic Data

Characteristic	Study Sample	Eligible, Not Entered
n	321	89
Age, mean	4 y 10 mo	3 y 1 mo
Boys, %	59	56
Race, %		
Black	63	60
White	35	37
Asian	1	1
Not specified	0	2
Admitted patients, %*	26	3

* $P < .05$.

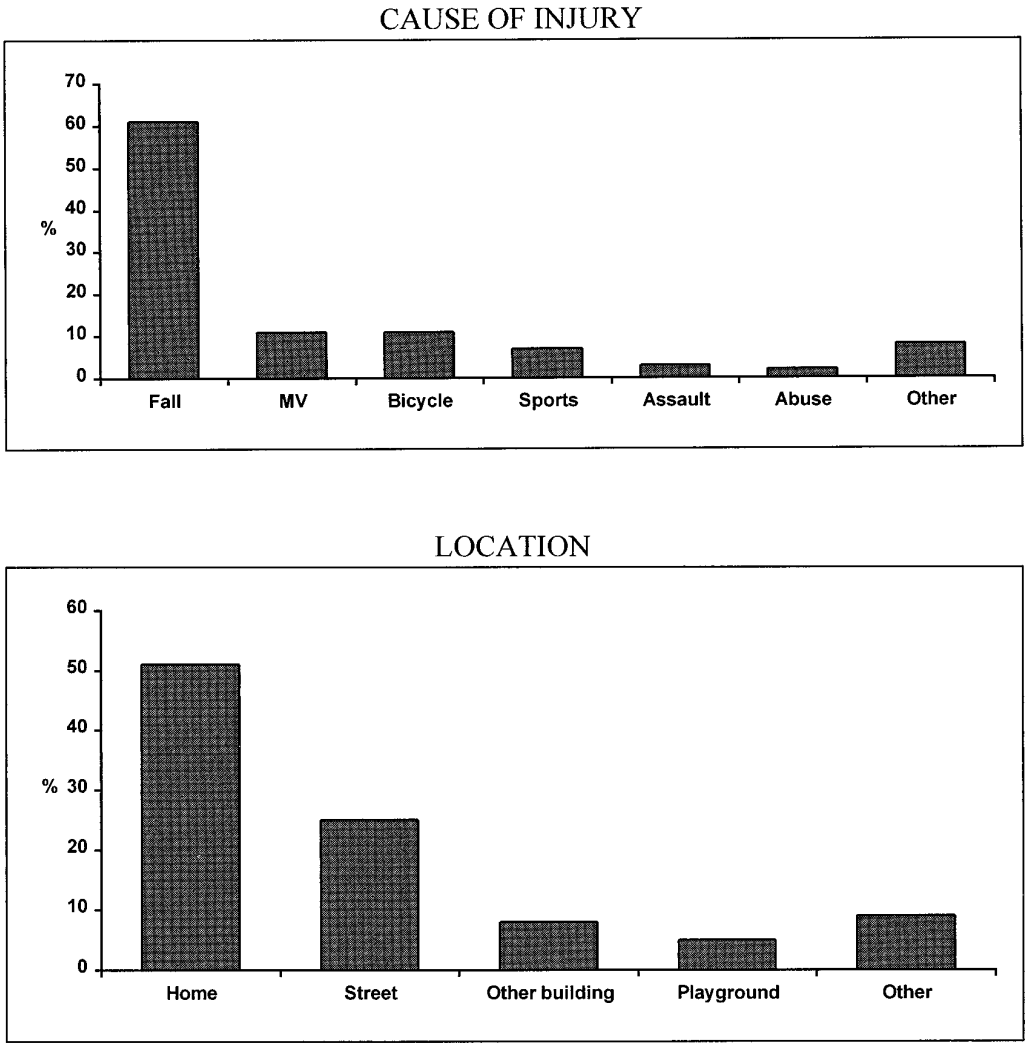


Fig 1. Injury circumstances.

skull fractures in our analysis. Neither of these 2 children underwent surgical elevation of the fractures.

