The Cause of Infant and Toddler Subdural Hemorrhage: A Prospective Study

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ABSTRACT. *Objective.* **To determine the frequency of child abuse and unintentional injury as a cause of infant and toddler subdural hemorrhage (SDH).**

Methods. **A prospective case series of a level I regional trauma center, regional children's hospital, and county medical examiner's office assessed consecutive children who were ≤36 months old and had SDH. Children who had previously known hemorrhagic disease, previous neurosurgical procedure, previously recognized perinatal brain injury, meningitis, renal dialysis, and severe dehydration were excluded. Concurrent medical, retinal, skeletal, and social work abuse evaluation were measured. Etiologic assessment using predetermined criteria was conducted.**

Results. **From March 1995 through December 1998, 66 children were admitted with SDH. Abuse was confirmed in 39 (59%), unintentional injury in 15 (23%), and indeterminate cause in 12 (18%). The mean age of abused children was 8.7 ± 8.1 months and of children with unintentional injuries was 19.1 ± 10.0 months. The predominant presenting histories for abusive injury were a minor fall or no mechanism for 33 (84%) of 39 patients. All unintentional injuries resulted from a motor vehicle accident or other documented major trauma. Chronic or mixed acute and chronic SDH were found only in abused children (17 [44%] of 39) and in children whose injuries were indeterminate (8 [67%] of 12), not in children who were unintentionally injured (0 [0%] of 15). Long bone and/or rib fractures were found in 20 (51%) of 39 abused children but in only 1 unintentionally injured child. Retinal bleeding was present in 28 (72%) of 39 of the abused children. Only 1 of the 3 unintentionally injured children who had a retinal examination had bleeding, which was of the type associated with acute increased intracranial pressure.**

Conclusions. **Nearly one fifth of infant and toddler SDH resulted from unintentional trauma. Of those without obvious unintentional trauma, 76% were corroborated to have been abused. Abused children were younger, more likely to have chronic SDH, and more likely to have multiple associated injuries. Their injury history usually was minor or absent.** ***Pediatrics*** **2001;108: 636–646;** ***subdural hemorrhage, child abuse, retinal hemorrhage, head injury.***

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Received for publication Nov 20, 2000; accepted Jan 15, 2001.

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ABBREVIATIONS. SDH, subdural hemorrhage; EDH, epidural hemorrhage; CT, computed tomography; HMC, Harborview Medical Center; CHRMC, Children's Hospital and Regional Medical Center; KCME, King County Medical Examiner's Office; MVA, motor vehicle accident; RH, retinal hemorrhage; SAH, subarachnoid hemorrhage.

Because of the recognition that children sometimes are abused, multiple studies have demonstrated a strong association of infant and toddler subdural hemorrhages (SDH) with inflicted head injury. Tardieu,[1] Caffey,[2,3] Kempe et al,[4] and Guthkelch[5] all reported SDH as a frequent element in inflicted childhood injury. Before these reports, SDH usually were attributed to falls reported by the child's caregiver or to unusual predisposition to injury, such as vitamin C or K deficiency, infection, or poor general condition.[6–8] Although some of these conditions may have predisposed a child to child injury, it is clear that associated injuries were not carefully sought and even when identified were not recognized as inflicted injury.

It is surprising that a number of recent studies continue to minimize the role of abuse in the cause of subdural bleeding in infants. Aoki and Masuzawa[9] attributed virtually all SDHs to minor falls. Ikeda et al[10] attributed them to rebleeds into old subdural membranes and to vitamin K deficiency. It is clear that the practice in Japan of oral instead of intramuscular vitamin K administration may have contributed to some of these SDHs.[11] The study by Hall et al[12] in 1989 attributed fatal intracranial bleeds to minor falls. It often is used to conclude that major SDHs result from minor falls. In retrospect, his methods were not adequate to evaluate for abuse. These included a full internal autopsy in only "the majority" of patients, review of a brief summary of the clinical record, use of gross examination and fluoroscopy instead of approved skeletal survey techniques to evaluate for skeletal injury, and grouping of SDH and epidural hemorrhage (EDH) as similar injuries for analysis. Although 2 deaths were from minor falls that occurred under medical supervision, insufficient detail is given to determine whether these were from EDH or contact injury–type SDH. Howard et al[13] conducted a retrospective series of 28 patients who were seen between 1970 and 1990. He made the unlikely postulation that children of all ethnicities except for native, white English children are susceptible to SDH from minor falls. Sunderland[14] published a review that cited the above stud-

ies as evidence for minor trauma as a cause of major SDH. His review also used studies of the mechanics of infant skull fracture[15] to make judgments about the mechanics and forces required to cause SDH and brain injury. Kim et al[16] retrospectively reviewed 729 falls in children who were younger than 15 years from the Children's Hospital of Los Angeles. Although short falls caused intracranial bleeding, the types of hemorrhage were not separated. Likewise, although 4 children died with SDH in falls of <15 feet, the height of their falls was not specified further.

In contrast to these studies, there is an extensive body of literature that documents the usually benign consequences of normal infant and toddler falls.[17–22] Likewise, stairway falls are unlikely to cause serious infant and toddler injury,[23,24] unless the child is in a walker.[25]

When attempts are made to reconcile the differences between these contradictory studies, it becomes clear that cultural barriers to the diagnosis of abuse, the intensity of the clinical evaluation, and the methods of data analysis are fundamental problems that must be addressed.

