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Head Injury in Very Young Children: Mechanisms, Injury Types, and Ophthalmologic Findings in 100 Hospitalized Patients Younger Than 2 Years of Age

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ABSTRACT. Head injury in the youngest age group is distinct from that occurring in older children or adults because of differences in mechanisms, injury thresholds, and the frequency with which the question of child abuse is encountered. To analyze some of these characteristics in very young children, the authors prospectively studied 100 consecutively admitted head-injured patients 24 months of age or younger who were drawn from three institutions. Mechanism of injury, injury type, and associated injuries were recorded. All patients underwent ophthalmologic examination to document the presence of retinal hemorrhages. An algorithm incorporating injury type, best history, and associated findings was used to classify each injury as inflicted or accidental. The results confirmed that most head injuries in children younger than 2 years of age occurred from falls, and while different fall heights were associated with different injury types, most household falls were neurologically benign. Using strict criteria, 24% of injuries were presumed inflicted, and an additional 32% were suspicious for abuse, neglect, or social or family problems. Intradural hemorrhage was much more likely to occur from motor vehicle accidents and inflicted injury than from any other mechanism, with the latter being the most common cause of mortality. Retinal hemorrhages were seen in serious accidental head injury but were most commonly encountered in inflicted injury. The presence of more serious injuries associated with particular mechanisms may be related to a predominance of rotational rather than translational forces acting on the head. ***Pediatrics* 1992;90:179–185; *head injury, infants, child abuse, retinal hemorrhage.***

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It has been well established that head injury in children differs in several important ways from that seen in the adult population. While various recent studies have focused on incidence,[1,2] mechanism,[3–5] various injury types,[6–9] and outcome[10–13] of head trauma in the pediatric population, most efforts have grouped all children together for purposes of comparison with adults. Because of our clinical impression that head injuries in babies have many features distinct from those seen in older children, and because of the relatively frequent question of nonaccidental injury in these very young children,[14,15] we prospectively studied all patients aged 24 months or younger who were admitted with a diagnosis of head injury in three institutions. The circumstances and mechanisms of the trauma, injury type and severity, and the ophthalmologic findings were analyzed in each case to establish both relative frequencies of different injury types and mechanisms and their associated findings.

MATERIALS AND METHODS

All consecutively admitted children 24 months of age or younger with a primary diagnosis of head injury determined at discharge or death were included in the study protocol; in this way, children in whom the diagnosis of head trauma was not apparent at the time of admission were not excluded. Patients were drawn from three teaching hospitals, of which two were located in urban settings. Criteria for hospital admission after head injury included history of loss of consciousness, abnormal level of consciousness or other neurologic abnormality, skull fracture, or intracranial hemorrhage. Children were identified for inclusion into the study by admission diagnosis or by regular surveillance of all trauma diagnoses apparent after neurosurgical, neurologic, or trauma surgery consultation.

A biomechanical profile (Table I) was administered at the time of admission to the hospital or upon entry into the study by the evaluating physician and amended as additional information became available. Fall heights were judged by the distance through which the patient's head moved, so that children falling from a standing or sitting position had distances adjusted accordingly. In general, couches were estimated at 1½ to 2 feet in height, beds at 2 to 2½ feet, and changing tables at 3 feet. Falls from an adult's arms were classified as falls greater than 4 feet. When available, specific measurements were used to assign fall distances. Police reports, emergency medical technician interviews, and accounts of additional witnesses were sought to corroborate injury details. When applicable in unwitnessed accidents, distance estimates were based on the child's position before and when first seen after the accident. In patients with clinical or radiographic evidence of trauma but with no history of trauma on admission, information was obtained regarding mechanism of injury by multiple interviews with caretakers by the appropriate members of the medical and social service teams. Injuries in which no history of trauma could be obtained after such efforts were designated with respect to mechanism as "no history of trauma."

Children underwent detailed physical examination by a pediatrician, neurosurgeon, and, in most cases, a trauma surgeon. Radiologic evaluation included skull films, computed tomographic scan, and/or magnetic resonance imaging scans as clinically indicated as well as skeletal survey in all children in whom additional injury was suspected on clinical or historical grounds. Patients with equivocal skeletal surveys underwent delayed, subsequent surveys or radioisotope bone scans for documentation of concomitant trauma.