Twenty-seven intracranial injuries (8%) were identified, including 14 parenchymal injuries, 12 intracranial hematomas, and 1 pneumoencephalus. Fifty skull fractures (16%) were diagnosed. Thirty-six were linear, 11 depressed, 2 basilar, and 1 orbital. Thirteen of the 27 children with intracranial injuries (48%) had no skull fractures. The odds ratio (OR) for intracranial injury in children with skull fractures (diagnosed by skull radiographs) was 21.5; 95% confidence interval, 6.42 to 71.63 (Table 2).

Depressed skull fractures were not considered intracranial injuries unless they occurred in combination with the aforementioned brain injuries. Four of the 11 depressed skull fractures were associated with brain injuries and were included in our data analysis as intracranial injury. Four of the remaining 7 isolated depressed skull fractures underwent surgical elevation of the depressed segment. These 7 patients were included having positive outcomes in separate univariate and multivariate analyses as described later.

Surgery was performed in 10 patients: 5 elevations of depressed skull fractures, 4 ventriculostomies, and 1 hematoma evacuation. Three of the 4 patients who underwent ventriculostomies had parenchymal contusions and intraventricular hemorrhages associated with depressed mental status (responsive only to pain or unresponsive). The fourth patient had a parenchymal contusion, subdural hematoma, subarachnoid hemorrhage, and brain edema and was unresponsive.

Univariate predictors of intracranial injury (χ^2 analysis, $P < .05$) included altered mental status, focal neurologic deficit, signs of a basilar skull fracture, loss of consciousness for more than than 5 minutes, and skull fracture. Findings not significantly associated with intracranial injury were headache, dizziness, vomiting, drowsiness, amnesia, loss of consciousness of any duration, palpable depression of the skull, scalp abrasion, contusion, laceration, or hematoma. There was a trend toward an association between seizures and intracranial injury ($P = .08$). The ORs and positive and negative predictive values of all variables in the univariate analysis are listed in Table 2. Negative predictive values were all greater than 90%. The five significant variables listed above had positive predictive values greater

TABLE 2. Predictor Variables for Intracranial Injury

Variable	Odds Ratio	Confidence Interval	Positive Predicted Value, %	Negative Predicted Value, %
Headache	0.87	0.38–2.00	7.9	91.0
Progressive headache	0.97	0.12–7.77	8.3	91.4
Dizziness	0.94	0.31–2.83	8.2	91.3
Vomiting	1.51	0.67–3.37	10.9	92.5
Drowsiness	1.44	0.65–3.22	10.0	92.9
Seizure	2.95	0.91–9.54	20.0	92.2
Amnesia	1.44	0.47–4.43	11.4	91.8
Loss of consciousness (any)	1.03	0.42–2.53	9.0	91.2
Loss of consciousness (>5 min)*	3.51	1.28–9.64	22.2	92.5
Abrasion	1.95	0.88–4.32	12.1	93.4
Contusion	1.31	0.58–2.92	10.0	92.2
Laceration	1.40	0.50–3.92	11.1	91.8
Hematoma	1.82	0.82–4.02	11.4	93.4
Skull depression	1.80	0.21–15.54	14.3	91.5
Signs of basilar fracture*	8.84	1.87–41.83	42.9	92.2
Altered mental status*	4.10	1.74–9.65	21.7	93.7
Focal deficit*	8.15	2.14–30.94	40.0	92.4
Skull fracture*	21.45	6.42–71.63	26.8	98.3

* $P < .05$.

than 20%, whereas all others were less. When depressed skull fracture was included as a positive outcome (ie, intracranial injury) in χ^2 analysis, then palpable depression of the skull was also a significant predictor ($P < .01$), and seizure had borderline significance ($P = .05$).

Multiple logistic regression analysis, however, identified skull fracture (as demonstrated on skull radiographs), focal neurologic deficit, and seizure as independent predictors of intracranial injury ($P < .05$). If the skull radiograph result variable was omitted, then the independent predictors of intracranial injury were altered mental status, focal neurologic deficit, and signs of a basilar skull fracture (Table 3). When depressed skull fractures were included as a positive outcome (ie, intracranial injury) and the skull radiograph variable was excluded, then palpable skull depression was added to the combination of altered mental status, focal neurologic deficit, and signs of a basilar skull fracture as an independent predictor of intracranial injury (Table 3).

