A Population-Based Comparison of Clinical and Outcome Characteristics of Young Children With Serious Inflicted and Noninflicted Traumatic Brain Injury

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ABSTRACT. *Objective.* **Diagnosing inflicted traumatic brain injury (TBI) in young children is difficult in practice. Comparisons of children with inflicted and noninflicted TBI may help to identify markers of inflicted TBI. The objective of this study was to compare inflicted and noninflicted TBI in terms of presenting complaints, clinical features, and hospital outcomes.**

Methods. **The presenting complaint, clinical finding, hospital course, and outcome of all children who were aged 2 years or younger in North Carolina and were admitted to a pediatric intensive care unit or died with a TBI in 2000 and 2001 were reviewed. Clinical presentation and injury types were compared between children with inflicted and noninflicted TBI. Risk ratios were used to compare clinical and outcome characteristics between the 2 groups. Among survivors, multivariate binomial regression was used to examine the adjusted risk of a poor outcome dependent on injury type.**

Results. **A total of 80 (52.6%) children had inflicted and 72 (47.3%) children had noninflicted TBI. Children with noninflicted TBI (not in a motor vehicle crash) were more likely to present to the emergency department asymptomatic (44.8% vs 8.3%) and to have a specific history of trauma than children with inflicted TBI. Retinal hemorrhage, metaphyseal fracture, rib fracture, and subdural hemorrhage were more commonly found in children with inflicted compared with noninflicted TBI. Skeletal survey and ophthalmologic examination combined would have missed 8 (10.0%) inflicted TBI cases.**

Conclusions. **Manner of presentation and injury types are helpful in distinguishing inflicted TBI. Clinicians should not rule out inflicted TBI on the basis of skeletal survey and ophthalmoscopy alone but should proceed to computed tomography and/or magnetic resonance imaging.** ***Pediatrics*** **2004;114:633–639;** ***child abuse, traumatic brain injury, shaken baby syndrome.***

ABBREVIATIONS. TBI, traumatic brain injury; PICU, pediatric intensive care unit; CT, computed tomography; MRI, magnetic resonance imaging; OCME, Office of the Chief Medical Examiner; CPR, cardiopulmonary resuscitation; GCS, Glasgow Coma Score; POPC, Pediatric Outcome Performance Category; RR, risk ratio; MVC, motor vehicle crash; CI, confidence interval.

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Inflicted traumatic brain injury (TBI) is the leading cause of death among children as a result of abuse.[1] Despite its seriousness, the diagnosis seems to be missed frequently as a result of the nonspecificity of the child's presentation to the clinician.[2,3] A missed diagnosis can result in repeat injury and/or death.[3] When the diagnosis of inflicted TBI is made, as many as 45% of children have signs of previous brain injury.[4] Children with inflicted TBI are thought to have a worse short-term outcome compared with children with noninflicted TBI.[4]

Inflicted TBI, which includes both the clinical entities of "shaken infant syndrome" and "shaken impact syndrome," has been well described.[2,5,6] However, most studies have relied on case series of inflicted TBI victims, precluding the comparison of children with inflicted TBI with similarly aged children with noninflicted TBI. This article compares reported mechanisms of injury, injury types, clinical characteristics, and hospital outcomes of children with inflicted and noninflicted TBI with the purpose of assessing the diagnostic importance of specific clinical or historical findings and comparing acute outcomes. Data come from a prospective, population-based study of all children who were aged 2 years or younger and admitted to any of the 9 North Carolina pediatric intensive care units (PICUs) and/or died with a TBI in North Carolina over a 2-year period.

METHODS

This prospective study identified all North Carolina resident children who incurred a serious or fatal TBI that occurred between January 1, 2000, and December 31, 2001, on or before their second birthday. Data were collected from all hospitals in North Carolina with a PICU or a monitored pediatric stepdown unit.