All patients underwent fundoscopic examination within 36 hours of admission by ophthalmologists or emergency department pediatricians familiar with the diagnosis and detection of retinal hemorrhages. The majority (82%) were performed using short-acting mydriatic agents.

The families or caretakers of each patient were interviewed by a trauma social worker or pediatric emergency department attending physician experienced in the evaluation of child abuse. Physicians and social workers from the child maltreatment evaluation team at each hospital assessed all patients in whom a suspicion of inflicted injury or inadequate supervision was raised. To determine whether a given patient's injury would be classified as inflicted or accidental for purposes of statistical analysis, an algorithm was developed which incorporates the patient's specific injury type, final best history attainable, and the associated physical and radiographic findings. The scheme was designed to use objective and readily available data and to be independent of ophthalmologic findings and family social circumstances (Fig. 1). Such a scheme provides a conservative estimate of the overall incidence of child abuse, focusing only on injuries believed by the authors to clearly result from a deliberate and intended assault. Determination is based on combinations of findings indicating the presence of either (1) unexplained injuries such as healing long-bone fractures; (2) injuries unequivocally caused by mechanical trauma with no history of trauma obtainable; or (3) a history of forces considered by the authors to be mechanically insufficient to cause particular injury types, when seen in association with a changing or developmentally incompatible history. These latter features of the history have been described as typical in child abuse.[16,17] Falls clearly described as less than 3 feet in height were designated as "trivial" trauma, and when given as an explanation for a high-force injury along with variability in the history or a developmentally incompatible scenario, nonaccidental injury was presumed. For example, an otherwise healthy 1-month-old baby with multiple skull fractures who "rolled off the center of a mattress" meets criteria, as does a 3-month-old with acute bilateral subdural hematomas, a fresh periorbital bruise, and no history of trauma. Conversely, a 6-month-old child with a linear skull fracture, who may have fallen off a bed or may have been struck by a falling object, is "suspicious" but not "presumptive" for inflicted injury according to the algorithm, and this would be classed as accidental. Such children in our experience may have been poorly supervised, rather than targets of intended assault. Likewise, patients with intradural hemorrhage and no history of trauma must also have clinical or radiographic findings of blunt impact to the head, unexplained long-bone fractures, or other soft-tissue inflicted injury, in order to completely eliminate the possibility of a spontaneous intracranial hemorrhage such as might rarely occur from a vascular malformation or a bleeding disorder. Thus, the scheme as shown provides a means to classify injuries as presumptively inflicted which is deliberately biased to reduce false positives and thus may underestimate the true incidence of child abuse.

In addition to injuries classified as inflicted according to the algorithm, admitted assaults were also classified as inflicted injuries. Instances of neglect resulting in accidental injury, inadequate supervision, accidents involving intoxicated caretakers, or suspicious circumstances not reaching criteria for presumptive infliction according to the algorithm were classified for purposes of statistical

TABLE 1. Biomechanical Profile

1. Narrative description of accident by witnesses.
2. What time did the accident occur?
3. Was the accident witnessed? By whom?
4. What position was the baby in prior to the fall/accident?
5. Through what distance did the baby move?
6. What position was the baby in after the fall/accident?
7. Did the baby strike the head? If so, where and against what?
8. If the baby was struck by a moving object, how was the object moving and how did it strike the baby?
9. If this was an auto accident, please note speed of car, point of impact to the car, speed of other involved vehicles, and other pertinent information.
10. Was there pressure on or compression of the chest or abdomen at or after the accident? Describe.
11. If the accident was unwitnessed, what is the estimated time between the accident occurring and when the baby was first seen?
12. What did the baby do immediately after the accident (or, if unwitnessed, when first seen)? Check all that apply:
    ______Unresponsive
    Eyes ______ Opened ______ Closed
    Tone ______ Flaccid ______ Increased______ Normal
    Time until responsivenesss returned:
    ______ Seizure   How long after accident and duration?
    ______ Cry or other sound
    ______ Other
13. What did the caretaker do on reaching the baby and how did the baby respond?
14. Was the baby manipulated in any way after the accident (eg, shaking, resuscitation, etc)? If yes, please describe.