Sixty-five children had at least one of the independent predictors described in the model using skull radiographs (skull fracture, focal neurologic deficit, and seizure). Fifteen (23%) of these 65 had intracranial injuries. Two children had at least two of these findings, and both had intracranial injuries (100%). Fifty-five children had at least one of the independent predictors described in the model omitting skull radiograph results (altered mental status, focal neurologic deficit, and signs of a basilar skull fracture). Twelve (22%) of these 55 children had intracranial injuries. Six children had at least 2 of these findings, and 5 of them had intracranial injuries (83%).

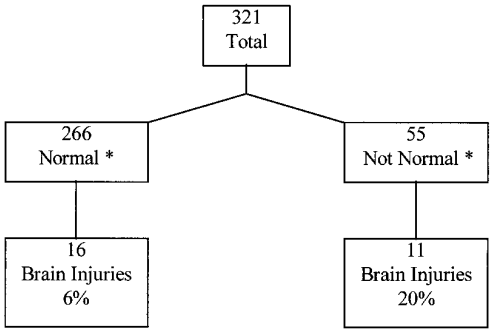
Fifty-five children had abnormal neurologic examination results, mainly represented as altered level of consciousness, and a total of 266 children were described as neurologically normal with alert mental status and nonfocal neurologic examination results (Fig 2). Sixteen (6%) of the 266 normal children had intracranial injuries (Table 4), whereas 4 children had depressed skull fractures, and 26 had linear fractures without intracranial injury. Five of the 266 neurologically normal children required surgery, 4 depressed skull fracture elevations and 1 hematoma evacuation.

The 16 neurologically normal patients with intracranial injuries accounted for 59% of all identified intracranial injuries. Six of the 16 neurologically normal children with intracranial injuries were infants

TABLE 3. Predictors of Injury From Multivariate Analysis

Variable	Odds Ratio	95% Confidence Interval
Independent predictors of intracranial injury using skull radiograph results*		
Skull fracture	92.4	10.8–793
Focal neurologic deficit	63.2	4.7–846
Seizure	19.2	1.5–243
Independent predictors of intracranial injury omitting skull radiograph results*		
Basilar skull fracture signs	12	2.1–67.1
Focal neurologic deficit	7.1	1.7–28.8
Depressed mental status	3.3	1.3–8.3
Independent predictors of intracranial injury including depressed skull fractures as intracranial injury (excluding skull radiograph results)*		
Palpable skull depression	17.9	3.6–88.9
Basilar skull fracture signs	10	1.7–57.3
Focal neurologic deficit	5.7	1.4–23.5
Depressed mental status	4.3	1.8–10

* $P < .05$.



*Normal = Alert mental status, no neurologic deficits

Fig 2. Neurologically normal children.

younger than 1 year; 5 had a scalp contusion or hematoma as the only finding; the sixth had a scalp hematoma and was drowsy at home by parent report. The 10 older neurologically normal children with intracranial injuries ranged in age from 2 to 12 years. All but one had external evidence of trauma, including abrasions, contusions, hematomas, or a combination of these signs. Three children had headaches as their only symptoms, but the others described a combination of two to five symptoms. Nine of the 10 children had headaches, whereas 7 had vomiting.

Age was not significantly associated with intracranial injury, including patients younger than 1 year. The OR of having an intracranial injury for a 1-year increase in age was 1.03 ($P = .47$). Age was not a significant predictor when categorized as a dichotomous variable (age younger than 1 year versus 1 year or older) or as a continuous variable.

As described previously, scalp hematomas were not significantly associated with intracranial injuries; however, scalp hematomas were significantly associated with skull fractures (but not intracranial injury) in infants younger than 1 year ($P < .001$). Twenty-four infants had skull fractures, and scalp hematomas were noted in 20 of those patients. The OR for skull fracture (diagnosed by skull radiographs) in an infant younger than 1 year with a scalp hematoma was 7.5 ($P < .001$). Seven infants had intracranial injuries; all 7 also had skull fractures (diagnosed by skull radiographs).