Definitions

The definition of the outcome, serious or fatal TBI, required evidence, through computed tomography (CT)/magnetic resonance imaging (MRI) or pathology, of intracranial injury including any type of intracranial hemorrhage, shear injury, lacerations, or contusions. Children with skull fractures but no evidence of intracranial injury were excluded. Inflicted TBI required evidence of TBI as defined above, accompanied by a confession documented in the medical record or a medical and child protective services determination that the injury was inflicted. The medical and social services evaluations were performed by the treating team at each hospital or, in the case of deaths, by the Office of the Chief Medical Examiner's (OCME's) forensic pathologists. Cases in which the cause was undetermined were reviewed by 2 of the authors (H.T.K. and D.K.R.), and a determination of cause was made in the manner described below. A witnessed injury was an injury in which >1 person reported that they saw the injury occur.

Prematurity was defined as ≤37 weeks' completed gestational age. Use of cardiopulmonary resuscitation (CPR) was defined as requiring CPR at any time during the child's clinical course (from scene of injury throughout hospitalization), and the patient was considered to have experienced a loss of consciousness when the child was found unconscious at the scene of injury by a caregiver or on presentation to the emergency department. Reasons for care seeking and initial mechanism of injury were those reasons reported to the medical staff by the care seeker and recorded on the chart or in the Emergency Medical Services record.

Injury severity was determined using 2 methods. First, the initial Glasgow Coma Score (GCS)[7] was recorded. Because GCS has previously been shown to be a poor predictor of outcome in children,[8] an alternative method of determining injury severity was also used. The length of time of unconsciousness has been shown to be a good predictor of quality of survival,[9,10] reflecting injury severity. Therefore, children who had either a GCS score of ≤8 or an impaired motor response at 72 hours were considered to have severe injury following the findings of Michaud et al.[10] All other children were considered to have moderate injury.

Outcome at hospital discharge was determined from the treating physician's and the physical and occupational therapists' notes. Information from the medical record was used to calculate a Pediatric Outcome Performance Category (POPC) score (ranging from 1 = normal to 6 = death).[11] This scale has been validated with functional outcomes at 1 and 6 months in PICU patients and is associated with several measures of morbidity, including length of PICU stay, and discharge needs.[11,12] The POPC scale was collapsed into 3 categories for this study: normal or mild deficits (score 1 or 2), moderate or severe deficits (score 3 or 4), and vegetative or dead (score 5 or 6). Among the surviving children, a good outcome was defined as a POPC score of 1 or 2; a poor outcome was defined as a score of 3, 4, or 5.

Subject Ascertainment

Hospitalized TBI

The methods used have been previously described.[13] Data were obtained from 2 sources: hospitals in North Carolina with a PICU and/or a monitored stepdown unit and the OCME. Children were required to have been admitted to a PICU or monitored stepdown unit and have evidence of a nonpenetrating TBI by CT, MRI, or pathologic examination. For ensuring complete ascertainment of North Carolina cases, the 3 closest out-of-state hospitals with PICUs to which children might be transported (1 in Virginia and 2 in Georgia) were queried during the study period about PICU admissions for North Carolina residents, injured in North Carolina, with head trauma. This study was reviewed and approved by the Institutional Review Board of each participating hospital.

Fatal TBIs

North Carolina has a state medical examiner system that conducts investigations on all cases of unexpected or violent deaths, including deaths from all traumatic injuries. The North Carolina OCME was queried to identify all deaths for children 2 years of age and younger. Charts were reviewed manually to identify children who died of head injuries. Data were abstracted, including pathologic evidence of brain injury and the results of the medical examiner's investigation into the cause of death. The OCME conducts autopsies on all children who do not have a self-evident cause of death. Double counting of deaths of children who were hospitalized and then became medical examiner cases was avoided by matching date of birth, date of death, race, gender, and place and manner of death of the OCME cases to those children who died in hospital.