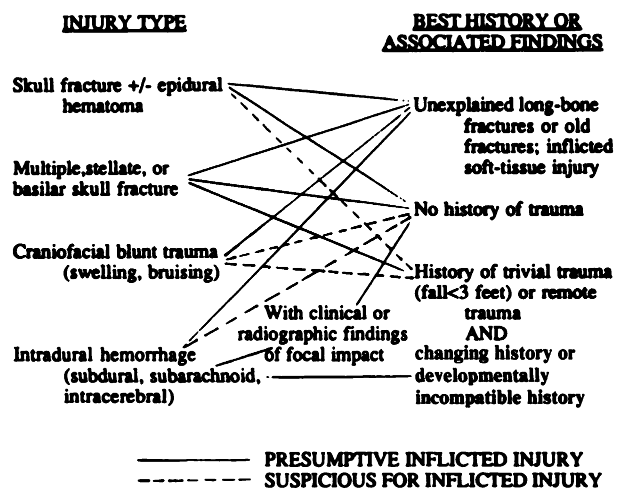

Fig 1. Scheme for determination of inflicted injury in very young children. The algorithm is used by finding the patient's injury type in the left-hand column, then matching it with the appropriate best history or associated findings in the right-hand column. If the columns are connected by a solid line, the injury is classified as "presumed inflicted injury." If the columns are connected by a dashed line, the injury is suspicious for inflicted injury but does not meet criteria for a presumption of inflicted injury, and so it is classified as accidental in this study. (Note that concussive injuries are assigned to a category in the left-hand column according to their associated objective clinical or radiographic findings, such as bruising, fracture, or hemorrhage.) For more details please see text.

analysis as accidental injuries, but referrals to the appropriate child protection agencies were made in all cases of suspected child abuse or neglect independent of the study classification.

Patients were categorized according to reported mechanism of head injury, head injury type (Table 2), presence or absence of retinal hemorrhages, inflicted or noninflicted injury, and whether the child died. Patients sustaining more than one injury type (eg, skull fracture and epidural hematoma) were classified for purposes of statistical analysis by the more severe injury type. The performance of a formal social service or child maltreatment evaluation team consult was also analyzed separately as an additional marker for suspicion for family or social problems, neglect, or abuse, to identify the frequency with which these issues were present in the population studied.

Data were analyzed using univariate analysis of variance to assess distribution of demographic variables and the χ^2 statistic for contingency tables to assess the relationship between variables.

RESULTS

Of the 100 children studied, 65 were male and 35 were female. Mean age was 9.0 months (standard deviation 7.1 months), with a range of 11 days to 24 months. The distribution of reported mechanisms of injury is given in Table 3. Grouping similar mechanisms, there were 73 reported falls, 9 motor vehicle accidents, 14 patients with no history, 2 patients with admitted assault, and 2 impacts by moving objects.

The distribution of injury types is shown in Table 2. Thirty-two children had a soft-tissue injury and/or concussion only. Twenty-seven children had a linear skull fracture with or without loss of consciousness. There were eight depressed fractures and eight instances of multiple, stellate, or basilar skull fracture. This study population had no cases of "ping-pong" fracture (in which the bone is indented but not fractured). Three children had epidural hematomas (all with fractures), and 22 children had intradural hemorrhages (subarachnoid or subdural hemorrhage or parenchymal contusion). In the latter category, 10 patients also had skull fractures.

TABLE 2. Distribution of Injury Types in 100 Consecutively Admitted Head-Injured Children 24 Months of Age or Younger

Injury Type	No.
Concussion/soft tissue injury only	32
Skull fracture (± concussion)	43
Linear	27
Depressed	8
Multiple	3
Stellate	1
Basilar	4
Epidural hematoma	3
Intradural hemorrhage	22
Subdural hematoma ± subarachnoid hemorrhage, contusion	16
Subarachnoid hemorrhage only	3
Focal contusion only	3
Total	100

TABLE 3. Reported Mechanisms of Injury

Mechanism of Injury	No.
Falls	73
<4 ft	34
>4 ft	21
Down stairs	10
Down stairs in walker	8
Motor vehicle accidents	9
Passenger—unrestrained	6
Passenger—restrained	2
Pedestrian	1
Impact by moving object	2
Assault (admitted)	2
No history	14
Total	100