Most studies of the proportion of abuse in head trauma of young children used head injury in general, as opposed to SDH, as the entry criteria.[26–30] Computed tomography scanning (CT) of the head allows easy, noninvasive diagnosis of smaller, less symptomatic bleeds. Since its advent, few case series specifically enrolled infant SDH victims.[31–33] All studies of head injury and SDH, except for that of Duhaime et al[28] from 1992, are retrospective and lack predetermined diagnostic criteria. Studies also have not reflected the growing awareness that SDH may result either from direct contact/impact forces[34–38] or from inertial forces of rotational acceleration of the head on the neck, with or without associated impact.[27,34–36,38,39] The former causes focal injury[34,37,38] in a similar manner to the forces that cause scalp contusions, simple skull fractures,[38,40] and EDH.[41] The latter simultaneously causes concussion accompanied by shearing injury within the brain.[27,34–36,38,39]

When we collected and reported a retrospective case series of infant and toddler EDH, we used a control group of children with subdural bleeding for comparison of the rate of abusive head injury.[41] It rapidly became apparent that the intensity of investigation of our control children varied greatly. Skeletal surveys, formal ophthalmologic examinations, careful physical examinations for other trauma, and social evaluations were not done consistently. In that study, we accepted the assignment of the diagnosis of inflicted injury that had been made by the clinicians and child protective services. We realized at the time that a more reliable series would require prospective evaluation of SDH victims, a uniform set of evaluation procedures, and predetermined criteria for categorization of injuries as either inflicted or unintentional. From March 1995 through December 1998, we attempted to collect such a series at the 2 hospitals that serve most children with serious head injury in King County, Washington. The purpose of the study was to determine the most common mechanisms associated with SDH among children who are younger than 3 years.

METHODS

From March 1995 through December 1998, all patients who had SDHs or effusions and had not reached their third birthday were evaluated at 2 medical centers in Seattle, Washington. Harborview Medical Center (HMC) is the only level I pediatric trauma center in King County. It receives >80% of severely injured children from the county as well as critically ill transport cases from the 5-state northwest region (Washington, Alaska, Idaho, Montana, and Wyoming). The Children's Hospital and Regional Medical Center (CHRMC) is the principal tertiary care center for children in the Pacific Northwest. Children from the county (and often the entire northwest region) with serious, medically unstable illnesses usually are referred directly to CHRMC for evaluation and care. In addition, children who initially are treated surgically at HMC for head injury usually are transferred to CHRMC for ongoing care and rehabilitation. The King County Medical Examiner's Office (KCME) conducts investigations and conducts autopsies for all deaths that occur in the county from trauma.

Before initiation of the study, pediatric emergency department, neurosurgical, neurology, and intensive care attending physicians and staff were informed of the study. They were asked to refer patients during their hospital stay to the study physicians for evaluation. HMC also maintains a Trauma Registry, which was notified of the study and whose surveillance staff were informed of referral procedures.

The institutional review boards at CHRMC and the University of Washington approved the study before case acquisition and data collection. Specific study consent was not required from the guardians because the procedures used to evaluate for abuse were deemed to be the standard of care for children with uncertain cause of SDH. All other procedures were standard treatment for head injury and not modified by the study. Study forms were coded to maintain subject anonymity.

Prospectively referred children who did not have a documented unintentional cause of head trauma, such as motor vehicle accident (MVA), were evaluated by child protection team consultants, social workers, and ophthalmology staff and had full skeletal surveys performed. Children with documented unintentional injury had social work evaluation, skeletal radiographs, and retinal examinations performed at the discretion of the attending clinicians, based on concerns and symptoms.

To find the files of children who were not enrolled during their hospital stay, we conducted searches of the computerized radiology transcription systems annually at both institutions, where a key word search for subdural bleeding and related diagnoses could be performed. The hospital discharge diagnosis coding system at CHRMC and the Trauma Registry files at HMC also were searched for missed cases. The KCME also referred several cases during their evaluation. The KCME's data system was searched subsequently for unrecognized cases. To minimize bias, we enrolled in the study all children who met inclusion criteria regardless of prospective or retrospective identification.

Children were excluded from the study if they had a previously recognized coagulation disorder. Children with perinatal brain insults, which had resulted in a previously recognized extra-axial bleeding, or brain atrophy were excluded. Also excluded were children who had developed the subdural bleeding as a sequel of neurosurgical procedures or cardiopulmonary bypass, had subdural effusions associated with central nervous system infections, experienced severe dehydration/hypernatremia, or were on renal dialysis. Children who were referred solely for medicolegal evaluation and who were not seen at either institution for clinical care were excluded. Two children had very small, asymptomatic, acute hemorrhages, and our radiologists were unable to decide whether they were in a subdural or epidural location; these patients also were excluded.

A schema for determining the level of certainty of the diagnosis of abuse or unintentional injury was developed by the study physicians before initiation of the study (Table 1). Although considerable literature supports the differential prevalence of retinal hemorrhage (RH) in intentional as opposed to unintentional head injury,[26–30,32,33,39] we elected to exclude RH as a criteria for the determination of abuse. Without knowledge of the type of RH, it is difficult to conclude whether it is a secondary consequence of

TABLE 1. Schema Developed for Classifying Children With SDH as Abusive or Unintentional Injury