Data Collection Procedures

Medical Record Abstraction and Data Collection

Two medical abstractors reviewed the complete medical chart or medical examiner record for each child. The clinical presentation, including details of the history as told by the parent or guardian, the physical examination, hospital course, and outcome, was abstracted from the medical record. The results of all radiographic, ophthalmologic, and electroencephalographic examinations were reviewed, as were all surgical procedure reports and discharge summaries. Involvement by the county Department of Social Services and the child's posthospitalization disposition as documented in the medical record were recorded. The initial head CT and/or MRI and subsequent radiologic examinations of each patient were read by a single pediatric radiologist, who was blinded to the mechanism of injury to ensure that each subject met uniform entrance criteria and to document the injury types.

Unknown Cause Classification

When no social service or medical information was contained about injury cause in the medical record, the project coordinator prepared an abstract of the case for review by 2 of the investigators (H.T.K., D.K.R.), adapting the method of Stier et al.[14] The abstract included a summary of each case; a description of the cause of injury as presented by the caregiver to the treating physicians; and a description of the injuries, including specific findings such as metaphyseal fractures, retinal hemorrhages, and old injuries found on long-bone studies. Demographic information such as race, gender, referring hospital, and socioeconomic status were not included. Child age was included in the summary as the likelihood of certain reported events are developmentally linked. Each reviewer independently classified the case as inflicted or noninflicted. Intent was determined for 2 cases in this manner. A mechanism was set up to jury any cases in which the 2 investigators did not agree, but the procedure never was required.

Statistical Analysis

Simple frequencies and proportions were calculated to describe the reasons for care seeking, parent-reported mechanism of injury, and types of injuries sustained by the children. T test was used to compare continuous variables. Medians and first and third quartiles were calculated for skewed continuous variables. The Wilcoxon rank sum test was used to compare nonnormal continuous variables. Risk ratios (RRs) were calculated to compare the children with inflicted injuries with the children with noninflicted injuries and to compare children with good versus poor outcomes. The χ^2 test, or Fisher exact test if any expected cell size was <5, also was used to compare these groups.

For examining factors that effect outcomes among surviving children, a multivariate binomial regression model was fit to the data.[15] The model estimated adjusted RRs of a poor outcome among children who survived a TBI dependent on injury type (inflicted vs noninflicted injury). Covariates were kept in the model when they changed the effect estimate of injury type (noninflicted vs inflicted) by 10% or greater. Prematurity was not entered into the multivariate model because of small cell sizes. This model was used because it provides valid estimators of relative risk, whereas logistic regression models (odds ratios) tend to overestimate the relative risk when used with such data as ours.[16]

RESULTS

A total of 152 children were identified with serious or fatal TBI: 80 (52.6%) sustained inflicted TBI. Of the 152, 87 (57.2%) were boys and 119 (78.3%) were infants. The median age of the children with inflicted TBI was 4 months and with noninflicted TBI was 7.5 months ($P < .001$, t test). There were a total of 40 (26.3%) fatalities. A more detailed description of these cases has previously appeared.[13] One chart of a child's initial hospitalization with inflicted TBI could not be located.

Reported Mechanism of Injury and Presenting Complaints

The mechanism of injury as initially reported by the person who sought medical care for the child is presented in Table 1. The majority of noninflicted cases were from motor vehicle crashes (MVCs) followed by falls and drops. Children with inflicted injuries had no mechanism of injury offered by the

TABLE 1. Mechanism of Injury as Initially Reported by Parents in Children With Noninflicted (n = 72) and Inflicted (n = 80) TBI

