Retinal Findings after Head Trauma in Infants and Young Children

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Background: Many authorities believe that the finding of retinal hemorrhages in a child younger than 3 years of age with a history of head trauma, in the absence of an obvious cause for the injury, is pathognomonic of child abuse. To date, no studies have examined the prospective retinal examination of children who have had head trauma. The authors undertook such a study because the presence of retinal hemorrhage from any head trauma in children may have medicolegal diagnostic significance in differentiating accidental from nonaccidental trauma.

Methods: Seventy-nine children younger than 3 years of age, each of whom experienced head injury, underwent an ophthalmologic assessment, which included a dilated funduscopic examination.

Results: Seventy-five children sustained accidental head injuries and had normal funduscopic examinations. Three children had nonaccidental head injuries and all were found to have varying degrees of retinal hemorrhages. One child, with a normal fundus examination, had injuries that were of indeterminate cause.

Conclusion: The finding of retinal hemorrhages in a child with a head injury suggests a nonaccidental cause. *Ophthalmology 1992;99:1718–1723*

Approximately 4% to 6% of abused children present with ocular involvement.[1,2] In the 1970s, Caffey[3] recognized an association of long bone fractures, subdural hemorrhages, and retinal hemorrhages in infants and used the term *whiplash shaken infant syndrome*, which is now referred to as *shaken baby syndrome.* Although virtually any type of ocular injury may be the result of child abuse, retinal hemorrhages are reported to occur in 5% to 23% of physically abused children.[1,4] In patients with shaken baby syndrome, the incidence of retinal hemorrhages is 50% to 100%.[5–8] These hemorrhages most often involve the posterior pole in the nerve fiber and intraretinal layers and are bilateral in 58% to 100% of cases.[4] Increased severity of retinal hemorrhages in shaken baby syndrome has been correlated with acute neurologic findings.[9] The natural history of retinal hemorrhages is variable, resolving anywhere from 10 days to several months.[4]

The presence of retinal or vitreous hemorrhages in a child younger than 3 years of age who has no other medical risk factors has been considered by some to be pathognomonic of child abuse (nonaccidental) injury.[10] We are unaware of any published data regarding the prospective retinal examination of children who have had head trauma. As the presence of retinal hemorrhage from any

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head trauma in children may have medicolegal diagnostic significance in differentiating accidental from nonaccidental trauma, we undertook such a study.

Methods

Approval of the study protocol was obtained from the Human Subjects Review Committee at The Hospital for Sick Children. All children between the ages of 4 weeks and 36 months who sustained head trauma within the preceding 48 hours and who were brought to the emergency department, neurosurgical service, or ophthalmology service of the Hospital for Sick Children between June and October 1990 were considered eligible for inclusion in the study. Exclusion criteria included more than 48 hours elapsed from the time of head trauma or the presence of other systemic diseases associated with retinal hemorrhages.

After obtaining informed consent, an ophthalmologic examination was performed, which included indirect ophthalmoscopy after dilating both pupils with phenylephrine 2.5% and tropicamide 0.5%. Proparacaine 0.5% was instilled first to produce a less noxious sensation.

Data collected included patient demographics, mechanism of injury, results of laboratory investigations, and findings on ophthalmologic examination. The degree of head trauma was assessed by the Children's Coma Score (Table 1).[11]

Patients were assigned to one of two groups: accidental or nonaccidental head injury. This categorization was based on the results of standard multidisciplinary evaluations (i.e., child abuse team, social work, law enforcement) obtained in cases suspicious for child abuse on the basis of history and or clinical findings. Children with retinal hemorrhages were automatically referred for investigation. If child abuse was not suspected, no referral was made, and the child was assigned to the accidental group. One case that remained indeterminate with regard to mode of injury despite extensive investigations was excluded from statistical analysis.

The data were analyzed statistically using chi-square or Fisher's exact test. Fisher's exact test was used in cases where the number of events observed were small, thus rendering the results of chi-square analysis unreliable.