Definite unintentional	Single vintage injury; major event corroborated by direct observation of the incident by a reliable and independent third party.
Highly likely unintentional	Single vintage injury; major event not observed directly but corroborated by scene investigation by reliable/independent third party.
Likely unintentional	Single vintage, isolated acute SDH; major event history (eg, fall down stairs in a walker, fall greater than 6 feet); developmentally appropriate history; history consistent/discrete, timing appropriate; associated injuries consistent with history; no third-party corroboration. Or Isolated chronic SDH; although perinatal SDH not previously recognized, natal history appropriate for SDH (eg, bleeding or severe asphyxia with subsequent seizures); postnatal head growth steady or progressive from birth.
Indeterminate	Single vintage, acute SDH; minor event history (eg, fall <6 feet, fall down stairs); developmentally appropriate; no independent witness; isolated injury, although RH and skull fracture at impact site may be present; minimal evidence of direct brain injury, beyond focal contact contusion/injury. Or Isolated single vintage chronic SDH or chronic SDH with rebleed into it without signs or symptoms of new acute brain injury or additional trauma; no history of major perinatal events to have caused SDH.
Likely abuse	Single vintage injury; minor (eg, fall from couch) or no event history; symptoms or signs of more global primary brain injury; associated injuries may be present but are limited to skull fractures, retinal bleeding, or single, local impact bruise; single injury field.
Highly likely abuse	Multiple vintages of injury, vintage not appropriate for the history or absent history; developmentally unlikely history; associated findings of likely abuse may be present, but other vintage, minor injuries of questionable history or multiple injury fields present.
Definite abuse	Corroborated, witnessed, or confessed event. Or Multiple injuries, incompatible with normal, unintentional childhood injury; incompatible with history of injury vintage(s) or child's development; multiple or patterned bruises; old, unexplained fracture(s); findings of cranial impact without history or with inadequate history of impact trauma.

the SDH and acute increased intracranial pressure as opposed to a separate direct consequence of the initial trauma. This also allowed RH to be a dependent variable.

During the study, we found it necessary to clarify further the criteria for abuse diagnosis for children with both acute and chronic SDH. We elected to treat the hemorrhages as complications of a single event when only rebleeding into an old SDH was observed. We considered them to represent multiple events of trauma when the second SDH was in a new location, multifocal, or accompanied by clinical evidence of new direct brain injury (as opposed to simply symptoms of an enlarging mass lesion). We also deemed them to be new events when they were accompanied by other new, unexplained trauma. For the purposes of the study, we intentionally made criteria for diagnosis of abuse strict, insisting on historical or physical corroboration of inflicted injury.

To derive sufficient numbers for statistical comparison, we collapsed the categorization scheme of Table 1. Children in categories 5 to 7 were analyzed as a single abuse group, whereas children in categories 1 to 3 were analyzed as a single unintentional injury group. The indeterminate cases (category 4) remained as a single, intact group. Statistical comparisons are made using the χ^2 test for categorical data and unbalanced analysis of variance for continuous data with corrections for small sample sizes where appropriate. The 2×2 tables compare abused children or children whose injuries were indeterminate against unintentionally injured children as the reference group.

RESULTS

Demographics

During the study period, 66 children who were younger than 3 years and had SDH and effusions were seen at the study institutions, for a mean rate of 17.6 children per year. Fifteen of these resulted from unintentional injury, 39 resulted from child abuse, and 12 remained of indeterminate cause (Table 2).

TABLE 2. Abuse Scores by Age, Children With SDH

Category	Number of Patients	Collapsed Category	Grouped Patients [*n* (%)]	Mean Age (Month ± SD)
Definite unintentional	6			
Highly likely unintentional	7	Unintentional	15 (23%)	19.1 ± 10.0
Likely unintentional	2			
Indeterminate	12	Indeterminate	12 (18%)	7.4 ± 9.2*
Likely abuse	4			
Highly likely abuse	17	Abuse	39 (59%)	8.7 ± 8.1*†
Definite abuse	18			

SD indicates standard deviation.
* Versus unintentional ($P < .0001$).
† Versus intermediate ($P > .05$).

Thus, on average, we evaluated approximately 1 child per month (10.4/y) with an inflicted SDH. More abused and unintentionally injured children were in the definite or highly likely categories as opposed to likely category. The abused children and children whose injuries were indeterminate both were significantly younger than the unintentionally injured victims but not significantly different in age from each other. Although a greater proportion of abused children were male, this did not reach statistical significance (Table 3). Likewise, there was no significant difference in ethnicity for the injury causation categories (Table 3). More children in unintentional and abused causation categories were uninsured or insured by Medicaid than had private insurance. However, there was no difference in insurance coverage between injury categories (Table 3). A nonsignificant trend was noted for more caregivers of abused children to be single or divorced or have live-in partners than unintentionally injured children ($P = .07$ [not significant]; Table 2). However, among the 11 situations in which the child's mother had a live-in partner, 10 of these children were abused. Social work evaluations were done for all except for 1 (38 of 39) of the abused children, and all abused children were referred for evaluation by child protective services. As specified in the protocol, social work evaluation in documented unintentional-injury cases was left to the discretion of the attending physician and occurred in 8 (53%) of 15. Two thirds of indeterminate cases (8 of 12) were evaluated by social work, and one third (4 of 12) were referred to child protective services.

Injury Scenario

Initial histories explaining the children's injuries were strikingly different among the injury causation groups (Table 4). All unintentionally injured children had histories of major trauma, with 87% having independent corroboration. These included 9 MVA victims and 3 fall victims (all >10 feet). One child was kicked by a horse, 1 had a dresser fall on his head, and 1 was struck by a falling log. Six of the MVA injuries were to passengers, 2 were to pedestrians, and 1 was to a child whose head was rolled over by car tires.

In the abuse group, 33 (85%) of 39 children had histories of short falls ($n = 16$; $P = .004$) or no explanation ($n = 17$). Of the remaining abused children, 3 had a history of a stairway fall, 1 was reported to have been fallen on by an adult from a standing height, 1 was reported to have been shaken, and 1 was reported to have fallen 35 feet. Adding the stairway falls and the adult falling on the child, 37 (95%) of 39 children had minor event histories. Among the 12 children with indeterminate injuries, short falls also were most common ($n = 5$); no history ($n = 4$), stairway falls ($n = 2$), and being fallen on by an adult ($n = 1$) accounted for the others.

