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Nonaccidental head trauma as a cause of childhood death

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Object. The authors present the demographic and clinical information in 36 children who died as a result of abusive head trauma at a Level 1 pediatric trauma center between January 1, 1997, and January 1, 2004.

Methods. Abusive head trauma was defined as radiographic evidence of intracranial injury and documentation from a multidisciplinary child protection team that the injury was nonaccidental. There was no sex bias for the children in the 1st year of life (nine girls, nine boys). In children older than 1 year of age, boys were much more likely to be victims (14 boys, four girls). At the time of admission, every child exhibited a seriously impaired level of consciousness and 81% had retinal hemorrhages. Injuries to other organ systems were rare (17%). The most common abnormality found on neuroimaging studies was subdural hematoma. Six children underwent craniotomy for extraaxial hematomas. Death occurred within 24 hours after hospital admission in one half of the cases.

Conclusions. Abusive head trauma was the cause of death in 36 (86%) of the 42 children whose deaths were classified as nonaccidental at the Children's Hospital in Denver between 1997 and 2003. The authors were unable to identify anything that could have been done from a medical or neurosurgical viewpoint to prevent the deaths of these children after they came to medical attention.

KEY WORDS • infanticide • nonaccidental trauma • child abuse • clinical feature • pediatric neurosurgery

CHILD abuse is a broad category that contains emotional, sexual, and physical maltreatment. A population within the physically abused category includes children with an inflicted brain injury. A subset of children in this group ultimately die as a result of their brain injuries, and little has been published about them. Authors of a 2005 study compared the initial GCS scores of children who died of both inflicted and unintentional fatal head injuries, but this study was limited to discussion of GCS scores only.[1] The purpose of this paper is to provide patient and guardian demographics, presenting complaints, injuries observed, radiographic results, operations performed, timing of death, and cause of death in children with fatal abusive head trauma admitted to a Level 1 pediatric trauma center.

Clinical Material and Methods

Data concerning all children (age range 0–18 years) who died as a result of abusive head trauma at The Children's Hospital in Denver between January 1, 1997, and January 1, 2004 form the basis of this report. Abusive head trauma was defined as clear neuroimaging evidence of intracranial injury (on CT scans and/or magnetic resonance images) as well as documentation from a multidisciplinary child protection team that the injury was inflicted. Although clearly brain injured, children with nonaccidental death due to hypoxia (that is, smothering) were excluded from this study unless there was also evidence of significant mechanical trauma to the cranium. Thirty-six of the 42 nonaccidental deaths that occurred at this institution within the designated time span met our criteria for inclusion. The available medical records, neuroimages, and trauma databases were reviewed. In some cases, newspaper articles were used to identify perpetrators who were arrested or convicted of the abuse. The perpetrator is defined as a person who confessed or was convicted of the crime. Also included in this study were two perpetrators who were arrested and awaiting trial with significant evidence against them. Our child protection team consists of social workers, nurse clinicians, and a physician who specializes in child abuse. Cases in which an alleged perpetrator was charged, tried, and found innocent were classified as "perpetrator unknown." This is not a population-based study, and it was done with the approval of the Colorado Multiple Institutional Review Board (Protocol No. 4-0143).

Abbreviations used in this paper: CT = computerized tomography; GCS = Glasgow Coma Scale.

Results

Patient Demographics

Thirty-six patients met the criteria established for inclusion in this study. The mean age of the children in this study

was 11.5 months for girls and 23 months for boys (Table 1). Half of the children were younger than 1 year of age. There was no sex predilection for abuse in children in the 1st year of life (nine girls, nine boys). Boys older than 1 year of age were much more likely to be victims (14 boys, four girls). For the entire group, there was an approximate 2:1 male predominance (13 females, 23 males). Two children in this study had been removed from their homes for previous issues of abuse and were subsequently returned.