Telephone follow-up was achieved for 95% of patients discharged home from the emergency department. Seven children had persistent problems during the week after their injuries. Three children had headaches, one child was falling more often, one was sleeping more often, one was dizzy, and one had a visual field deficit. None of these children had intracranial injury identified by CT. Subsequent follow-up of these seven children was done several months later, and two had persistent headaches. All others were well without symptoms. We were unable to contact the remaining 5% of the patients discharged home; however, none returned to this hospital seeking additional treatment of the head injury based on review of medical records. The hospital medical records of all admitted children were reviewed, and only one change had been made from the initial diagnosis. A subdural hematoma was described by CT; however, the diagnosis was changed to an epidural hematoma after direct visualization in the operating room.

DISCUSSION

This study identified univariate and multivariate predictors for intracranial injury in head-injured children. Univariate predictors included altered mental status, focal neurologic deficit, signs of a basilar skull fracture, loss of consciousness for more than than 5 minutes, and skull fracture. There was a trend toward association of seizure and intracranial injury. As a univariate predictor, skull fracture had an OR for intracranial injury of 21.5. Using multivariate analysis, however, the following independent predictors of intracranial injury were identified: focal neurologic deficit, signs of a basilar skull fracture, seizure, altered mental status, and skull fracture. As an independent predictor, skull fracture had an even higher OR for intracranial injury (92.4; 95% confidence interval, 10.8 to 793). Despite the identification of the above independent predictors, half of the intracranial injuries occurred without fractures, and 59% of all intracranial injuries occurred in children described as alert and neurologically normal.

The development of a set of clinical criteria identifying which children should receive imaging studies after a head injury has been an elusive goal. Contributory data from past studies have been largely retrospective, with few dedicated to head-injured children. Several recent pediatric studies have collected data prospectively but have studied children who underwent head CT based on unspecified criteria.

Previous retrospective studies have identified predictive clinical criteria for intracranial injury in children. Hennes et al[5] retrospectively studied 55 children and identified altered mental status, evidence of increased intracranial pressure, seizures, and focal deficits as predictors of intracranial injury. Rivara et al[20] retrospectively studied 98 children, and described an abnormal Glasgow Coma Scale (GCS) score, altered consciousness, and focal neurologic abnormality as predictors of intracranial injury. Dietrich et al[15] and Ramundo et al[16] prospectively studied children who underwent head CT for evaluation of head injury after presentation to the emergency department. Dietrich et al[15] reported loss of consciousness, amnesia, GCS score less than 15, and neurologic deficit as significant associations with intracranial injury. Ramundo et al[16] described suspicion of child abuse, focal motor deficit, and pupillary asymmetry as predictors of intracranial injury. The presence of neurologic deficits was the only predictor common to all studies, including our own. The studies by Dietrich et al[15] and Ramundo et al[16] prospectively collected data; however, the unspecified selection of these children for CT may have introduced bias into the studies. Our work is the first prospective study of head-injured children selected as a result of predetermined criteria.