	Inflicted		Noninflicted	
	n	%	*n*	%
No explanation offered	51	63.8	0	0
Shaking to revive	3	3.8	0	0
Shake/hit intentionally	2	2.5	0	0
Unknown	1	1.3	0	0
Fall	12	15.0	15	20.8
Dropped	6	7.5	8	11.1
Other	5	6.3	4	5.6
Fall down stairs (with parent)	0	0	2	2.8
Pedestrian versus car	0	0	5	6.9
MVC	0	0	38	52.8

caregiver for the injury 63.8% of the time. Reasons for seeking care for children who sustained inflicted TBI and non–MVC-related, noninflicted injuries are presented in Table 2. Parents of children with non-MVC, noninflicted TBI (n = 29) were more likely to go to the emergency department when the child was asymptomatic or had swelling or redness on the face or head after a fall (n = 13, 44.8%) compared with 6 (8.3%) children who had inflicted TBI and were asymptomatic but with unexplained bruising or limb deformity (P < .001, Fisher exact test). Noninflicted injuries had a witness to the injury event 75.0% of the time (n = 54) in comparison with 2.5% (n = 2) of inflicted injuries (P < .001, Fisher exact test). In the inflicted TBI group, 24 (30.8%) of perpetrators confessed to inflicting the injury at some time during the hospital course.

Injury Types

Fractures

Children with inflicted and noninflicted injuries differed in the types of injuries sustained (Table 3). Children with inflicted TBI were more likely to have rib fractures, long-bone fractures, and metaphyseal fractures than children with noninflicted TBI. The only noninflicted case with a metaphyseal fracture entered the study after a TBI as a result of an MVC. Radiographic examination revealed a healing metaphyseal fracture, rib fractures, and a long-bone fracture unrelated to the MVC. Fractures were seen

TABLE 3. Types of Injury Sustained by Children With Noninflicted (n = 72) and Inflicted (n = 80) TBI

	Inflicted		Noninflicted	
	n	%	*n*	%
Retinal hemorrhage	61	76.3	6	8.3
Rib fracture	22	27.5	4	5.6
Long-bone fracture	15	18.8	5	6.9
Skull fracture	14	17.5	39	59.1
Metaphyseal fracture	14	17.5	1	2.8
Brain injuries				
Subdural	75	93.8	40	60.6
Edema	25	31.3	9	13.6
Anoxic/ischemic	15	18.8	7	10.6
Hydrocephalus	12	15.0	2	3.0
Other brain injuries	10	12.5	5	7.6
Subarachnoid	9	11.3	15	22.7
Contusion	8	10.0	12	18.2
Intracranial hemorrhage	5	7.0	9	14.8
Epidural	1	1.3	12	18.2

in 17 (58.6%) children with non–MVC-related, noninflicted TBI: all of these were skull fractures. Children with noninflicted TBI were more likely to have skull fractures than children with inflicted TBI (59.1% vs 17.5%; χ^2 14.2, df = 1, P < .001, respectively).

Retinal Hemorrhages

Children with inflicted injuries seemed to be more likely to incur retinal hemorrhages, although it must be noted that retinal hemorrhages were looked for more often when inflicted injury was suspected or when there was direct trauma to the eye. In the group of children with noninflicted injuries, only 24 (33.3%) of the 72 children had a documented ophthalmologic examination, with 6 (25.0%) of the 24 having retinal hemorrhage. A description of the retinal findings and associated head injuries of these 6 children are found in Table 4.

Other Injuries

Thirty (37.5%) of the children with inflicted TBI had injuries in addition to their head injury and rib fractures. A total of 28 (35.0%) children with inflicted TBI had no external signs of trauma on presentation, and 8 (10.0%) of children had the absence of both

TABLE 2. Reason for Care Seeking in Children With Inflicted TBI (n = 80) Versus Noninflicted TBI (Excluding MVCs) (n = 29) as Represented by the Caregiver

	Inflicted TBI		Noninflicted TBI	
	n	%	*n*	%
Apnea	14	17.5	0	0
Respiratory distress	12	15.0	0	0
Found lifeless*	11	13.8	0	0
Seizure	10	12.5	0	0
Unexplained facial bruising/limb deformity	6	7.5	0	0
Unknown	1	1.3	0	0
Lethargy	8	10.0	6	20.7
Irritability	8	10.0	2	6.9
Unresponsive	7	8.8	4	13.8
Vomiting	3	3.8	4	13.8
Asymptomatic/parental concern	0	0	6	20.7
Facial/head swelling postinjury	0	0	7	24.1

* In cardiopulmonary arrest per Emergency Medical Services.

