

Analysis of Perpetrator Admissions to Inflicted Traumatic Brain Injury in Children

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Background: Scientific and courtroom debate exists regarding the timing of onset of symptoms and the mechanism of injury in infants and children with inflicted traumatic brain injury (ITBI).

Objectives: To determine the time interval between ITBI and the onset of symptoms and to explore the mechanism of ITBI.

Design, Setting, and Patients: Retrospective review of all cases of pediatric ITBI admitted between January 1, 1981, and July 31, 2001, to a large academic medical center and cases admitted to 2 additional academic institutions between January 1, 1996, and August 31, 2000, and January 1, 2001, and July 31, 2001, comparing 81 cases of ITBI in which perpetrators admitted to abuse with 90 cases in which no abuse admission was made. The patients with perpetrator admissions to ITBI consisted of 53 boys (65%) and 28 girls (35%). Their ages ranged from 2 weeks to 52 months.

Main Outcome Measures: Characteristics associated with perpetrator admissions to ITBI in children.

Results: Shaking was the most common mechanism of injury among all cases with perpetrator admissions: 55 (68%) of the 81 perpetrators admitted to shaking the children. Impact was not described in 44 (54%) of the 81 cases. In cases in which only impact was described, 60% (12/20) of the children showed skull or scalp injury, compared with 12% (4/32) with skull or scalp injury in the shake only group. In 52 (91%) of 57 cases in which the time to the onset of symptoms was described, symptoms appeared immediately after the abuse. In 5 cases (9%), the timing of symptoms was less clear, but they occurred within 24 hours. None of the children were described as behaving normally after the event.

Conclusions: The symptoms of inflicted head injury in children are immediate. Most perpetrators admitted to shaking without impact. These data, combined with the relative lack of skull and scalp injury, suggest that shaking alone can produce the symptoms seen in children with ITBI.

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INFLICTED TRAUMATIC BRAIN INJURY (ITBI) is a leading cause of death and disability in young children.¹⁻⁶ While many descriptive studies of ITBI have been published, questions remain regarding the timing and mechanism of injury. Although studies^{7,8} have identified the perpetrators of abusive head trauma, none have focused primarily on information provided by admitted perpetrators.

The determination of the timing of an abusive event is critical for investigators attempting to determine the identity of a perpetrator. Because initial histories often are falsified or minimized, the historical timing of injury is obscured. In a study of 95 cases of accidental head injury, Willman et al⁹ found that 94 children experienced immediate symptoms after sustaining their injuries. Their conclusion was

that the symptoms of severe head injury are immediate.⁹ In a study by Starling et al,⁷ 36 of 37 confessed perpetrators were with the child when the symptoms began, supporting the conclusion that the symptoms of ITBI are immediate.

Debate continues regarding the exact mechanism of ITBI in children. Whether shaking alone can cause the severe intracranial injury associated with the condition known as shaken baby syndrome is a topic of considerable debate. Duhaime and colleagues¹⁰ concluded that blunt impact was necessary to cause the intracranial injuries seen in shaken baby syndrome. However, Alexander et al¹¹ reported that the intracranial injuries seen in patients with no evidence of external trauma were of equal severity to those found in patients in whom direct head trauma was observed, concluding that shaking alone could cause these injuries.

The analysis of perpetrators' admissions of ITBI can be used to evaluate the timing and mechanisms of injury. In this study, cases in which perpetrators admitted to ITBI were examined to elucidate the length of the time interval between injury and the onset of symptoms and to better understand the mechanisms of ITBI. In many cases, the perpetrators admitted to injuring the children, but did not give detailed confessions of abuse.

METHODS

The medical records of hospitalized head-injured children at 3 academic medical centers were reviewed: The Children's Hospital, University of Colorado Health Sciences Center, between January 1, 1981, and July 31, 2001; Vanderbilt University Medical Center, Nashville, Tenn, between January 1, 1996, and August 31, 2000; and the Children's Hospital of The King's Daughters, between January 1, 2001 and July 31, 2001. Institutional review board-approval was obtained at each center before the project onset. Cases of ITBI were identified by each hospital's child abuse evaluation team using the following criteria: child younger than 5 years with radiological evidence of intracranial bleeding and no history of trauma explaining the findings and either retinal hemorrhages or associated noncranial injuries considered highly concerning for abuse, such as fractures or bruising. Perpetrators' admissions to inflicted head trauma also were used as evidence that the injuries were abuse related. Cases in which there were perpetrator admissions to some or all of the injuries were included in the study. Data extracted included information regarding the nature, timing, and mechanism of injury; relevant medical and social histories; and case outcomes. Perpetrators of ITBI who did not admit to abuse were used as a comparison group. Perpetrators in the nonadmitting comparison group were identified by various methods, including whether they were the primary suspect in a criminal investigation.⁷