TABLE 4. Intracranial Injuries in Normal* Children

Age	Sex	Mechanism	Symptoms	Signs	Injury†	Surgery
2 wk	F	Fall <5 ft	None	Scalp hematoma and contusion	Parenchymal contusion, skull fx	No
1 mo	M	Fall <5 ft	None	Scalp contusion	IVH, skull fx	No
1 mo	M	Child abuse	None	Scalp hematoma	IVH, brain edema, skull fx	No
3 mo	F	Fall <5 ft	None	Scalp hematoma	Parenchymal contusion	No
3 mo	F	Fall <5 ft	None	Scalp abrasion and contusion	Epidural hematoma, skull fx	No
7 mo	M	Fall 5–9 ft	Drowsy	Scalp abrasion and hematoma	Subdural hematoma, skull fx	No
2 y	M	Fall <5 ft	Headache, emesis, drowsy	Scalp contusion	Subdural hematoma	No
3 y	F	Fall 5–9 ft (stairs)	Headache	Scalp hematoma	Subdural hematoma, depressed skull fx	No
4 y	F	Fall 10–19 ft	Emesis	Scalp abrasion, contusion, hematoma	Pneumoencephalus, skull fx, orbital fx	No
5 y	F	Fall 5–9 ft	Progressive headache, emesis, drowsy	Scalp hematoma	Epidural hematoma, skull fx	Yes, epidural evacuation
8 y	M	Pedestrian motor vehicle collision	Headache, dizzy, emesis, drowsy	Scalp hematoma	Parenchymal contusion	No
8 y	M	Bicycle collision	Headache, dizzy	Scalp hematoma, contusion	Parenchymal contusion, pneumoencephalus, skull fx	No
9 y	F	Fall <5 ft	Headache, dizzy, emesis, drowsy, amnesia	Scalp abrasion and contusion	Parenchymal contusion	No
9 y	M	Fall 5–9 ft	Headache, emesis, drowsy, amnesia	Scalp abrasion and contusion	Parenchymal contusion, depressed skull fx	No
9 y	M	Bicycle collision	Headache	Scalp abrasion and hematoma	Subdural hematoma	No
12 y	M	Skating collision	Headache, dizzy, amnesia, emesis	None	Parenchymal contusion	No

* Normal indicates alert mental status, no focal neurologic deficits.
† fx indicates fracture; and IVH, intraventricular hemorrhage.

Our study identified clinical features that were significantly associated with brain injury. Yet brain injuries also occurred in the absence of these criteria. Sixteen (6%) of the neurologically normal children had intracranial injuries, including 1 who had an epidural hematoma evacuated. Dietrich et al[15] reported a similar occurrence (5%) of neurologically intact children who had intracranial disorders. Hahn and McLone[21] reported a 7% incidence of mass lesions in head-injured children admitted to the hospital with GCS scores of 15. However, in a recent report by Davis et al,[22] none of the 49 neurologically intact children older than 2 years with isolated head injury had intracranial hemorrhage. In our series of 321 patients, 9 neurologically normal children older than 2 years with isolated head injuries had intracranial injuries. The sample sizes from these prior studies are such that the findings from all studies are consistent with a prevalence of intracranial injury in neurologically normal children of 3% to 7%.

The significance of brain injury in neurologically normal children is unclear. Neurosurgical interventions are rare in this subgroup.[15,22] The long-term impact of subtle, nonsurgical intracranial injury on the neuropsychologic development of children is controversial. There is general agreement in the literature that severe head injuries are associated with significant disabilities in both children and adults. The adult literature has described disabilities after minor head injury[23–25]; however, conflicting reports exist concerning disability after mild head injury in children. The report by Di Scala et al[6] on children with a wide spectrum of injury severity revealed impairments of daily living functions, cognition, and behavior in children with minor head injury. Casey et al[26] surveyed the parents of children with minor head trauma and discovered transient functional and behavioral problems in a significant number of the children. More recent reports found no clinically significant neurobehavioral impairments in children with minor head injuries.[27,28]

The significance of the signs such as vomiting, headache, drowsiness, and amnesia is also unclear. Although these clinical findings were not statistically associated with intracranial injury, this may reflect a power limitation of our study, given 27 intracranial injuries. These findings occur frequently in those children who have intracranial injuries but also in those who do not.

Loss of consciousness in general was not a significant predictor of intracranial injury, but a loss of consciousness for more than 5 minutes was predictive in the univariate analysis. However, on review of the data, none of the 7 patients unconscious for more than 5 but less than 20 minutes had intracranial injury. Moreover, all of the patients unconscious for 20 minutes or longer had altered mental status at presentation to the emergency department. Because of the relationship between these two variables, prolonged loss of consciousness was not identified as an independent predictor in the multivariate analysis. Because prior studies[15,29,30] have suggested that loss

of consciousness may be associated with intracranial injury, we think that the history of loss of consciousness should still be considered in the evaluation of intracranial injury in children.