TABLE 4. Description of Retinal Hemorrhages in Children With Noninflicted TBI

Case	Mechanism of Injury	Type of Hemorrhages	Other Head Injuries
1	MVC	≥15 preretinal hemorrhages from ¼ to ½ disc area in size seen in both eyes, more numerous around the optic nerve and extend into the midperiphery	Bilateral orbital roof fractures; fractures of orbital medial walls with intact inferior walls; right parietal skull fracture; right subdural hemorrhage
2	MVC	Right-sided retinal flare hemorrhages; Purtscher retinopathy	Bilateral parietal skull fracture; left subdural hemorrhage
3*	Television fell on head	Blood around optic nerves (bilaterally); extensive, confluent retinal hemorrhages involving all layers of the retina and extending to the periphery; retinal detachments bilaterally	Bilateral parietal fracture; bilateral epidural and subdural hematoma; intracranial hemorrhage; anoxic brain injury
4	MVC	Preretinal hemorrhages on the left side	Left orbital roof and left-frontal fracture; left subdural hemorrhage
5†	MVC	Bilateral retinal hemorrhages	Epidural hemorrhage; anoxic injury
6	Dropped 4 feet onto tile	Left retinal and preretinal hemorrhages; scattered posterior pole dot/blot retinal hemorrhages and preretinal hemorrhages	Linear right parietal skull fracture; left cerebral confusion; left subdural with midline shift

* Pathology report.
† Pediatrician examination only.

retinal hemorrhages and fractures. Eleven children sustained blunt trauma to the chest or abdomen: 2 in the inflicted group and 9 in the noninflicted group. Two children incurred burns: 1 in the inflicted and 1 in the noninflicted group. Evidence of old injury was found in 28 (35.0%) of children in the inflicted group on radiographic and/or physical examination. Evidence of old injury was found in 1 (1.4%) child in the noninflicted group. This was a child who was in an MVC.

TBIs

Children with inflicted and noninflicted injuries sustained different types of TBI (Table 3). Types of injury were determined by pathology, CT scan, and/or MRI. There were 7 (7.5%) cases of children who were admitted to hospital for which radiographs could not be obtained for review by the study radiologist: 3 in the inflicted group and 4 in the noninflicted group. In these cases, 1 had a neurosurgical intervention to relieve an epidural hematoma, 2 had written documentation of the injury by the neurosurgeon and outside radiologist, and 4 had documentation by the outside radiologist alone. All had significant injuries with neurologic sequelae. There were 6 cases of noninflicted TBI in children who died at the scene of injury. In these cases, the head injury was so severe that separate types of injury were not classified. Subdural hemorrhage was seen more frequently in children with inflicted TBI than noninflicted TBI (93.8% vs 60.6%; χ^2 29.8, $df = 1$, $P < .001$), whereas epidural hemorrhage occurred more frequently in children with noninflicted TBI (18.2% vs 1.3%; $\chi^2 = 11.4$, $df = 1$, $P < .001$). Cerebral edema was more frequent in children with inflicted TBI (31.3% vs 13.6%; $\chi^2 = 7.6$, $df = 1$, $P = .01$), as was hydrocephalus (15.0% vs 3.0%; $\chi^2 = 6.8$, $df = 1$, $P < .01$). There were no other statistical differences appreciated between the other types of brain injury.

Clinical and Outcome Characteristics

Injury severity, as measured by the method of Michaud et al,[10] was similar in the inflicted and noninflicted TBI groups (Table 5). The inflicted group had more children with a GCS of 9 to 12[7]; however, the estimate was imprecise. The Pediatric Risk of Mortality scores were significantly higher in the noninflicted TBI group.[17] Children with inflicted injuries were more likely to have seizures and less likely to have other organ injury than children with noninflicted injuries. Length of overall hospital (7 days vs 3 days) and PICU stays (4 days vs 1 day) both were significantly higher in the inflicted TBI group than in the noninflicted TBI group, respectively.