Twenty-four patients were classified as having inflicted injuries. All of these children were also identified by the child maltreatment teams using hospital-specific protocols, and reports to child protection agencies were filed in each case. An additional 32 patients had social service or child maltreatment evaluation team consults because of social problems or suspicion of a nonaccidental injury or neglect but did not meet criteria for presumed inflicted injury as defined in this study. Of the 24 patients meeting criteria for presumed inflicted injury, there were 15 boys and 9 girls, with a mean age of 8.7 months (standard deviation 6.3 months), which did not differ from the overall study population. Reported history in this group was a fall less than 4 feet in 8 patients, admitted assault in 2 patients, and no history in 14 patients. Two children with presumed inflicted injury had craniofacial soft-tissue injury; 7 had linear or depressed skull fractures without intradural hemorrhage; 2 had multiple, basilar, or stellate fractures; and 13 had intracranial hemorrhage with or without fracture. All 13 of these latter patients had subdural hemorrhage. Subarachnoid hemorrhage and focal contusions were also seen, particularly in those patients who underwent magnetic resonance imaging. Five of the 13 patients with subdural hemorrhage also had skull fractures diagnosed radiographically. Nine of the 24 patients with inflicted injury also had acute long-bone fractures or healing fractures. The relationship between inflicted injury and the presence of an intradural hemorrhage is statistically significant ($P <$ .0002).

Excluding those children with inflicted injury, an analysis can be made of the association between mechanism of injury and injury type. Linear skull fractures were as likely to occur from a fall less than 4 feet as from falls greater than 4 feet, falls down stairs, or falls down stairs in walkers. However, more complex skull injuries were associated with the greater mechanical impact forces generated from the higher falls. All noninflicted depressed skull fractures occurred from falls greater than 4 feet, falls down stairs, or impact from a moving object. Basilar (n = 3) or bilateral (n = 3) fractures without intracranial hemorrhage were all associated with falls greater than 4 feet or falls down stairs. The only instance of stellate fracture in this series was in a child with an admitted assault who was struck on the head by her caretaker.

While all three epidural hematomas occurred from falls less than 4 feet, no other types of intracranial hemorrhages were associated with this mechanism of injury when the trauma was accidental. In contrast, more significant falls resulted in focal parenchymal contusions (n = 4) or focal subarachnoid hemorrhage (n = 2); these children typically had a benign clinical course. Motor vehicle accidents (n = 7) were associated with a high incidence of subdural (n = 3) or diffuse subarachnoid hemorrhage (n = 2) and parenchymal contusions and a more severe neurologic injury. The difference in injury types seen among patients with accidental injuries sustained in motor vehicle accidents compared with those from all other mechanisms (excluding inflicted injury) is significant, with the former having a higher incidence of intradural hemorrhage (χ^2 contingency tables, $P < .0002$).

Retinal hemorrhages were found in 10 patients. Mean age was 10.9 months (range 3 to 24 months). Nine of the 10 were inflicted injuries ($P < .0005$), with 2 of these patients reporting a history of a trivial fall, 1 having an admitted assault, and the remaining 6 patients having no history of trauma. One patient had a history of unexplained apnea, shaking to resuscitate, and cardiopulmonary resuscitation but was later found to have multiple long-bone fractures. No other patients had a history of shaking. The patient with an accidental injury and retinal hemorrhages was a passenger in a high-speed motor vehicle accident who subsequently died of his head injury. All 10 patients with retinal hemorrhages also had subdural hemorrhage; these were all small and were not treated surgically. Seven of the 9 patients with inflicted injury and retinal hemorrhages had seizures as part of their acute course. Two had skull fractures and 5 had associated long-bone or old fractures.

There were four deaths in the overall series. One of these was accidental and three were inflicted; all had subdural hemorrhage and three of the four (two inflicted and one accidental) had retinal hemorrhages.

DISCUSSION

The most common mechanisms of head injury in very young children involve falls from short distances which impart a predominantly translational (linear) force to the head. While such forces may result in local skull deformations sufficient to cause simple skull fractures, translational forces of this degree applied to the brain are not of great acute clinical consequence, except when an epidural hematoma occurs.[18–20] In our experience, ping-pong fractures also frequently occur from short falls against a pointed object such as a table corner, though there were none found in the present series. Greater degrees of translational force as occur in falls from greater heights appear to result in focal impact forces associated with multiple, depressed, comminuted, or basilar skull fractures as well as focal brain contusions and subarachnoid hemorrhage.[6,7,9,21,22] However, except when translational forces are extreme, damage is predominantly focal and recovery of global neurologic function is usually rapid. In contrast, it has been shown experimentally and clinically that more significant diffuse brain injury results from the introduction of a significant angular component to the head's deceleration. Angular (rotational) deceleration leads to much more brain deformation and shear strain than is seen in translational events, and at progressively greater angular decelerations the phenomena of concussion, subdural hematoma, and diffuse axonal injury will occur.[18,19,23,24]