Demographics of Perpetrators and Reporters of Abuse

Women were slightly more likely (20:17) to bring the injured child to medical attention (call for help or bring the child to a healthcare facility) than were men (Table 2). Most frequently, the person bringing a child to medical attention was a biological parent or parent figure, and this person was almost equally likely to be male or female (15:17). Fourteen of the 22 biological parents who brought a child to medical attention were biological mothers. Twenty-seven of the inflictors were male and three were female; therefore women were much more likely to report the event, even though they were much less often the perpetrators (Table 3). Biological fathers and other father figures accounted for 24 (80%) of the 30 perpetrators. Of the 30 identified perpetrators 13 (43%) were also the reporters of the event (Table 4).

Complaint at Presentation

The most common complaint was apnea and/or pulselessness. Observed trauma was the chief complaint in only one case (Table 5). The mean age of the 22 apneic patients was 11 months. When it was available, the mean arterial pH at admission (generally obtained after resuscitation and intubation) was 7.28 (25 patients). Two of the children (19 and 44 months of age) who presented with apnea had a fractured skull. At the time of admission, every child had a decreased level of consciousness, and 81% had retinal hemorrhages (Table 6). Forty-seven percent of patients were coagulopathic, which is a slightly smaller proportion than in a previous report.[16] Approximately two thirds of the children had coagulation studies available for review. The mean GCS score at the first medical facility was 3.9 (Table 7). Seventy-five percent of our patients had GCS scores of 3 (range 3–9). The score did not usually improve after hospitalization and resuscitation.

Abnormalities Demonstrated on Imaging Studies and Skeletal Surveys

The most common abnormality on imaging studies was subdural hematoma (89%); the locations were most often intrahemispheric, tentorial, and at the posterior occipital convexity (Table 8). A few patients had evidence of acute hemorrhage into chronic subdural hematomas. Evidence for diffuse axonal injury was not assessed in this study because this is difficult to identify on CT scanning, the main method of imaging we used. Skeletal surveys demonstrated rib fractures in 14% of the children. Multiple organ injury was not apparent in most victims; only 17% had evidence of significant noncranial injury (Table 9). All children in this study underwent detailed ophthalmological examinations and complete skeletal surveys.

Operations and Invasive Procedures

Six children in this series underwent craniotomy for ex-

TABLE 1

Distribution of children in this study by age and sex

Age	No. of Cases		
	Female	Male	Total
0–1 mos	2	2	4
1–3 mos	5	3	8
3–6 mos	2	2	4
6–12 mos	0	2	2
1–2 yrs	1	5	6
2–5 yrs	3	8	11
5–10 yrs	0	1	1
total	13	23	36

TABLE 2

Person bringing child to medical attention

Reporter	No. of Reports		
	Male Victim	Female Victim	Total
male			
biological father	4*	4	8
other father figure	6†‡	1	7
other relative	0	1	1
babysitter	1	0	1
other person	0	0	0
subtotal	11	6	17
female			
biological mother	9*‡	5	14
other mother figure	2†	1	3
other relative	0	0	0
babysitter	2	0	2
other person	1	0	1
subtotal	14	6	20
unknown	1	1	2
total	26	13	39

* One child reported by both biological parents.
† One child reported by both foster parents.
‡ One child reported by biological mother and other father figure (boyfriend).

TABLE 3

Distribution of perpetrators of injury by sex of child and person bringing child to medical attention

Perpetrator	No. of Perpetrators		
	Male Victim	Female Victim	Total
male			
biological father	4	7	11
other father figure	11	2	13
other relative	1	1	2
babysitter	1	0	1
other person	0	0	0
subtotal	17	10	27
female			
biological mother	0	1	1
other mother figure	0	0	0
other relative	0	0	0
babysitter	2	0	2
other person	0	0	0
subtotal	2	1	3
unknown	4	2	6
total	23	13	36

TABLE 4

Distribution of reporters who were perpetrators

Perpetrator	No. of Cases
male	
biological father	4
other father figure	7
babysitter	0
female	
biological mother	1
other mother figure	0
babysitter	1
total	13

traaxial hematoma. The subdural hematomas in most of the children were not of significant size to require evacuation. Two children died intraoperatively of exsanguination (one of intracranial bleeding and one of multiple sites, including intracranial bleeding). Another child required multiple intraoperative cardiopulmonary resuscitations and survived only a few hours after surgery (Table 10). Four children underwent thoracic or abdominal surgery.