Although we achieved telephone follow-up of 95% of the patients discharged home from the emergency department, the collected information reflects the general well-being of the child in the week after the injury. More detailed information regarding the neuropsychologic functioning of these children is not available. Furthermore, even children with normal head CT results, and thus with no identified intracranial injuries, may have subtle brain injury better detected by magnetic resonance imaging or perhaps second CT scanning, neither of which were obtained in these patients.

Another limitation of this study was the exclusion of children with trivial head injury. Our study sample was a preselected group, and our findings may not be generalizable to children seeking emergency evaluation for trivial head injury. In addition, 89 children were eligible but not entered in the study. The study enrollees' higher admission rate (Table 1) seems to imply a more seriously injured subset of patients compared with children who were eligible but not entered.

Our data suggest clinical approaches to pediatric patients with head injury. Because altered mental status, focal neurologic deficit, signs of a basilar skull fracture, and seizure are independent predictors of intracranial injury, patients with these findings should receive head CT and/or neurosurgical consultation. However, intracranial injuries occurred in patients without the clinical features listed above. Fifteen patients in our series would not have received head CT if the presence of any of the independent predictors had been used as the only criteria for imaging studies. (This represents 15 of the 16 neurologically normal children with intracranial injury; 1 of the 16 had signs of a basilar skull fracture.) Only one of these 15 underwent surgery. Clinicians must decide when to obtain head CT in children who have vomiting, amnesia, headache, drowsiness, or a history of loss of consciousness but who have none of the independent predictors that we identified. In some children, careful observation may be chosen rather than head CT, realizing that intracranial injuries may be missed. The majority of these injuries will not require surgery; however, their long-term impact is unclear.

Based on these data and review of the literature, we have developed guidelines for our own practice that others might find useful. Head CT is recommended for head-injured children with altered mental status, focal neurologic deficits, signs of a basilar skull fracture, seizure, or a palpable depression of the skull. Because intracranial injuries occur in the absence of these findings, head CT should be considered for neurologically normal children with histories of loss of consciousness, vomiting, headache, drowsiness, or amnesia. Careful observation of these children at home or in the hospital may be an alternative approach depending on the availability of head CT, hospital beds, or reliable care givers. Children without symptoms or signs listed above may be carefully observed at home by reliable adults. Neurologically normal children who have normal head CT results may also be safely observed at home when reliable care givers are available.[31]

Because a significant number of intracranial injuries occur in the absence of skull fractures, skull radiographs are not generally recommended for screening when CT is readily available. However, when CT is not available, skull radiographs provide some screening information, because the relative risk of intracranial injury is greatly increased in the presence of a skull fracture. Documentation of a skull fracture may also be useful in evaluation for nonaccidental trauma and in young infants as discussed below.

Even though age younger than 1 year was not significantly associated with intracranial injury, we recommend a more conservative approach for children younger than 12 months, based on our findings that these infants may have intracranial injuries with few or subtle signs and symptoms. In addition to the findings of altered mental status, focal neurologic deficits, seizure, signs of a basilar skull fracture, and a palpable depression of the skull, any symptoms related to head injury in an infant should prompt strong consideration for head CT. Although we do not recommend skull radiographs for most children, we do recommend skull radiographs in infants younger than 1 year with hematomas or contusions after head injury, because these infants are at greater risk for skull fracture, as demonstrated by the OR of 7.5 for skull fractures in infants with scalp hematomas. An infant with an identified skull fracture should warrant in-hospital observation, head CT, or both.

In conclusion, independent predictors of intracranial injury include altered mental status, focal neurologic deficit, signs of a basilar skull fracture, seizure, and skull fracture. However, intracranial injury may also occur with few or subtle signs and symptoms, especially in infants younger than 1 year. Furthermore, the majority of patients with intracranial injury were neurologically intact; therefore, CT scans should be considered in children with symptoms such as vomiting, headache, drowsiness, amnesia, and a history of loss of consciousness, even in the absence of the independent predictors of intracranial injury we identified. The significance of nonsurgical intracranial injury in neurologically normal children needs further study.

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