The results of this study confirm the widely noted observation that simple falls from low heights rarely, if ever, result in significant primary brain injury.[4,5] Secondary brain injury from the mass effect and herniation resulting from an arterial epidural hematoma, which requires only that a fracture or skull displacement occurs across and ruptures a dural artery, may result from such falls; however, when the hematoma is evacuated before secondary damage occurs the outcome is usually very good.[25] While the exact frequency and biomechanics are unknown, calvarial, linear, depressed, and ping-pong fractures occur fairly commonly from falls in young infants as the requisite skull deformation can be produced with relatively little impact force in this age group. Underlying brain injury is almost always minimal when the mechanism is a low-height fall.

The present results also confirm the intuitive notion that greater biomechanical forces produce more significant injuries, but here too the type of force determines the particular type of associated injury. Translational forces of greater magnitudes (eg, falls from greater heights or focal impact from a heavy moving object) produce more extensive skull fractures. These include basilar fractures which occur through bone of greater stress tolerance than that of the convexity, depressed fractures, stellate fractures, or multiple fractures. These forces may also be associated with focal contusions and usually localized subarachnoid hemorrhage. Such forces may also be generated when a child acts as a missile in a motor vehicle or pedestrian accident if the head and brain move in a line rather than rotate when they decelerate. These children often have a relatively benign clinical course even when fractures and focal contusions are extensive (Fig. 2). Contusional brain swelling and focal neurologic deficit may complicate recovery or increase mortality when large forces are involved.

Subdural hematomas result from displacement of the brain relative to the dura sufficient to cause rup-

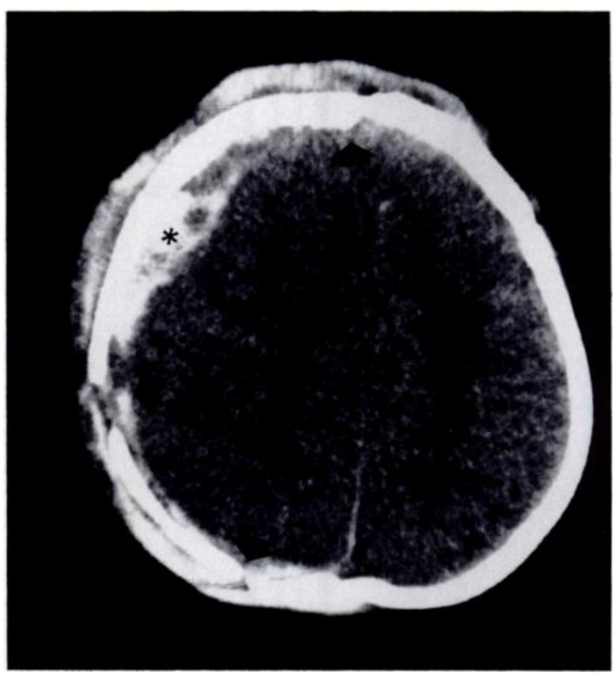

Fig 2. Computed tomographic scan of an 11-month-old child who was an unrestrained passenger in a motor vehicle accident. Despite extensive fractures (arrows) and focal contusions and extraaxial hemorrhage (asterisk), the child made a good recovery.

ture of the bridging veins which course from the brain's surface to the overlying venous sinuses.[26–28] Thus, unlike epidural hematomas which occur from focal impact injuries, subdural hematomas almost always result from angular deceleration of the head in which the brain continues to rotate relative to the more stationary skull and dura. This explains the high incidence of subdural hematoma seen in adults involved in motor vehicle accidents in which the head rotates around an axis in the lower cervical spine, often decelerating abruptly as it impacts against a surface. The same shear forces involved in rupturing the bridging veins are also applied to the brain parenchyma itself and, depending on the velocity and duration of the deceleration, may give rise to diffuse axonal injury. This type of brain damage often results in severe and permanent neurologic sequelae.[18,29–31] While an unusual focal impact could theoretically tear a cortical vessel or bridging vein and result in hemorrhage into the subdural space, such an injury would be expected to produce the appropriate focal neurologic deficits, rather than diffuse neurologic dysfunction. Such an injury is rarely encountered and was not seen among the patients studied.