Categorical variables were described using frequencies. Differences between the admission and control groups were compared using χ^2 analysis. Continuous variables were tested for normality using the Shapiro-Wilk test, and were described using the median and range when the data were nonparametric and the mean and standard error when the data were normally distributed. Nonparametric continuous variables were compared between groups using the Wilcoxon rank sum test, and normally distributed variables were compared using the *t* test. Simple and multiple logistic regression analyses were used to identify crude and independent predictors of admission. The Cramer V was used to measure the strength of the association between nominal variables and admission group. The Cramer V takes a value of 0 when there is no correlation and 1 when the variables are perfectly correlated. $P < .05$ indicated significance. The McNemar test was conducted to determine any difference in agreement between perpetrator-reported symptoms and those noted on admission. The data were analyzed using SAS statistical software, version 8.0 (SAS Institute Inc, Cary, NC).

RESULTS

A total of 628 head-injured patients were screened, with 453 cases of ITBI identified using the criteria described. Of these cases, suspected or admitted perpetrators could be identified in 171 (38%). Perpetrators admitted to abuse in 81 cases; and in 90 cases, no admission was made. All cases with a perpetrator admission had evidence of intracranial bleeding, including 80 (99%) of the 81 chil-

Table 1. Relationship of Perpetrators to Children*

Perpetrator's Relationship to the Child	Perpetrators Admitted to the Abuse	
	Yes (n = 81)	No (n = 90)
Mother of child	12 (15)	11 (12)
Father of child	45 (56)	32 (36)
Mother's boyfriend	13 (16)	17 (19)
Baby-sitter	4 (5)	27 (30)
Other	7 (9)	3 (3)

*Data are given as number (percentage) of each group. Percentages may not total 100 because of rounding.

dren with an acute and/or chronic subdural hematoma and 1 child with an isolated subarachnoid hemorrhage. Of the 81 children, 67 (83%) had both intracranial bleeding and retinal hemorrhages. Twelve children (15%) had intracranial bleeding with other abuse-related injuries, but no retinal hemorrhages, on presentation. Two children (3%) had intracranial bleeding with perpetrator admission, but no retinal hemorrhages or other injuries. Thirty-two (40%) of the children had intracranial bleeding, abuse-related injuries, and retinal hemorrhages. The demographic information of the 81 children (mean age, 3.5 months; age range, 0.5-52.0 months) who experienced ITBI by admitted perpetrators is summarized as follows:

Characteristic	No. (%) of Children
Sex	
Female	28 (35)
Male	53 (65)
Condition at discharge*	
Normal	8 (10)
Impaired	57 (71)
Died	15 (19)
Acute subdural hematoma	73 (90)
Retinal hemorrhages	67 (83)

*One child had an unknown discharge condition.

Of the perpetrators admitting to inflicted injury, the most common perpetrator was the father, followed by the mother's boyfriend, and then by the mother (**Table 1**). Few baby-sitters admitted to injuring the children, with a frequency 14 times less that of the parents. Most of the perpetrators lived with the child (mother, 11 [92%] of 12; father, 38 [84%] of 45; or mother's boyfriend, 11 [85%] of 13). Although most (59% or 48 of 81) of the children lived with both parents, perpetrators were alone with the child at the time of injury in 67 (91%) of 74 cases. In the remaining 7 cases (9%), whether the perpetrator was alone with the child could not be determined.

The most common initial symptoms reported by the admitted perpetrators were loss of muscle tone ("became limp") (n=29), seizures (n=25), vomiting (n=24), lethargy (n=23), and apnea (n=21). Some perpetrators reported more than 1 symptom occurring simultaneously. Seizures and lethargy were the 2 most common symptoms noted by medical staff at the time of the hospital admission.

No significant differences were seen between symptoms as reported by the perpetrators and those noted on

hospital admission, including seizures, lethargy, fussiness or crying, and respiratory or cardiac arrest. Of the 81 cases examined, 58 (72%) had agreement between the hospital and perpetrator on the presence of symptoms consistent with seizures; in 8 children (10%), seizures were noted by the perpetrator but not on hospital admission; and in 15 children (19%), seizures were noted on hospital admission but not by the perpetrator ($P=.14$). Of the 81 cases, there was agreement that the patient was lethargic for 46 (57%); for 16 children (20%), lethargy was noted only by the perpetrator but not on hospital admission; and for 19 children (24%), lethargy was noted only on hospital admission but not by the perpetrator (percentages do not total 100 because of rounding) ($P=.61$). For 64 (79%) of the cases, there was agreement that the patient was fussy or crying; for 8 children (10%), fussiness was noted by the perpetrator but not on hospital admission; and for 9 children (11%), crying was noted on hospital admission but not by the perpetrator ($P=.81$). For 68 (84%) of the cases, there was perpetrator and hospital agreement that the patient was in respiratory or cardiac arrest; for 7 children (9%), respiratory arrest was noted by the perpetrator but not on hospital admission; and for 6 children (7%), respiratory arrest was noted on hospital admission but not by the perpetrator ($P=.78$).