Table 1. Children's Coma Score

Ocular Response	
4 pursuit	
3 extra ocular movements intact, reactive pupils	
2 fixed pupils or EOM impaired	
1 fixed pupils and EOM paralyzed	
Verbal Response	
3 cries	
2 spontaneous respirations	
1 apneic	
Motor Response	
4 flexes and extends	
3 withdraws from painful stimuli	
2 hypertonic	
1 flaccid	
Level of Function (Total Scores)	
Cortical	11
Subcortical	8-10
Brainstem	3-7

Table 2. Comparison of Enrolled and Nonenrolled Populations

	Enrolled	Nonenrolled	P Value
Age (mos)	16.1	15.9	NS (0.77)*
Male/female	1.8	1.3	NS (0.30)*
Admitted	30	7	S (1×10^{-6})†
CCS < 11	5	1	S (0.04)*
Mode of injury:			
fall versus no fall			NS (0.08)*
height of fall			NS (0.08)*
type of surface			NS (0.34)†

NS = not significant; S = significant; CCS = Children's Coma Score.

* Chi-square.

† Fisher's exact test (two-tail).

Results

Two hundred patients met the inclusion criterion. Dilated funduscopic examination was performed on 79 children (39.5%). The reasons for missed patients were inability to return for examination within 48 hours from the time of injury (85 children), refusal to consent for examination (31 children), and no interpreter available to obtain consent (5 children). Age of the enrolled study population was 1.1 months to 35.2 months old (mean, 16.1 months). There were a total of 50 males and 28 females. Statistically there was no significant difference demographically between the enrolled and nonenrolled populations (Table 2).

The most frequent mode of injury was accidental falls from an average height of 4.4 feet (Table 3). Three children (3.8%) had nonaccidental head injuries. In one child with an unremarkable retinal examination, the cause of his skull fracture remained indeterminant after extensive investigation. Therefore, this child was excluded from statistical analysis.

The majority of children in our study sustained mild head injuries as defined by a Children's Coma Score of 11 in 73 (93.6%) children (Table 4). Despite a Children's Coma Score of 11, 2 of these children sustained significant nonaccidental head injuries (cases 1 and 3).

Computed tomography scans of central nervous system hemorrhage or infarction were present in 8 patients (10.3%), 3 of whom were abused (Table 5). Five children

Table 3. Mechanism of Head Injury

	Number (%)
Fall from a height*	51 (64.6%)
Fall down stairs	16 (20.3%)
Missile*	7 (8.9%)
Nonaccidental	3 (3.8%)
Motor vehicle accident	2 (2.5%)

* One child was first hit in the head by a baseball followed by a 4' fall off a slide.

Fall from a height		Fall down stairs	
Height			
≤4 ft	45 (88.2%)	<3 stairs	1 (6.3%)
4 ft–10 ft	1 (2.0%)	≥3 and ≤10 stairs	7 (43.8%)
≥10 ft	5 (9.8%)	>10 stairs	8 (50.0%)
Surface			
Hard	39 (76.5%)	Carpeted	6 (37.5%)
Soft	10 (19.6%)	Noncarpeted	10 (62.5%)

Hard surface = hardwood, concrete, ceramic.
Soft surface = carpet, grass.
Noncarpeted stairs = hardwood, concrete, marble.

had evidence of intracranial abnormalities due to accidental head injuries. A 6.1-month-old girl fell 3.5 feet onto a hardwood floor and had a skull fracture with epidural hemorrhage that required neurosurgical evacuation. On admission, her Children's Coma Score was 9. An 18.3-month-old boy was struck by a motorcycle, thrown 5 feet, and sustained an orbital fracture and intracranial hemorrhage and presented with a Children's Coma Score of 7. He was managed with close observation. Another 28.1-month-old boy fell into the corner of a table and had a Children's Coma Score of 11 despite cerebellar and occipital infarcts. In this case, investigations included a cerebral angiogram, which showed vertebral artery narrowing. A presumptive diagnosis of vasculitis was made. A 5.6-month-old girl fell from a stroller to a hardwood floor and presented with a Children's Coma Score of 11, intracranial hemorrhages, and contusions. She was managed by observation. Finally, a 1.1-month-old boy, while being carried, was struck on the head by a hard object and had

Table 4. Severity of Head Injury

CCS	Accidental Injury	Nonaccidental Injury	Total (%)
11	71	2	73 (93.6%)
8–10	2	0	2 (2.6%)
3–7	2	1	3 (3.8%)

CCS = Children's Coma Score.