In this series, subdural hematomas were uncommon in accidental injuries, occurring in only three children involved as passengers in motor vehicle accidents. None were treated surgically. One child died from uncontrollable diffuse brain swelling and the other two children made gradual recoveries. The small size and less erect sitting posture in very young children probably contribute to the uncommon occurrence of sufficient angular rotation to cause subdural hemorrhage in the clinical setting of accidental injury.

In contrast, subdural hemorrhage and diffuse subarachnoid hemorrhage are common in inflicted injury in very young children, occurring in 13 of 24 patients in this series. The mechanism of injury of inflicted trauma is rarely clear, as an accurate history is almost always lacking and the mechanism varies among patients. In most cases, an extrapolation of forces required to cause a given injury type can be approximated; this is true for both fractures and for intracranial hemorrhages. While subdural hematomas in child abuse classically have been attributed to shaking,[32,33] it is our belief that the high incidence of subdural hemorrhage in inflicted injury in infants results from the application of a rapid angular deceleration to the brain which requires an impact to occur. The mechanism postulated is that of a child being held by the perpetrator who shakes, swings, or throws the child, the head thus moving through an arc, stopping abruptly against a surface. Previous autopsy studies and biomechanical analysis using infant models suggest that shaking alone does not generate sufficient deceleration forces to cause the subdural hemorrhages and brain injuries seen in these children.[34] The frequent radiologic or clinical findings of blunt impact in series of "shaking" injuries corroborate this conclusion, as does the rarity of an unsolicited history of shaking.[34–39] For these reasons, we now refer to this syndrome as the "shaken impact syndrome."[36] The presence of fractures or bruises will be determined by the surface against which the rotating head decelerates. Thus, if the head strikes a soft padded surface, contact forces will be dissipated over a broad area and external or focal injuries may be undetectable while intracranial rotational shear forces can be sufficient to result in subdural hemorrhage and severe brain injury.[18,34]

In young children with malleable skulls and patent sutures, the possibility of dural sinus tears resulting from bony displacement associated with impact is also a possible source of subdural hemorrhage. Such a mechanism might explain the preponderance of hemorrhages in the occipital region and posterior interhemispheric fissure, where the lambdoid and sagittal sutures overlie the confluence of venous sinuses. The diffuse brain injuries often associated with these hemorrhages in nonaccidental trauma are likely to result from large angular deceleration forces and shearing of the brain parenchyma. The degree to which superimposed hypoxia, possibly related to seizures, cervicomedullary compromise, or concomitant strangulation, exacerbates the brain injury and subsequent swelling in these patients remains unknown.[40–42] In some patients, particularly those with a more unilateral injury, the entire affected hemisphere appears swollen or infarcted, though in our experience magnetic resonance angiography performed within 24 hours of admission demonstrates patency of the circulation. Whether a transient functional effect of the injury on vasomotor tone or a local toxic effect of subdural blood plays a role in this phenomenon remains to be studied.[43]

Retinal hemorrhages are also overrepresented in nonaccidental trauma (9 of 24, $P < .000002$), being found in only one patient with accidental trauma, the victim of a fatal motor vehicle accident associated with subdural hemorrhage. The mechanism of retinal hemorrhage which is found so often in child abuse remains speculative. Historically this also had been attributed to violent shaking.[32,33,44–46] Other postulated mechanisms include increased pressure to the central retinal vein from increased intracranial or increased intrathoracic pressure or some effect related to direct head trauma.[47,48] Studies linking cardiopulmonary resuscitation to retinal hemorrhages have been inconclusive, and they further complicate attempts to determine mechanism of injury in cases of suspected abuse with a history of resuscitation.[49,50] Nonetheless, it is clear that retinal hemorrhages can occur under a variety of circumstances, including vaginal delivery, spontaneous subarachnoid hemorrhage, systemic hypertension, intracranial hypertension, thoracic or abdominal trauma, and in-hospital resuscitation.[49–55] Whether superimposed hypoxia or ischemia with reflow exacerbates the finding remains unknown.