In 69 of the 81 cases with perpetrator admissions to ITBI, enough information was provided to define the historical mechanism of ITBI. Twenty perpetrators admitted only to impact without shaking. In 17 of these children, acute subdural hematomas were present; and in 14, retinal hemorrhages were noted. Eight of these children had skull fractures and an additional 4 had scalp swelling. Admissions of impact for these 20 patients included being struck by an object or slapped ($n=8$), being thrown onto a hard surface such as the floor ($n=6$), being thrown to a soft surface ($n=3$), being dropped ($n=2$), and

being hit against an object ($n=1$). In contrast, 32 perpetrators admitted to only shaking. Among these children, skull fractures were noted in only 2, and scalp swelling in 2 others. In children with only admitted shaking, subdural hematomas were noted in 29 and retinal hemorrhages were present in 27. Seventeen perpetrators admitted to a combination of shaking and impact (**Table 2**).

No relationship was found between the mechanism of injury to which the perpetrator admitted (impact only, shaking only, or impact and shaking) and the condition of the child at hospital discharge ($P=.58$) (**Table 3**). Also, no correlation was noted between the mechanism of injury and initial symptoms noted by the perpetrator, such as seizures (Cramer $V=0.14$), apnea (Cramer $V=0.16$), respiratory arrest (Cramer $V=0.04$), or respiratory distress (Cramer $V=0.02$). Similarly, there was no correlation between the mechanism of injury and the symptoms noted on hospital admission.

The period between injury and the onset of symptoms was documented, and could be ascertained in 57 of the 81 cases with perpetrator admissions to ITBI. In 52 (91%) of these cases, perpetrators indicated that symptoms appeared immediately after the abuse (**Figure**). In the remaining 5 cases (9%), the perpetrators' statements tangentially addressed timing issues regarding the abusive event, but the exact time was not specified. In 3 of these cases, the children were not observed for up to 6 hours after injury, but when next observed were severely symptomatic. In the remaining 2 cases, the parents' history changed substantially over time and/or did not include specific information regarding the timing of onset of symptoms. In both of these cases, however, the perpetrator provided sufficient information to conclude that the injured child became ill no later than 24 hours after the injury.

Table 2. Comparison of Injuries by History Among the 69 Children Whose Perpetrators Admitted to Inflicting Traumatic Brain Injury*

Type of Injury	Impact Only (n = 20)	Shaking Only (n = 32)	Impact and Shaking (n = 17)
Subdural hematoma	17 (85)	29 (91)	17 (100)
Retinal hemorrhage	14 (70)	27 (84)	16 (94)
Skull fracture	8 (40)	2 (6)	3 (18)
Scalp swelling	4 (20)	2 (6)	2 (12)

*Data are given as number (percentage) of each group.

Table 3. Comparison of Patient Outcome With Mechanism of Injury Among the 68 Children Whose Perpetrators Admitted to Inflicting Traumatic Brain Injury*

Patient Outcome	Impact Only	Shaking Only†	Impact and Shaking	Total
Died	4 (20)	5 (16)	4 (24)	13 (19)
Impaired	12 (60)	24 (77)	11 (65)	47 (69)
Healthy	4 (20)	2 (6)	2 (12)	8 (12)
Total‡	20 (25)	31 (46)	17 (29)	68 (100)

*Data are given as number (percentage) of the total of each column unless otherwise indicated.

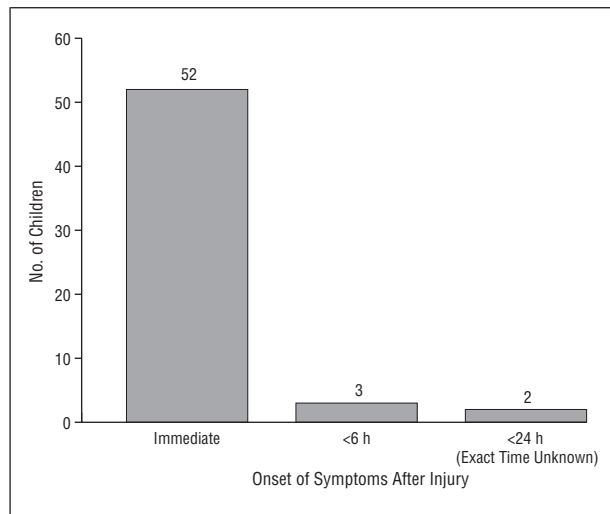
†One child in this group had an unknown outcome and is not included in this analysis.