We examined the associations between child demographics/clinical characteristics and outcome among the surviving children ($n = 112$; Table 6). Children with inflicted TBI were more likely to have a poor outcome (POPC 3 or 4) than children with noninflicted TBI (unadjusted RR: 1.5; 95% confidence interval [CI]: 1.2–1.9). There were no children with a vegetative outcome (POPC 5) in either group. In the univariate analysis, poor outcome was also associated with age >1 year, a loss of consciousness on presentation, a requirement for CPR, and presence of seizures during the hospital course. Other organ injury (nonbrain) did not increase the risk of a poor outcome. As expected, injury severity was strongly associated with poor outcome, although the result was imprecise. In a multivariate binomial regression model, the risk of a poor outcome was 1.2 (95% CI: 0.6–2.6) among surviving children with inflicted TBI compared with surviving children with noninflicted TBI after adjustment for presence of seizures and loss of consciousness at the scene (Table 7). Therefore, seizures (adjusted RR: 3.0; 95% CI: 1.4–6.3) and loss of consciousness (adjusted RR: 1.9; 95% CI: 1.3–2.9) were partially explanatory of the worse outcomes experienced by children with inflicted TBI. Seizures and loss of consciousness were the only covariates from Table 6 included in this model because they were the only variables that changed the effect estimate for injury type (noninflicted vs inflicted) by 10% or greater.

TABLE 5. Clinical Characteristics of Children With Noninflicted (n = 72) and Inflicted (n = 80) TBI

	Inflicted		Noninflicted		RR	95% CI
	n	%	*n*	%		
Required CPR						
Yes	31	38.8	21	29.2	1.3	0.9–1.8
No	47	58.8	48	66.7	1.0	Referent
Missing	2	2.5	3	4.2		
Loss of consciousness at presentation						
Yes	25	31.3	29	14.6	0.8	0.6–1.2
No	53	66.3	43	85.4	1.0	Referent
Missing	2	2.5	0	0		
Seizures						
Yes	39	48.8	12	16.7	2.6	1.5–4.4
No	32	40.0	51	70.8	1.0	Referent
Missing	9	11.3	9	12.5		
Other organ injury than head injury						
Yes	3	3.8	16	22.2	0.5	0.4–0.7
No	75	93.8	56	77.8	1.0	Referent
Missing	2	2.5	0	0		
GCS						
13–15	28	35.0	32	44.4	1.0	Referent
9–12	15	18.8	7	9.7	1.7	0.9–3.2
3–8	29	36.3	25	34.7	1.2	0.8–1.7
Missing	8	10.0	8	11.1		
Injury severity*						
Moderate	49	61.3	45	62.5	1.0	Referent
Severe	29	36.3	27	37.5	1.0	0.7–1.4
Missing	2	2.5	0	0		
	Median (25th, 75th %)	Range	Median (25th, 75th %)	Range	*P* Value†	
Pediatric risk of mortality score	2 (0, 5)	0–39	3 (0, 10)	0–46	.03	
Length of stay, d						
Hospital	7 (3, 14)	0–48	3 (1.5, 6.5)	0–35	<.01	
PICU	4 (1.5, 6.5)	0–34	1 (1, 2)	0–26	<.01	

* Injury severity was defined as severe if unconsciousness persisted ≥72 hours or GCS ≤8.
† Wilcoxon rank sum test.