Traumatic retinoschesis resulting from acceleration/deceleration forces applied to the eye has also been postulated as a mechanism for retinal hemorrhages.[56] The latter may be particularly relevant in very young children because of the more solid consistency of the vitreous body in the infant and the stronger adhesions at the vitreoretinal interface.[57–59] Threshold values for the degree of deceleration required to result in retinal hemorrhage have not been established. Since this study was completed, we have seen three additional patients with well-witnessed accidental head injuries who had acute retinal hemorrhages. Mechanisms included a nonfatal motor vehicle accident, a fall down stairs in a walker, and a fatal three-story fall. Thus, because of the variable etiologies and unclear biomechanical thresholds for retinal hemorrhages, it is at the present time impossible to extrapolate a specific mechanism of injury for a given patient with this finding.

Deciding whether a head injury in a very young child is accidental or nonaccidental has always be problematic for clinicians and is complicated by the fact that there is often no history given by the caretakers who bring the child to medical attention.[21,34,60,61] Most determinations of nonaccidental injury are based on the notion of "history insufficient to explain injuries." Social factors and certain specific associated injuries such as long-bone fractures or injuries of different ages have also been used. The presence of retinal hemorrhages is believed by some authors to be virtually pathognomonic for child abuse,[39,44] but for the reasons stated above this is unreliable. From the data generated in this study and in our larger experience over many years, the expected injuries associated with various accidental mechanisms can be approximated, although some uncertainty remains (Table 4). Further biomechanical studies are needed to determine specific threshold conditions for various injury types in this age group.

The scheme used in the present study for determination of inflicted injury incorporates our current understanding of the biomechanical forces associated with a given injury type as well as reliance on those features of the history, physical examination, and radiographic findings which are most objectively verifiable. The scheme was designed to eliminate dependence on the presence of retinal hemorrhages or psychosocial factors to determine nonaccidental injury. In addition, the possibility of a rare medical condition mimicking trauma is maintained. The scheme also includes strict criteria for a *presumption* of inflicted injury, with lesser injuries with no history of trauma or very trivial trauma, which may occur when children are unsupervised, classified as suspicious but not presumptive for inflicted injury. The conclusions reached by using the algorithm correlated extremely well with those reached by the trauma social workers and child abuse team, who often had additional social data available.

TABLE 4. Expected Injury Types Associated With Accidental Mechanisms in Very Young Children*

Mechanism	Injury Types
Fall <4 ft	Concussion/soft tissue injury Linear fracture Epidural hematoma Ping-pong fracture ? Depressed fracture
Fall >4 ft	Injuries listed above plus the following: Depressed fracture Basilar fracture Multiple fractures Subarachnoid hemorrhage Contusion ? Subdural hematoma ? Stellate fracture
Motor vehicle accident	Injuries listed above plus the following: Subdural hematoma Diffuse axonal injury

* Injury types preceded by question marks are uncommonly associated with the given mechanism.

In light of these strict criteria for determining inflicted injury, it is of interest that nearly one quarter (24%) of all admissions for head injury in this age group can be classified as inflicted. This figure is higher than that of more general series[1,11] and is cause for grave concern. Compared to accidental injuries, inflicted injuries have a disproportionately high incidence of intracranial hemorrhage (13 of 24, $P < .0002$) and mortality (3 of 24, or 12.5%). An additional 32% of all patients in this series required further investigation because of a suspicion of abuse or neglect. Thus, the majority of head injuries in very young children appear to be preventable, with social or family problems a major risk factor for their occurrence.

CONCLUSIONS

Accidental blunt head injuries in children younger than 2 years of age are very common, but except for those caused by motor vehicle accidents and falls from extreme heights, they are almost always benign in their acute clinical consequences. Inflicted injury is extremely common among children admitted for head injury, accounting for nearly one quarter of admissions in this series. This mechanism is associated with more severe brain damage and was the most common cause of mortality. The determination of inflicted injury can be assisted by using a scheme incorporating biomechanical information and related physical and radiographic findings independent of ophthalmologic findings and social history. Finally, while retinal hemorrhages can occur in severe accidental head trauma and in other benign circumstances, they were never seen in trivial accidental head injuries. Retinal hemorrhages are highly associated with inflicted injuries in very young children and, like subdural hemorrhages and diffuse axonal injury, may result from rotational, rather than translational, forces applied to the head.

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