Delay Between Injury and Treatment

The interval between injury and arrival at the pediatric trauma center was unknown for nearly half of the children because the timing of the trauma could not be established. Often, no definitive traumatic event could be identified or the reports conflicted. In the 18 children in whom the timing of the trauma could be established with reasonable confidence, 16 arrived at the trauma center within 12 hours (Table 11). Death occurred within 24 hours after hospital admission in one half of the cases (Table 12). Fourteen of the children who survived beyond 24 hours died within the next 6 days because care was considered futile and was withdrawn. All of the children who survived beyond 1 week were recognized much earlier to be terminally ill; two were discharged to hospices after being extubated. The primary cause of death in 31 of the 36 children was withdrawal of care and brain death declaration (Table 13).

Discussion

Cranial trauma accounts for most nonaccidental deaths in children.[10,22] Abusive head trauma was the cause of death in 36 (86%) of 42 of the nonaccidental deaths at the Children's Hospital in Denver in the period between 1997 and 2003. Given the critical condition of the children on arrival at the hospital and the documented interval between the trauma and the time of first medical attention, it seems reasonable to believe that the caretakers involved, perhaps even those who eventually brought the children to medical attention, delayed in doing so. Only 17% of the victims arrived at the hospital in fewer than 3 hours after the lethal injury. This issue of delay in seeking care is often contested in the medical literature and in court. It is argued that the child may have had a lucid interval after the injury and care was sought only after deterioration of the child's condition.[6] Others doubt this claim and state that these children are symptomatic immediately after the abusive event.[30] Establishment of the timing of the initial event and the subsequent clinical picture of the victims in the moments before they enter the medical system will continue to be an area of debate. The exact time of trauma could not be determined in 17 (47%) of the 36 patients.

One half of the 36 children died within the first 24 hours of admission and 86% died within 1 week. Children who died within the 1st day were either in a state of brain death on arrival or died in the operating room. Some children determined to be brain dead received life support until a sec-

TABLE 6

Injuries identified at time of admission

Type of Injury	No. of Cases
altered level of consciousness	36
anisocoria	15
bite marks (human)	0
bruising	
extremity	9
head	17
trunk	12
burns	1
coagulopathy	17
dehydration	1
evidence of poor nutrition	1
hemiparesis	0
retinal hemorrhage	29
sexual assault	2

TABLE 5

Chief complaint by person bringing child to medical attention

Reporter	Altered Consciousness	Seizure	Apnea &/or No Pulse	Observed Trauma	Gunshot Wound	Total No. of Cases
male						
biological father	1	0	7*	0	0	8
other father figure	1†	0	8‡	0	0	9
babysitter	0	0	0	1	0	1
female						
biological mother	5	2	6*‡	0	0	13
other mother figure	1†	1	1	0	0	3
babysitter	1	1	2	0	0	4
unknown	0	0	0	0	1	1
total	9	4	24	1	1	39

* One child reported by both biological parents.
† One child reported by both foster parents.
‡ One child reported by biological mother and other father figure.

TABLE 7

Distribution of initial GCS scores in 36 patients

GCS Score on Arrival	No. of Cases (%)
3	27 (75.0)
4	2 (5.6)
5	1 (2.8)
6	2 (5.6)
7	1 (2.8)
8	0 (0)
9	1 (2.8)
not recorded	2 (5.6)

ond confirmatory examination or test could be performed, and this may have been well beyond 24 hours of admission. Children who died between 1 and 7 days after admission had devastating neurological injuries that were clearly apparent, but the declaration of brain death was often not possible because of the retention of a brainstem reflex. These children were not removed from life support until a multidisciplinary team agreed that continuing support constituted futile care.