Table 5. Abnormalities of Computed Tomography Scan

	Accidental Injury	Nonaccidental Injury
Intracranial hemorrhage	4	3*
Infarction	1	1*

* One child had both.

a cerebral hemorrhage. He had a Children's Coma Score of 11 and was managed by observation. All cases, with the exception of the motor vehicle accident, were investigated by the multidisciplinary team as described in the Methods section, and nonaccidental injury was ruled out.

Radiographic evidence of skull fractures were found in 15 accidentally injured children (19.2%), 2 of whom required surgical elevation of depressed skull fractures. An additional four accidentally injured children sustained orbital fractures without evidence of ocular trauma. One accidentally injured child sustained a fractured nose. Ninety-six percent of the accidentally injured children were managed by observation alone.

Results of dilated funduscopic examinations were normal in the 75 accidental head injuries. Three children (3.8%) were found to have retinal hemorrhages. All had nonaccidental injuries. In all three cases, the mechanism of injury was believed to be shaken baby syndrome.

Selected Case Reports

Case 1. At presentation, a 6.3-month-old boy had a Children's Coma Score of 11, extensive bilateral chronic subdural hemorrhages, which required a subdural peritoneal shunt, and evidence of a previous fracture involving the right distal femur. Results of funduscopic examination showed a single dot intraretinal hemorrhage in the posterior pole of the right eye.

Case 2. A 5.7-month-old boy arrived clinically brain dead and died within 24 hours of admission. Results of autopsy showed subdural and subarachnoid hemorrhages, moderate cerebral edema, and a fractured left clavicle. Results of funduscopic examination showed extensive bilateral nerve fiber layer, subhyaloid and vitreous hemorrhages, and a left retinal detachment (Fig 1).

Case 3. At presentation, a 1.3-month-old boy had a Children's Coma Score of 11 and cerebral infarction and hemorrhage. Bone scan showed uptake in the costovertebral junctions consistent with fractures. Results of funduscopic examination showed bilateral subhyaloid and nerve fiber layer hemorrhages (Fig 2).

Discussion

In shaken baby syndrome, the pathophysiology of retinal hemorrhages may be due to one or more of the following mechanisms. First, the repeated violent shaking described

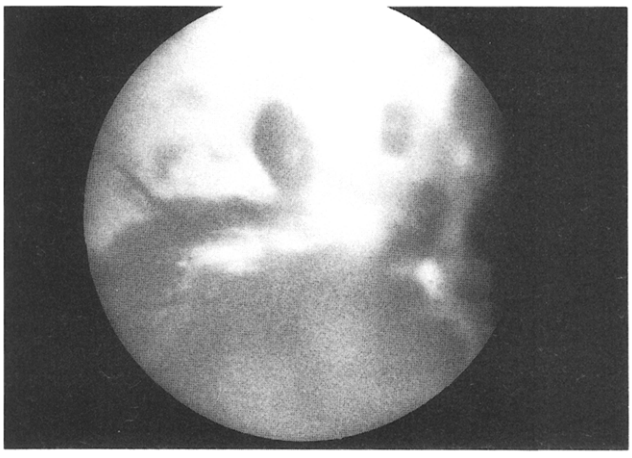

Figure 1. Case 2. Right fundus photograph shows extensive retinal and vitreous hemorrhages.

in the shaken baby syndrome may result in repeated severe acceleration/deceleration of the vitreous, which may cause trauma to the retina and retinal blood vessels. This mechanism also has been proposed as the cause of traumatic retinoschisis[12] and retinal folds in the shaken baby syndrome.[13,14] Second, as the perpetrator grasps the infant's chest, there may be a rise in intrathoracic pressure that is sufficient to be transmitted to the eye and result in the rupture of veins.[15] This mechanism causes Purtscher's retinopathy and is characterized by large white patches of retina in the macular and peripapillary areas.[15] Although perpetrators may compress an infant's chest with such force that rib fractures occur, Purtscher's retinopathy has only rarely been reported in the shaken baby syndrome.[4] Finally, retinal hemorrhages may be caused by the transmission of subarachnoid blood, subdural blood, or elevated intracranial pressure into the optic nerve sheath and as is seen in Terson syndrome.[16] The exact mechanism of this process is not clearly understood.[17]