Six of the abused children were in the care of their mother, 10 were in the care of their father, and 6 were in the care of a live-in male partner or other adult male. Nine were with a babysitter, and 3 were with grandparents. Five were in the care of unknown caregivers at the time of injury or symptom onset. Two of the babysitter events were known to have

TABLE 3. Demographic Attributes in Children With SDH

Attribute	Unintentional ($n = 15$)	Indeterminate ($n = 12$)	Abuse ($n = 39$)
Gender			
Male	8 (53%)	8 (67%)*	25 (64%)*
Female	7 (47%)	4 (33%)	14 (36%)
Ethnicity			
White	7 (47%)	9 (75%)	23 (59%)
Black	2 (13%)	1 (11%)	6 (15%)
Hispanic	5 (33%)	1 (8%)	3 (8%)
Native American	1 (7%)	0	4 (10%)
Asian	0	1 (8%)	2 (5%)
Other	0	0	1 (3%)
Total nonwhite	8 (53%)	3 (25%)†	16 (41%)†
Insurance status			
Insurance	6 (40%)	7 (58%)	16 (41%)
Medicaid	6 (40%)	5 (42%)	17 (44%)
Charity	2 (13%)	0	3 (8%)
Self-insured	0	0	1 (3%)
Unknown	1 (7%)	0	1 (3%)
Total Medicaid/charity/self	8 (53%)	5 (42%)‡	21 (54%)‡
Primary caregiver marital status			
Married	9 (60%)	9 (75%)	18 (46%)
Single	2 (13%)	2 (17%)	5 (13%)
Divorced	0	1 (8%)	6 (15%)
Live-in partner	1 (7%)	0	10 (26%)
Unknown	3 (20%)	0	0
Total single/divorced/live-in partner	3 (20%)	3 (25%)§	21 (54%)§

All comparisons are either indeterminate or abuse versus unintentional cases.
* $P > .1$.
† $P > .1$, white versus total nonwhite.
‡ $P > .1$, insurance versus total Medicaid/charity/self.
§ $P > .1$, married versus total single/divorced/live-in partner.

TABLE 4. Initial History of Mode of Injury, Children With SDH

	Unintentional (n = 15)	Indeterminate (n = 12)	Abuse (n = 39)
Total FFH	3	5	17
FFH ≤4 ft	0	5*	16†
FFH >4 ft	3‡	0	1§
Fall down stairs	0	2	3
Abuse/shake	0	0	1
MVA	9	0	0
Unknown/no history	0	4	17
Other	3¶	1‖	1‖

FFH indicates fall from height.
All comparisons are either indeterminate or abuse vs unintentional cases.
* P = .02, Fisher's exact test.
† P = .004, Fisher's exact test.
‡ 2 = 10 feet, 1 = 20 feet.
§ 1 = 35 feet.
¶ Kicked by horse, dresser fell on head, hit in head by falling log.
‖ Adult fell on child from standing height.

been caused by the male partner of the sitter. The abused children often lacked a clear history of a discrete time of injury or symptom onset. However, best estimates from the history indicate that all 15 children with unintentional injury were brought to care within 2 hours, whereas delay beyond 2 hours in seeking care was common with both the indeterminate (9 of 12; $P < .0001$) and abused (19 of 39; $P = .002$) children. Many of the children whose care was delayed >1 day had chronic SDH.

The initial symptoms of the 39 abused children included central nervous system irritability or depression (n = 17), apnea or altered respiration (n = 7), seizures (n = 7), vomiting (n = 2), and increasing head size (n = 2). Three presented for a complaint of trauma and 1 for hypothermia.

Severity of Head and Associated Injuries

Although the injury mechanisms reported for the abused children were dramatically less serious than that for the unintentionally injured children, their head injury severity was similar (Table 5). All 3 groups had serious intracranial injuries and similar need for surgical evacuation, but evidence of parenchymal injury was infrequent and fatalities were absent among the children whose injuries were indeterminate (Table 5). Both brain parenchymal injury and mortality were common among unintentionally injured and abused children ($P > .1$). All unintentionally injured children had only acute SDH (Table 5). However, 17 (44%) of 39 abused children ($P = .002$) and 8 (67%) of 12 children whose injuries were indeterminate ($P = .0002$) had chronic or both acute and chronic SDH.

Skull fractures were more common in the unintentionally injured children and tended to be complex (Table 5). Abused children had fewer skull fractures ($P = .01$), but they were equally likely to be complex. Skull fractures in the children whose injuries were indeterminate also were less common and usually simple linear injuries. Head bruises were present in equal numbers of abused (54%) and unintentionally injured (60%) children (Table 6). Approximately one third of both groups also had facial or both facial and cranial vault bruising. Cranial bruising was present less often (33%) in indeterminate cases ($P = .04$), and none had facial injuries.