‡Data are given as number (percentage) of 68 children.

COMMENT

The determination of the timing of injury is critical to the investigation of ITBI, and physicians are frequently asked to comment on these issues. Although argument will be made that perpetrator admissions are not reliable scientific evidence, such statements constitute the only witnessed accounts available for analysis. When the reported symptoms noted by the perpetrators were compared with those seen at hospital admission, no significant differences were noted.

Most perpetrators in this study reported that symptoms appeared immediately after the injury was in-



Timing of onset of symptoms after injury in 57 of the 81 children with perpetrator admissions to inflicted traumatic brain injury.

flicted. The 5 cases in which the symptoms seem to have been delayed all involved children who were not observed closely in the immediate period after their injuries. These results suggest that children do not behave normally immediately after inflicted intracranial injury, and confirm recent studies¹²⁻¹⁴ showing immediate onset of symptoms in children who sustain primary head injury. A history in which the child initially was behaving completely normally and only later developed symptoms is, therefore, unlikely.

In the 69 cases of admitted shaking and/or impact in which perpetrator admission data could be analyzed, 49 offenders admitted to some form of shaking. Thirty-two perpetrators in the study admitted only to shaking the children, with no account of impact given. Only 4 of the cases of perpetrators with admissions to shaking alone had evidence of impact, indicating incomplete admissions to the mechanism of injury. Children with only admitted shaking were 2.39 times more likely to have retinal hemorrhages than those who had only admitted impact, suggesting that shaking is more likely to cause retinal hemorrhages than impact. Although undisclosed impact cannot be ruled out, our data support the position that shaking alone can cause symptoms of ITBI.

In contrast, in the 20 cases in which the perpetrators admitted impact without shaking, trauma resulted in acute subdural hematomas in 17 children (85%) and retinal hemorrhages in 14 children (70%). These data suggest that impact alone can cause subdural and retinal hemorrhages. Impact may cause violent rotational acceleration or deceleration of the head, leading to noncontact subdural hematomas typically associated with rotational head injury.¹⁵⁻¹⁷ To our knowledge, linear impact without head rotation has not been associated with these findings. Children with linear falls resulting in cranial impact rarely sustain retinal hemorrhages. In those cases, the hemorrhages tend to be few and limited to the posterior pole.¹⁸⁻²² Many reports^{3,23-25} refute the association of accidental head injury with extensive retinal hemorrhages.

The discrepancy between examination findings and history may be accounted for by the fact that perpetra-

What This Study Adds

There has been debate in the field of child maltreatment for many years regarding the mechanism of injury in ITBI and whether impact is necessary to produce the clinical findings. Another debated issue involving ITBI is the determination of the timing of injury, which can be critical for physicians treating the child and investigators attempting to determine the identity of a perpetrator. An analysis of perpetrator admissions to inflicted injury in children provides a unique insight into the mechanism and timing of injury.

This study supports research showing that the onset of symptoms in children with ITBI is immediate. It also supports the position that shaking alone produces the symptoms seen in ITBI. Physicians treating these children will have a more accurate understanding of the timing and mechanism of injury to provide appropriate medical care for the children and more accurate information to investigators.

tor admissions may be inaccurate or incomplete, either purposefully or inadvertently recalling only a portion of the history. Many of these admissions may contain only partial descriptions of the events, including details that may meet the minimum requirement for the legal prosecution but lack detailed descriptions necessary for biomechanical evaluation.

There seems to be no correlation between the mechanism of injury admitted by perpetrators and the initial symptoms on presentation. Children who were reportedly shaken appeared similar to those who were reportedly both shaken and impacted or impacted alone. The most commonly reported symptoms exhibited by the children after their injuries were limpness, seizures, vomiting, lethargy, and apnea. These findings are similar to those reported by Johnson and colleagues²³ in 1993. Seizures and lethargy were the 2 most common symptoms noted by physicians at admission to the hospital. If a previously healthy child presents with a history of sudden decrease in consciousness or seizures and no history of injury, a physician should consider ITBI in the differential diagnosis.

The primary limitations of the study involve the reliability of perpetrator admissions. Many statements were made to investigators, and an argument could be made that the perpetrators were coerced in some manner or that mechanisms were suggested to them. An analysis of the investigative techniques involved in eliciting the admissions is beyond the scope of this article.

In conclusion, this study supports the theory that onset of symptoms is immediate in children with ITBI. In this series of analyzable cases of ITBI, 91% of the perpetrators reported immediate onset of symptoms after the injuries occurred. The perpetrators did not report normal child behavior following the injury in any case. In addition, 49 (73%) of the 69 perpetrators admitted to some form of shaking injury to the children, with 32 (59%) not describing any impact at all. This suggests that shaking alone is able to produce the symptoms seen in ITBI.

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