Our study was designed to ascertain the funduscopic findings after head trauma in the pediatric population. An age restriction of older than 4 weeks was selected to exclude retinal hemorrhages secondary to birth.[4] As retinal hemorrhages in child abuse are largely a phenomenon of shaken baby syndrome, which is seen almost exclusively in children younger than 3 years of age, children older than 3 years of age were excluded.[6]

Our sample size of 75 accidental and 3 nonaccidental head injuries does not allow for valid statistical comparison between the groups because of the disproportionately small number of nonaccidentally injured children. However, we found no retinal hemorrhages after accidental head injury. The pattern of enrollment in our study would result in an overestimation of the incidence of retinal hemorrhages since we were more likely to be involved with the care of more severely injured children. By performing a one sided *t* test, with our sample size we would expect to detect an incidence of retinal hemorrhages as low as 2.5% in accidental head injuries with a power of 80%. Or stated in another way: if the frequency of retinal hemorrhages after accidental head injuries is greater than 2.5%, this should have been detected in our population of 75 accidental head injuries. Similarly, if we exclude the 5 cases of intracranial abnormalities and perform the same calculation on a sample size of 70, we would expect to detect an incidence of retinal hemorrhages as low as 2.7% with a power of 80%. Thus, we conclude that retinal hemorrhages in children younger than 3 years of age rarely occur in association with accidental head injuries.

A review of the literature supports our conclusion that retinal hemorrhages only occur very rarely after severe head trauma in children. In infants and children, retinal hemorrhages have been reported in association with subdural and/or subarachnoid hemorrhage. Unfortunately, both studies reporting the incidence of these findings did not evaluate the mechanism of injury.[18,19] A majority of these cases may be the result of nonaccidental injuries, especially since the two often quoted studies were published before widespread recognition of the battered child syndrome. Duhaime et al[20] studied the retinal findings after acute accidental head trauma in 100 children younger than 2 years of age. They found that retinal hem-

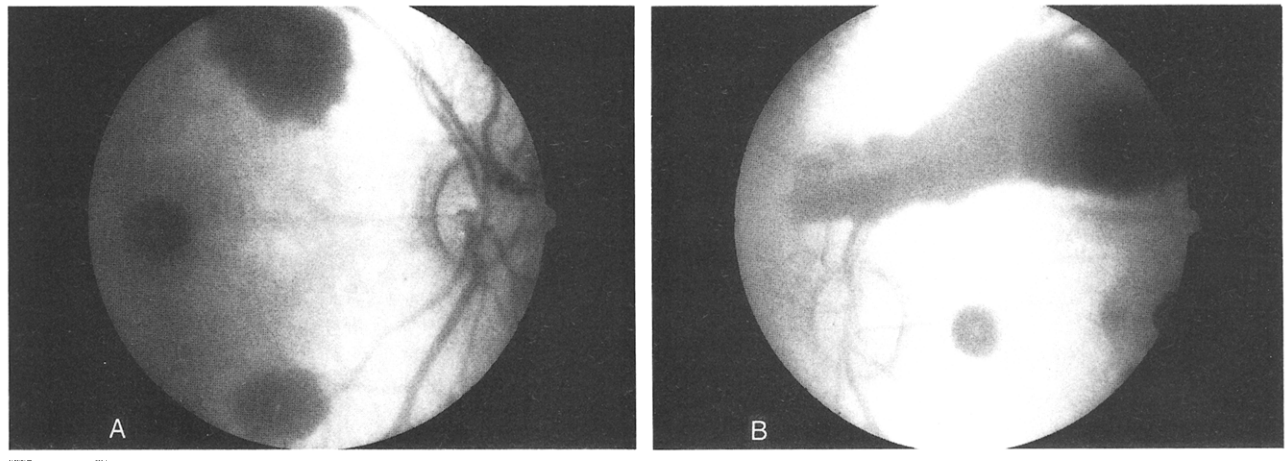

Figure 2. Case 3. **A,** right and **B,** left fundus photographs show retinal hemorrhages of the shaken baby syndrome.

orrhages did not occur after minor accidental head trauma but may occur only in severe accidental head trauma. We have examined (AVL) one child (before this study) who sustained bilateral retinal hemorrhages after fatal accidental head trauma after being thrown 50 feet during a motor vehicle accident.