More striking differences were seen outside the cranial region. Although radiologic surveillance was

TABLE 5. Severity of Cranial Injuries

	Unintentional (n = 15)	Indeterminate (n = 12)	Abuse (n = 39)
Skull fracture	11 (73%)	5 (42%)‡	12 (31%)§
Skull fracture complex*	9 (82%)	1 (20%)‖	9 (74%)¶
Retina examined	3 (20%)	7 (58%)	39 (100%)
RH†	1 (33%)#	0 (0%)‡	28 (72%)‡
SAH	7 (47%)	3 (25%)‡	12 (31%)‡
Brain edema	6 (40%)	1 (8%)¶	15 (38%)‡
Brain infarction	3 (20%)	1 (8%)‡	11 (28%)‡
SDH			
Acute	15 (100%)	4 (33%)**	22 (56%)††
Chronic	0	3 (25%)	12 (31%)
Acute and chronic	0	5 (42%)	5 (13%)
SDH evacuated	6 (40%)	6 (50%)‡	10 (26%)‡
Intracranial pressure monitored	8 (53%)	1 (8%)‡‡	17 (44%)‡
Other nonsurgical procedure	4 (26%)	3 (25%)‡	12 (31%)‡
Death	3 (20%)	0 (0%)‡	4 (10%)‡

All comparisons are either indeterminate or abuse versus unintentional cases.
* Complex skull fracture defined as diastatic (>3 mm), involving multiple skull bones, crossing sutures, branching, depressed.
† Percentage of patients who had retinal examination.
‡ $P > .1$.
§ $P = .01$, Yates corrected χ^2.
‖ $P = .04$, Fisher's exact test.
¶ $P = .09$, Fisher's exact test.
# Ten-ft fall onto concrete, complex skull fracture, SDH, SAH, contusion-developed edema, infarction-persistent vegetative residua- few right intra- and preretinal hemorrhages around the disc.
** $P = .0002$, Fisher's exact test, acute only versus chronic with or without acute.
†† $P = .002$, Fisher's exact test, acute only versus chronic with or without acute.
‡‡ $P = .02$, Fisher's exact test.

TABLE 6. Associated Injuries: Skin and Miscellaneous

	Unintentional (n = 15)	Indeterminate (n = 12)	Abuse (n = 39)
Head bruises	9 (60%)	2 (17%)*	21 (54%)†
Cranial vault	4 (27%)	2 (17%)	8 (21%)
Face	2 (13%)	0	3 (8%)
Both	3 (20%)	0	10 (26%)
Other bruises	4 (27%)	2 (17%)†	15 (38%)†
Abnormal distribution	0	0	14 (36%)‡
Abuse pattern	0	0	10 (26%)§
Burns	0	0	1 (3%)†
Sexual abuse	0	0	1 (3%)†
Visceral injury	1 (6%)	0	3 (8%)†
Intra-oral trauma	1 (6%)	0	4 (10%)†

All comparisons are either indeterminate or abuse versus unintentional cases.
* P = .04, Fisher's exact test.
† $P > .1$.
‡ P = .005, Fisher's exact test.
§ P = .05, Fisher's exact test.

less complete for children in the unintentional and indeterminate groups, abused children were significantly more likely to have either rib or long bone fractures: 51% had such fractures (Table 7). Of the abused children with rib fractures, 75% had nonacute fractures; of those with long bone fractures, 36% had nonacute injuries (Table 8). In contrast, the single fracture identified in an unintentionally injured child was acute.

Four (28%) of the unintentionally injured and 2 (16%) of the children whose injuries were indeterminate were reported to have extracranial bruises, whereas 38% of the abused children did ($P > .1$; Table 6). However, 93% of the abused children with bruises had them in abnormal distributions (P = .005), and 66% had patterned bruises indicative of abuse (P = .05). Visceral injuries were observed in 3 abused children (pulmonary contusion; mesenteric and thymic contusion; and pulmonary contusion, liver laceration, and free intra-abdominal air) and in 1 MVA victim (mediastinal hemorrhage; not significant). Intra-oral trauma was observed in 4 of the abused and 1 of the unintentionally injured children (not significant). Burn injuries and sexual abuse were present only in 1 abused child; she sustained anal lacerations and an electric stove element contact burn of the buttocks.

TABLE 7. Associated Injuries in Children with SDH: Fractures

	Unintentional (n = 15)	Indeterminate (n = 12)	Abuse (n = 39)
Skeletal survey done	10	7	39
Any long bone fractures	1 (10%)*	0 (0%)*†	14 (36%)*†
Rib films done	12	9	39
Any rib fractures	0 (0%)*	1 (11%)*†	8 (21%)*†
Either rib or long bone fractures	1 (10%)*	1 (11%)*†	20 (51%)*‡

All comparisons are either indeterminate or abuse versus unintentional cases.
* Percentage of evaluated children.
† $P > .1$.
‡ P = .03, Fisher's exact test.

TABLE 8. Types and Frequency of Fractures in Abused Children with SDH

Type	Number
Radius	6
Vertebrae	4
Humerus	2
Ulna	2
Femur	2
Tibia	2
Clavicle	1
Hand	1
Pelvis	1
Mean number of fractures per patient with fractures 1.66	
Rib fracture	
1 (3 patients)	
2 (1 patient)	
4 (2 patients)	
7 (1 patient)	
16 (1 patient)	
Mean number of rib fractures per patient with rib fractures 4.75	
Acute fractures	
Long bone	9
Rib	2
Old fractures	
Long bone	4
Rib	5
Acute and old	
Long bone	1
Rib	1

Retinal examination was performed only in 3 (20%) of the unintentionally injured victims; 1 had RH (33%; Table 5). This child had severe brain injury with resultant edema and infarction as the consequence of a 10-foot fall onto concrete. A few unilateral pre- and intraretinal hemorrhages were observed surrounding the optic disk. None of the 7 (58%) children whose injuries were indeterminate and who had retinal examinations had hemorrhages, but 28 (72%) of the abused children had retinal bleeding ($P < .001$).

Indeterminate Case Reports

Although 12 cases were indeterminate by our predetermined classification scheme, clinical histories and injury patterns often suggested causation. Several of the 4 acute SDH cases likely represent impact/contact injuries. Two of these had minor symptoms that led only to overnight inpatient hospitalizations; they were evaluated incompletely for abuse because of retrospective identification. Some of the 8 chronic or mixed chronic and acute cases may have had an original, undetected SDH caused by perinatal events. Three chronic and 1 chronic with acute SDH were identified retrospectively and evaluated incompletely for abuse. Some of these indeterminate cases probably could have been classified as unintentional or abusive injury if they had been evaluated fully and concurrently. Four indeterminate cases that illustrate their potential injury mechanisms are described next.