DISCUSSION

Children with inflicted TBI may be difficult to detect on presentation to the clinician. In this study, the chief complaint as given by the caregiver was most often respiratory followed by neurologic symptoms. These symptoms may be confused with children's manifesting signs of more common illnesses such as upper respiratory tract infections, gastroesophageal reflux disease, or sepsis. Thirty-five percent of children with inflicted injuries had no external signs of trauma such as bruising, palpable fractures, or limb deformities, which might alert the clinician to a correct diagnosis. This is compatible with a previous case series in which 54 (31.2%) of 173 children who had presented to a clinician with nonspecific symptoms after abusive head trauma had not received a diagnosis of head trauma.[3] Although lack of external signs of trauma does not preclude impact injury, this does suggest that at most, 35% of children sustained shaking alone as the mechanism of injury.[18]

Differentiating children with inflicted and noninflicted TBI can be challenging.[19] In the United States, a differential in screening children with long-bone fracture for abuse in the emergency department differed by race, with minority children more likely to be screened for abuse.[20] This may reflect an incorrect perception by physicians that they can tell who is likely to be the victim of abusive injury on the basis of sociodemographic differences. We previously reported that sociodemographic characteristics of children, such as race or parental marital status, are poor predictors of whether a child's injury was inflicted or not inflicted.[13] If the diagnosis of TBI is suspected, there are both clinical signs and historical cues that are more frequent among those with inflicted TBI than noninflicted TBI. In this study, children with inflicted and noninflicted TBI presented differently for care. Nearly 45% of caregivers of children with non–MVC-related, noninflicted TBIs sought care for their child after the injury event before any clinical symptoms developed, whereas children with inflicted injuries presented with either symptoms or unexplained injuries. In addition, all children with noninflicted injuries presented with a very specific history of trauma, whereas the majority of children with noninflicted TBI presented with no history of trauma. This finding is consistent with those of Hettler and Greenes,[19] who found a specificity of 99% and a positive predictive value of 92% for inflicted head injury in children with head injury and no history of trauma. Clinically, retinal hemorrhage was seen in only 2 non–MVC-related cases in the noninflicted group; however, only children in whom inflicted TBI or direct trauma to the eye was suspected were examined routinely. Rib fracture and metaphyseal fracture were not seen in children who had noninflicted TBI and were not involved in an MVC.

TABLE 6. Associations Between Clinical and Demographic Characteristics of Children With Inflicted and Noninflicted TBI and Outcome Among Surviving Children (n = 112)

	Poor Outcome (n = 37)		Good Outcome* (n = 75)		RR	95% CI
	n	%	n	%		
Injury type						
Inflicted	28	75.7	34	45.3	1.5	1.2–1.9
Noninflicted	9	24.3	41	54.7	1.0	Referent
Age						
>1 y	13	35.1	10	13.3	1.7	1.0–2.7
≤1 y	24	64.9	65	86.7	1.0	Referent
Gender						
Male	24	64.9	43	57.3	1.1	0.9–1.4
Female	13	35.1	32	42.7	1.0	Referent
Prematurity						
Yes	2	5.4	9	12.0	0.8	0.6–1.1
No	32	86.5	63	84.0	1.0	Referent
Missing	3	8.1	3	4.0		
Injury severity						
Severe	14	37.8	2	2.7	6.2	1.7–22.8
Moderate	21	56.8	73	97.3	1.0	Referent
Missing	2	5.4	0	0		
CPR						
Yes	10	27.0	7	9.3	1.8	1.0–3.2
No	24	64.9	69	90.7	1.0	Referent
Missing	2	5.4	0	0		
Loss of consciousness at presentation						
Yes	11	29.7	6	8.0	2.1	1.1–4.0
No	24	64.9	69	92.0	1.0	Referent
Missing	0		2	5.4		
Seizure						
Yes	25	67.6	20	26.7	1.9	1.4–2.7
No	10	27.0	55	73.3	1.0	Referent
Missing	2	5.4	0	0		
Other organ injuries than head injury						
Yes	4	10.8	3	4.0	1.6	0.7–3.9
No	31	83.8	72	96.0	1.0	Referent
Missing	2	5.4	0	0		

* Good outcome was defined as a POPC score of 1 or 2; poor outcome was defined as a score of 3, 4, or 5.