Nonaccidental Head Trauma in the US

At least 280 to 479 children die of nonaccidental head trauma in the US each year. The first number is from a population-based study in North Carolina in 2000, which found 17 serious or fatal inflicted brain injuries per 100,000 persons in children younger than 2 years of age, with a fatality rate of 22% (3.74 deaths per 100,000).[21] Considering that there were 7.62 million children younger than 2 years of age in the US in 2000 (http://www.census.gov), and assuming that the fatality rate for abusive head trauma in North Carolina (22%) is representative of the US,[23] then 280 deaths would occur each year from abusive head trauma.[15] Unfortunately, death resulting from abuse is not always recorded as such in official records.[5] The higher number of deaths (479) takes into account children ranging in age from neonates to teenagers. The National Child Abuse and Neglect Data System estimated that there were 1400 child fatalities in 2002 from child abuse and neglect. Physical abuse alone or physical abuse combined with other forms of abuse accounted for 48.9% of these deaths. The percentage of deaths from head injury as a subset of physical abuse deaths is 45

TABLE 8

Abnormalities identified in 36 patients on imaging studies

Type of Structural Injury	No. of Cases (%)
skull fracture	
nondepressed	8 (22.0)
depressed	0 (0.0)
cerebral contusion	2 (5.6)
hematoma	
subgaleal	2 (5.6)
epidural	3 (8.3)
subdural	32 (88.9)
intraparenchymal	3 (8.3)
blood in subarachnoid	14 (38.9)
fractures (not cranial)	
rib	5 (13.9)
extremity	0 (0.0)
vertebral	0 (0.0)

TABLE 9

*Distribution of injuries by organ system**

No. of Organ Systems Injured	No. of Cases
1 (brain)	30
2 (brain, lung)	3
3 (brain, GI, kidney)	2
5 (brain, spleen, kidney, lung, GI)	1

* GI = gastrointestinal tract.

to 70%, or 308 to 479 deaths per year.[4,22] This number is likely underestimated because the data were received from child protection services in each state and these agencies may not be involved in cases of child fatalities due to abuse, unless there are other children living in the same home.

Sex Differences in Reporting and Committing Child Abuse

Male and female caretakers were approximately equally likely to bring the injured child to medical attention (17 men compared with 20 women), but mother figures did so more often than father figures (including boyfriends, 11 women compared with two men). Considering that the chief complaint by the person bringing the child to medical attention was usually dire—apnea or pulselessness in 24 children and an altered level of consciousness in nine—the nearly equal sex representation of persons reporting probably reflects whoever was present to sound the alarm in the face of an obvious crisis.

The male-inflictor predominance of 9:1 in our sample corresponds to the sex difference for violent crimes in society. Men are more likely to commit all types of violent crimes than are women (11.6 per 100,000 compared with 1.2 per 100,000).[7] Gender socialization, limited exposure to childcare and childcare role models, less education in normal child development, emphasis on toughness and aggressiveness, and less verbal skill have been blamed for the male predilection for child abuse.[3,9] Some of these are likely the same risk factors for the commission of many other violent crimes. Men may simply commit more child abuse for many of the same reasons that they commit more violent crimes of any other type.

Sex Differences in Victims

Male children are much more likely to be killed (23 boys compared with 13 girls in this series) by nonaccidental head trauma, and this predominance has been reported repeat-

TABLE 10

*Operations and other invasive procedures undergone by trauma victims**

Procedure	No. of Cases
craniotomy	6
drainage of subdural fluid	2
ventriculostomy	2
intracranial pressure monitor insertion	12
abdominal surgery	1
extremity surgery	0
thoracic surgery	3

* Excluding vascular access procedures and tracheal intubation.