Case 1: Acute Hemorrhage/Minor Symptoms

A 2-month-old male, while restrained in a bouncy seat, tipped off a kitchen counter onto a hardwood

floor. The child landed head down and developed acute right scalp swelling. There was no loss of consciousness or subsequent altered consciousness, although he subsequently vomited once. CT and skull films revealed a simple linear right parietal fracture with a small subjacent acute SDH. Social evaluation, the rest of the physical examination, retinal examination, and skeletal survey all were normal. The child was discharged from the hospital after an asymptomatic overnight observation.

Impression: Unintentional small contact SDH. This case did not meet criteria for unintentional injury because of the lack of an independent witness.

Case 2: Acute Hemorrhage/Major Symptoms

The parents of a 7-month-old boy returned from the grocery. As the child's mother took a bag of groceries inside, his father stepped with 1 foot into the car to pick up the infant. His father, a very large man, caught his foot in a seat belt, tripped, and fell onto the child. The infant landed face down, still restrained in the car seat, on the adjacent asphalt. The child's mother returned to observe immediate swelling of his right scalp. The child had no loss of consciousness, but his parents immediately took him to the nearby fire station, where he was believed to be normal and sent home. The parents were still concerned and took him to an emergency department, where his examination was normal except for the swollen scalp. He vomited once while there. As he was being readied for discharge to home, he developed an acute transfalcine herniation syndrome. He was transferred to HMC, where a large acute right SDH was evacuated from under a right parietal fracture and diastatic coronal suture. Social evaluation, retinal examination, and skeletal survey were normal. The infant had residual hemiparesis at hospital discharge.

Impression: Unintentional diastatic skull injury with associated SDH-contact injury, symptoms attributable to mass effect alone, no primary brain injury. Although the history was of a short fall, it would not be considered a minor fall. The child's inertia at impact was augmented by the full weight of his father's landing on him. This case also did not meet criteria for unintentional injury because of the lack of an independent witness.

Case 3: Chronic Effusion With Rebleed

A 2-month-old boy was being carried down the stairs by his father. The maternal grandmother saw the father trip and fall down 3 carpeted stairs. Neither the child's father nor the grandmother saw whether the infant hit his head or whether the father fell on him. The child initially became apneic. He was intubated in the field and arrived somnolent. CT revealed bilateral chronic SD effusions with scattered fresh subarachnoid hemorrhage (SAH). He improved with supportive care and was discharged to his parents. He returned 2 weeks later with a rapidly expanding head size. Shunting was performed. At this time, social evaluation and retinal examination were normal, but skeletal survey revealed healing fractures of the left tenth and eleventh rib necks. The degree of rib healing was compatible with the timing of the stairway fall. In retrospect, the chest film from the initial hospitalization provided inadequate detail to determine whether these fractures had been present. This first pregnancy resulted in a term vaginal, forceps-assisted delivery. The child had good apgars and did well except for postnatal jaundice. Head size was 95% at birth and greater than 95% from 2 weeks of age.

Impression: Indeterminate witnessed event led to rebleed. Chronic effusions possibly developed from perinatal injury but might have resulted from postnatal trauma. The cause of his rib fractures also remains unclear.

Case 4: Chronic Effusion With Rebleed

A 4-month-old infant had been asleep with his mother on the platform above the seat of a semi truck. As the truck was being unloaded, it was struck by a crane. The infant was thrown onto the floor in front of the seat, and his mother landed on top of him. His scalp swelled rapidly. Although he did not lose consciousness, his Glascow coma scale at presentation was 12. Skeletal survey was negative except for an occipital fracture. He had a 90th-percentile head size. CT scan revealed bifrontal chronic subdural effusions, with bifrontal fresh subarachnoid bleeding. Social evaluation, skeletal survey, and retinal examination were normal. He had been born at 36 weeks and was his mother's first pregnancy. Delivery was by vacuum extraction with subsequent significant head molding and caput. He was jaundiced for a week but had had good apgars and subsequently did well. Although his head size at birth had been at the 10th percentile, it was at the 50th percentile by 2 weeks of age. His hospital course was uncomplicated, and he was discharged to his family.

Impression: Possible unintentional. Chronic effusions may represent unrecognized birth injury. Acute SAH and skull fracture explicable by witnessed acute history.

DISCUSSION

Unintentional trauma, especially MVA-related trauma, is reported inconsistently in most series of childhood SDH. The retrospective population study of SDH by Jayawant et al[32] in Wales and southwest Great Britain found only 1 child who had sustained MVA trauma. Eighty-two percent had been abused, and 15% had unclear histories but no corroboration of abuse. In Tzioumi and Oates's[33] retrospective Australian study, 39% of the 38 SDHs of children who were younger than 2 years were attributed to unintentional injury. Five children each had SDH from MVAs and falls. An additional 5 with unclear histories were included as unintentional trauma in this series, but the authors opined that they might represent unrecognized abuse. Fifty-five percent of Tzioumi and Oates's series were diagnosed as abuse. Ewing-Cobbs found 18 of 29 children who were younger than 6 years and had been admitted for

unintentional head injury to have been in MVA trauma and 7 in falls,[42] yet 71% (22 of 31) of the abused children as opposed to 31% (9 of 29) of the unintentionally injured children had SDH. Dashti et al[43] found that 69% (22 of 32) of children who were admitted for abusive head injury but only 7% (5 of 68) of unintentionally injured children had SDH. Eighty-one percent of the SDHs in his series of children who were younger than 2 years and had head injury resulted from abuse. In series of childhood head injuries that span the severity range from minor to fatal, such unintentional events are more common. For example, Reece found 81% of head injury in children who were younger than 6½ years to be unintentional; 23% were MVA related, and 58% were fall related.[30]