TABLE 7. Binomial Regression Analysis Examining the Risk of a Poor Outcome* Among Surviving Children Who Were Admitted to a PICU With a TBI After Adjustment for All Other Covariates

	Unadjusted RR	95% CI	Adjusted RR	95% CI
Inflicted vs noninflicted TBI	1.5	1.2–1.9	1.2	0.6–2.6
Seizures (yes)	1.9	1.4–2.7	3.0	1.4–6.3
Loss of consciousness	2.1	1.1–4.0	1.9	1.3–2.9

* Good outcome was defined as POPC score of 1 or 2; poor outcome was defined as a score of 3, 4, or 5. Seizures and loss of consciousness were the only covariates included in this model because no other covariates changed the effect estimate for injury type (inflicted vs noninflicted) by 10% or greater.

It is important to note that although skeletal survey would have been helpful in making a diagnosis in 41 (51.3%) of the inflicted TBI group, presence of fracture alone did not differentiate inflicted and noninflicted TBI well. A combination of ophthalmologic examination and skeletal survey still would have missed 8 (10%) cases. These data support previous recommendations that clinicians with an index of suspicion high enough to order a skeletal survey to rule out abusive injury should also consider imaging of the head by CT and/or MRI in young children.[21]

Children with inflicted TBI have been reported to have worse short- and long-term outcomes than children with noninflicted TBI.[4,22] However, children of similar ages and injury severity with inflicted and noninflicted injuries have not been previously compared. The results of this study confirm the finding of worse outcome among children with inflicted TBI and suggests that increased risk of seizures and loss of consciousness at the scene of the injury are key reasons for this difference.[23] This is in concordance with the work of Ewing-Cobbs et al,[4] who found that children with inflicted TBI had worse short term outcomes as measured by the Glasgow Outcome Scale[24] than children with noninflicted TBI.

Children with inflicted injuries tended to be symptomatic on presentation as compared with children with noninflicted injuries and tended to have a higher frequency of cerebral edema, anoxic/ischemic damage, and hydrocephalus on radiographic examination. These findings would support the hypothesis that children with inflicted injuries have a delayed presentation for medical care compared with children with noninflicted injuries, which may be partially explanatory of their worse outcomes. However, because of the difficulty in knowing the exact timing of a shaking event and because nearly one third of children with inflicted injuries have documented previous injury, we cannot state this with certainty.

This study has several limitations. First, it examined only children who were admitted to a monitored unit. Therefore, the children with inflicted TBI probably presented for care with more severe symptoms than many children who present for care with inflicted TBI. There was no standardized history performed on each child in this study. We relied on medical records, including the emergency medical system records, the hospital chart, and the OCME. The differences in how the presenting complaint was recorded may have differed by history taker but probably not in a systematic manner. However, documentation of injuries may have been better in children once inflicted injury was suspected because of the legal ramifications. The ophthalmologic findings in this study are incomplete. Most children with a noninflicted TBI did not receive an ophthalmologic examination unless there was concern about the eye or the diagnosis was in question. We were unable to obtain photographs of all of the children's retinal examinations and have them evaluated by an ophthalmologist who was unaware of the clinical history. Therefore, a direct comparison of the eye examinations of the inflicted and noninflicted TBI children could not be done. Finally, the follow-up in this study is short term. Although the POPC has been correlated with longer term outcomes, there is a paucity of data on long-term outcomes of children who survive TBI at a very young age.

CONCLUSION

Children with inflicted TBI had several features that distinguished them from children with noninflicted TBI. They were more likely to present to the clinician with symptoms, a history of trauma was rarely revealed, and retinal hemorrhages and metaphyseal and rib fractures were more common. When clinicians have a suspicion of inflicted TBI, skeletal survey and direct ophthalmoscopy can be helpful in making the diagnosis but will still miss some children. Clinicians with a high degree of suspicion for inflicted injury should proceed to CT and/or MRI.

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