TABLE 11

Interval between injury and arrival at The Children's Hospital in 36 patients

Interval (hrs)	No. of Cases
<1	3
1–3	3
3–6	5
6–12	5
12–24	2
24–48	1
unknown	17

edly by other investigators, who could find no satisfying explanation.[2,8,14,20,21,24,29] Authors of reports from the 1960s and 1970s have suggested that men were more likely to abuse boys and women more likely to abuse girls, but this contention has not been subsequently supported.[19,26] Both men and women abuse children of both sexes at approximately the same rate.[8,28] Perhaps male babies are more likely to cry, or their cry is, for unknown reasons, more likely to provoke violent behavior. A leading cause of crying in infants is colic, but there is no sex predilection for colic to explain the male victim bias.[27]

Clinical Findings at Presentation

It was clear on arrival at the hospital that each of these children was critically ill. All 36 patients had a severely impaired level of consciousness, and apnea or cardiac arrest was apparent in 24 children. Seventy-five percent of the children had a GCS score of 3 when first assessed, and only two scored higher than 6. Although not assessed in many of the children, coagulopathy was present in 47%, which is consistent with the results of Hymel and colleagues.[16] The mean initial arterial pH in our patients was 7.29, a value probably influenced by initial efforts at resuscitation and by the hydration in some of the children.

Apnea has been reported in 34 to 77% of cases of nonaccidental head injury.[12,19,27] Its cause is not well understood, but recent reports have focused attention on the craniocervical junction and the cervical spinal cord.[13] At autopsy, Hadley, et al.,[13] found hemorrhages and contusions within the high cervical spinal cord in five of 13 patients with nonaccidental trauma. Geddes, et al.,[11] found localized axonal injury in the craniovertebral junction or the cervical spinal cord in 11 of 53 patients. Johnson, et al.,[18] found significant pathological conditions in the cervical spine of three of four children whose bodies underwent autopsy (atlantooccipital dislocation in the first patient, spinal cord contusion and laceration in the second, and cervical and thoracic subdural in the third). Speculation about the mechanism for apnea includes brainstem injury from direct craniocervical trauma, shaking, seizures, concussion, and cardiac and chest trauma.

TABLE 12

Interval between arrival at The Children's Hospital and death in 36 patients

Interval	No. of Cases
<1 day	18
1–7 days	14
1–2 wks	1
2–3 wks	1
3–4 wks	2

TABLE 13

Primary cause of death in 36 children with fatal nonaccidental cranial trauma

Cause of Death	No. of Cases
care withdrawn (futile care)	16
brain death declaration	15
exsanguination/coagulopathy	2
cardiac arrest	2
other or multiple organ injury	1

The trauma was not randomly distributed anatomically. The perpetrator focused the traumatic attention to the child's head. This finding raises the possibility that the perpetrator intended to inflict serious bodily injury or even to commit murder. This would be consistent with the observation that the nervous system was the only organ system that was seriously injured in most of the children in this study. Evidence of serious multisystem injury was the exception (Table 9). Cutaneous bruising was most common over the head. Most of the children (89%) had subdural hematomas. The combination of subdural hematoma and retinal hemorrhage was common, as has been found in other studies of nonaccidental trauma.[3,9,12,17,18,21,25,26]

Conclusions

Evidence for hypoxic brain injury was our most common finding on CT scans. Although the initial CT scan was not always diagnostic, the second often was. Initial suspicion of a partial or subtle loss of gray–white matter differentiation evolved rapidly into strong evidence for massive hypoxia and/or edema, with the characteristic "black brain" appearance. Significant extraaxial hematomas were demonstrated in a few patients; however, the majority had small subdural hematomas only. The most common locations for extraaxial hematomas were the subdural spaces over the tentorium, along the posterior falx, and over the cerebral convexities, as has been reported by others in studies of children with abusive head trauma.[24,31] Subdural hematoma was often associated with retinal hemorrhage, and this association has been noted by others in reviewing cases of nonaccidental trauma.[3,9,11,17,18,24,26,31] Relatively few (16%) of the intracranial hematomas in our series required surgical intervention.

The authors were unable to identify anything that could have been done from a general medical or neurosurgical viewpoint to prevent the deaths of these children after they came to medical attention.

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