We also found unintentional trauma to be a relatively common cause of infant and toddler SDH, accounting for 23% of our case series. Sixty percent of these were MVA related. These children sustained traumatic injuries with clear histories, which usually were witnessed. There would be little difficulty in recognizing the cause of these injuries. Although falls caused unintentional SDH in 3 (4%) of our series, they all were greater than 10 feet onto unyielding surfaces. This supports previous observations that although falls from significant heights can cause SDH, SDH is an infrequent consequence.[44–47] However, it is unlikely that normal, short childhood falls (<4 feet) cause SDH that is associated with significant concurrent brain injury. Conversely, short falls may cause simple contact SDH.[34,38] Our indeterminate case 2 emphasizes that major contact SDHs may have minimal or no symptoms of primary brain injury.[34] These children may not be diagnosed until catastrophic space-occupying hemorrhages accumulate. Sixty-one percent of the deaths from falls in the study by Hall et al[12] were due to mass lesions, and 67% deteriorated between the injury scene and the hospital. It is possible that many of these cases with EDH or SDH were contact injury deaths.

Once the SDHs with obvious causation were excluded, 76% of our remaining cases had findings to corroborate abuse, by means of a predetermined classification scheme. Eighty-one percent (13 of 16) of the SDHs in the prospective series by Duhaime et al,[28] which also used a predetermined classification scheme, were caused by abuse. The cause of the others was not specified. Even among our indeterminate cases, further case analysis allowed us to suspect abuse in an additional 3 children (see below). Morris et al[31] similarly discussed how abuse can be diagnosed in some children who lack corroborative physical evidence.

It is somewhat circular reasoning that children who received a diagnosis of SDH because of abuse had a high rate of additional physical injuries of abuse. However, it is noteworthy that similar injuries were rare in children who sustained documented major trauma, such as MVA injuries or falls from significant heights. Our results differ from the fall study by Kim et al,[16] in which extracranial injuries were common. However, 46% of those pediatric falls were from heights greater than 15 feet. It is not clear in the article what proportion of the extracranial injuries is in this high-height fall group. The differences in bruising and fractures that we observed were particularly striking. These features occurred in abused children with minor or no injury history. Duhaime et al[28] and Reece and Sege[30] affirmed similar associations of abuse with extracranial injury. Although we did not use RH as a factor in the diagnosis of abuse, only 1 of the 3 unintentionally injured children and none of the 7 children whose injuries were indeterminate and had retinal examinations conducted had RH. In that child, massive brain injury and edema were associated with a few posterior pole hemorrhages. These are seen nonspecifically in any case of sudden increased intracranial pressure and/or papilledema.[48] This compares with the 72% incidence of RH that we observed in abused children. As has been noted in all studies of inflicted head injury with SDH, RH is not a uniform finding.

Skull fractures in our series were more common among the unintentionally injured children than among the abused or indeterminate cases. It was striking, though, that when fractures were present, complex fractures were equally common for both unintentionally injured and abused children. This suggests that both groups, when sustaining skull fractures, experienced a formidable impact force. Conversely, only 1 child whose injuries were indeterminate had a complex skull fracture. Duhaime et al[28] and Hobbs[40] observed that if legitimate falls cause complex skull fractures, then they are from significant heights, generally >6 feet. Our results differ from the data on skull fractures in abused children in general. Merten et al[49] observed that 88% of abused children with skull fractures had simple linear parietal injuries, and Hahn et al[50] reported that 81% were linear. Our rate is closer to that of Hobbs, who found 79% of skull fractures due to child abuse to be complex.[40] His series was skewed toward child abuse mortality (19 of 29 fatal). Our series, by selecting only children with SDH, also is skewed toward more severe head injury than general series of head injury in child abuse.

Families of abused children had higher, although not statistically different, rates of single, divorced, or live-in boyfriend arrangements. In particular, the live-in boyfriends were found almost exclusively among the abuse cases and often were recognized to be the child's abuser. They have little commitment to the child as opposed to their relationship with the child's mother. They often are drafted, unprepared, into child caregiving roles. This is similar to Starling and Holden's[51] observations. The 2 babysitters' male partners who were recognized to be responsible for abuse probably share this dynamic.

Our abused patients exhibited nonspecific and often misleading symptoms, and 44% lacked trauma histories. Changes in consciousness, apnea or respiratory abnormalities, and vomiting may not lead clinicians to search for intracranial trauma. Jenny et al[52] observed that this lack of symptom specificity or

direction resulted in missed diagnosis at the initial medical encounter in 31% of children with abusive head injury. In the current series, we did not see children whose presenting symptoms were bleeding or bruising. However, 54% of our abused patients had cranial vault and/or facial bruises. We subsequently have seen children whose sole clue to intracranial abuse was bruising in infancy. Jenny et al[52] observed that 37% of the infants with missed abusive head injury diagnoses had cranial or facial bruising at the initial visit.

Our study, by plan, excluded children who developed SDH as a consequence of neurosurgical procedures, recognized brain injury from birth, and cardiopulmonary bypass. Although we also planned to exclude children with SDH subsequent to renal dialysis and hypernatremic dehydration, no such patients were seen during the study period. Handy et al[53] subsequently suggested that SDH usually is not caused by the hypernatremic dehydration. They believed that the hypernatremic dehydration usually is the consequence of brain injury accompanying the SDH. Also, although, before and subsequent to the study period, we have seen children who developed SDH as the presenting manifestation of severe hemophilia or vitamin K deficiency, none were observed during the study. In those patients, we have seen more intraparenchymal and intraventricular hemorrhage than is common with the abused infants.