Eisenbrey's study of victims of head trauma found retinal hemorrhages in 16 of 26 battered children (62%) and only 1 of 32 (3%) nonbattered children. The one child with retinal hemorrhage in the nonbattered group was a "newborn infant, following a traumatic delivery."[10] He concluded that beyond the neonatal period, retinal hemorrhage did not occur after accidental head injury in children. However 10 of the children in his study had no comment regarding funduscopic examination in their charts and were included in the normal fundus examination group. Fifteen of the nonbattered children were older than 4 years compared with 1 child in the battered group. This retrospective study had several flaws, including unmatched age groups for accidental and nonaccidental injury and no documentation of the type or severity of head injury. Retrospective studies also are limited by the fact that cases of retinal hemorrhage easily could have been missed, since routine funduscopic examinations were not performed on all of the children.

One of the investigators in our study found no evidence of retinal abnormalities in 25 children of various ages less than 14 years who had experienced moderate to severe accidental head trauma.[21] One recently published study looking at children with ocular complications from head trauma found that retinal hemorrhages accounted for 70% of the ocular findings in children aged 0 to 12 years and 40% in children aged 12 to 18 years.[22] Unfortunately, this study only evaluated children with positive ocular findings, thus making it impossible to establish the incidence of retinal hemorrhages as a result of head trauma. Furthermore, they failed to evaluate the mechanism of injury, including differentiation of cases of nonaccidental versus accidental head injuries.[23]

Raimondi and Hirschauer,[11] in a retrospective review of closed head injuries involving 462 children between the ages of 1 and 36 months, found that retinal hemorrhages were reported in 57 (12%) cases. There was no evaluation of the mechanism of injury. It may be that the majority of cases with ocular involvement were victims of nonaccidental injuries. This is suggested by the fact that bilateral retinal hemorrhages were significantly more common in infants younger than 15 months of age. Serious head injuries in infants in the absence of an obvious cause, such as motor vehicle accidents, are rarely due to unintentional trauma.[7,24] Billmire and Myers,[7] in a retrospective study of infants younger than 1 year of age who were admitted to the hospital with a head injury, reported retinal hemorrhages in 89% of the 28 abused infants and in none of the 54 infants with accidental head injuries.

Another study of 811 children with traumatic brain injury found retinal hemorrhages in 27 patients (3%).[25] Of these, 26 were younger than 3 years of age. Eighty-one percent of the children with retinal hemorrhages sustained nonaccidental injuries. Only 5 (0.6%) children had accidental injuries and retinal hemorrhages. One child was noted to have received a severe head injury after a motor vehicle accident. However, there was no mention of the severity of injury in the four other accidentally injured children with retinal hemorrhages. Twenty-six of the 27 children with retinal hemorrhages were noted to have abnormal computed tomography scans.

Accidental head trauma in adults also may be associated with large areas of preretinal hemorrhage that may appear clinically to be very similar to the traumatic retinoschisis of shaken baby syndrome.[26] Purtscher's retinopathy also may be found after severe accidental crush chest injuries. Such injuries may occur in association with accidental head injury. To our knowledge, retinal hemorrhage after head trauma without intracranial abnormality and without direct ocular trauma has not been reported in children. Perhaps a single fatal or near fatal blunt impact can produce a single acceleration/deceleration event that briefly approximates the repetitive severe acceleration/deceleration that is characteristic of the shaken baby syndrome, thus resulting in retinal hemorrhages.

Our study and literature review support the conclusion that retinal hemorrhages occur only rarely in children younger than 36 months of age after severe head trauma and not at all after moderate or mild head trauma. When a child presents with a head injury and retinal hemorrhages in the absence of an obvious cause, an investigation for child abuse should be considered.

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