Our radiologists could not determine whether the extra-axial bleeding in 2 of the excluded patients was subdural or epidural in location. These injuries seemed to have resulted from focal impact and are similar to the disappearing subdurals described by Duhaime et al.[37] Their lack of primary brain injury or associated manifestations of abuse distinguish them from the usual subdural of abuse. Among our indeterminate cases, 2 seem to represent such unintentional contact injuries and an additional 2 were similar clinically but were evaluated incompletely for abuse.

Charting of head growth suggests that 5 children who had chronic effusions with or without associated acute bleeding had onset of rapid head growth immediately after the perinatal period. All had some complication of pregnancy or delivery, including 1 premature infant; 1 with congenital heart disease; and 1 forceps, 1 vacuum, and 1 cesarean section delivery for cephalopelvic disproportion during labor. Two were evaluated fully at presentation, yielding no corroboration of abuse. One was evaluated only when subsequent corroborated trauma led to further head growth and shunting (see case 3 in "Results"). Rib fractures were found but could not be attributed to abuse or the witnessed trauma of the initial presentation. Two children never had retinal, skeletal, or social work evaluations. It is possible that some of these children with chronic SDH represent unrecognized perinatal SDHs. They may present later as a result of the enlarging head size or because of rebleeding into chronic SDH. Cesarean delivery subsequent to labor and vacuum- or forceps-assisted delivery have been reported to cause symptomatic intracranial bleeding. Rates were 1 in 664 to 1 in 907 newborns.[54] No studies document how often these delivery modes result in asymptomatic perinatal hemorrhage. Likewise, it is not known how often these perinatal SDHs progress to chronic effusions. One of our children whose injuries were indeterminate and who had unexplained onset of increasing head size after documented normal postnatal head growth was evaluated fully for abuse. A second child with postnatal onset and 1 child with uncertain onset of excess head growth were not evaluated fully. It is more likely that these 3 children with postnatal or undocumented onset of increasing head size without explanation sustained inflicted injury.

Bifrontal extra-axial hypodense fluid on the CT scan may represent either extremes of the normal expanded subarachnoid space of infants or subdural effusions. Magnetic resonance imaging and/or fine detail ultrasonography usually can define the location of these fluid collections.[55] Children with chronic effusions or SDH pose difficulty in diagnosis. Because there is a delay between subdural bleeding and diagnosis, skin, retinal, and even skeletal injuries may have healed without residua by the time of evaluation. Even so, Parent[56] found 46% (13 of 28) of chronic pediatric SDH seen between 1980 and 1989 to have resulted from abuse. Accidents, shunt surgery, and birth trauma accounted for an additional 36% (10 of 28). Ewing-Cobbs et al[42] observed that 13% (4 of 30) of abused children had subdural hygromas, 30% (9 of 30) had brain atrophy, and 23% (7 of 30) had ventriculomegaly. However, none of the 29 unintentionally head-injured children who were younger than 6 years had such evidence of previous injury or effusions. Of the 25 chronic or acute and chronic SDH we observed, 17 (68%) had documented evidence of abuse. In several, there was no suspicion of abuse until the postoperative shunt series revealed healing rib fractures. We believe that all children with expanded extra-axial fluid spaces should be evaluated carefully for whether the fluid is subdural or subarachnoid in location. Those with subdural collections should have a full evaluation for causation, including review of birth records, head growth pattern and past brain injuries, surgeries, or central nervous system events. If a benign cause is not readily apparent, a full child abuse evaluation should be conducted.

Our study, despite our best efforts to identify and study SDH victims concurrently, was hampered by incomplete evaluation of some children. Such evaluation might have reduced the rate of indeterminate diagnoses. As opposed to the series by Jayawant et al,[32] we performed an institution-based instead of a population-based study. Although we believe that almost all children with significant head injuries are transferred to 1 of our study institutions, inclusion of lesser-acuity regional hospitals might have modified our results. Although many of the criteria that we evaluated exhibited strong trends, the rate of statistical significance might have been greater with a larger study. Because we required corroboration to judge a child to have been abused, we probably did

not identify some children whose sole manifestation of abuse was their intracranial injury.

CONCLUSION

Nearly one fourth of the infants and toddlers in our SDH series had sustained major, easily recognizable trauma. They exhibited serious head injury but had little evidence of extracranial trauma. Among the children without an obvious traumatic cause of their SDH, three fourths had corroborative physical and/or historical evidence of abuse. These children had not only significant cranial injury but also commonly had extracranial trauma, including bruises, fractures, and visceral injury. Although they presented with histories of minor falls or no trauma history, their head injuries were as serious as children who had been involved in an MVA. They were younger than unintentional trauma victims. Children with chronic SDH or subdural effusion present a unique diagnostic problem because many lack a clear time of onset or corroborative physical findings. Any infant or toddler with SDH or subdural effusion and no major trauma history should be evaluated carefully for child abuse.

ACKNOWLEDGMENTS

This project was funded, in part, by the HIPRC center grant from the Centers for Disease Control and Prevention (R49/CCR002570).

We thank Christopher Mack for assistance with data processing and analysis.

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DEATHLY SILENCE

There's a conspiracy of silence in medicine around death and dying. Physicians have no opportunity to ventilate their feelings and soon become hardened to death to survive emotionally. When a patient dies, the physician should be able to sit down and talk about it with other physicians and about what a dignified optimal death entails.

Brody J. A doctor's story of hope, healing, and deadly cancer. *New York Times.* May 15, 2001

Submitted by Student