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Odds of abuse associated with retinal hemorrhages in children suspected of child abuse

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Abstract

Purpose—To describe the prevalence of retinal hemorrhages in children being evaluated for abusive head trauma and quantify the association between the likelihood of abuse and the presence and severity of retinal hemorrhages.

Methods—Retrospective cross-sectional study of 110 children aged 15 months or younger who were evaluated for abusive head trauma and received an ophthalmological examination. The child abuse specialist's diagnosis was categorized as definite accident, probable accident, probable abuse, or definite abuse, according to an algorithm that excluded eye findings. Retinal hemorrhage severity was scored on a 12-point scale (6 points per eye) based on type, size, location, and extent. Higher scores indicated greater severity of eye findings.

Results—Seventy-four percent of children were under 6 months old. Forty-five percent of cases were definite-abuse and 37% were definite-accident. The prevalence of retinal hemorrhages was 32%. Across all subjects, the presence of retinal hemorrhage was highly associated with definite or probable abuse versus definite or probable accident (age-adjusted odds ratio 5.4 [95% CI, 2.1-13.6]). The odds ratio in children under age 6 months (n = 81) was 11.7 (95% CI, 2.9-66.8). Retinal hemorrhage severity was higher in abuse versus accident ($p < 0.0001$) and correlated positively with abuse (Spearman $r = 0.406$, $p < 0.0001$). Scores above 8 (n = 13) were only present in abused children

Conclusions—Retinal hemorrhages are highly associated with abusive head trauma, particularly in children under age 6 months. Increasing retinal hemorrhage severity is correlated with increasing likelihood of abuse.

Introduction

Child abuse is a leading cause of death in infancy.[1,2] The majority of these early deaths are attributed to abusive head trauma (AHT), which has been referred to as the shaken baby

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syndrome (SBS), inflicted head trauma, inflicted traumatic brain injury, or inflicted childhood neurotrauma.[3] Abusive head trauma is characterized by intracranial hemorrhage and/or intraocular (primarily retinal) hemorrhages with or without additional injuries, including bony fractures. The mechanism of trauma is believed to be repetitive acceleration-deceleration of an infant with or without blunt impact.

Ophthalmologists are often asked to evaluate children suspected of having been abused to look for retinal hemorrhages. Retinal hemorrhages are present in 50% to 100% of victims of abusive head trauma.[4-11] However, both the frequency of such requests and the likelihood of ocular pathology may vary with the practice patterns of pediatricians, emergency room physicians, and child abuse specialists. In addition, the term *retinal hemorrhages* has been used indiscriminately by many physicians and investigators to describe a spectrum of findings. When bilateral, numerous, extensive in location, and of multiple types, retinal hemorrhages are highly suggestive of abuse.[6,8,10,12] However, retinal hemorrhages may also be unilateral and few in number and type in cases of abusive head trauma. Making these distinctions is crucial for determining the specificity of retinal hemorrhages for the diagnosis of child abuse. Currently there is no uniform grading system for the classification of retinal hemorrhages in abusive head trauma.

We sought to describe the prevalence of retinal hemorrhage in children being evaluated for abusive head trauma and to quantify the association between the presence and severity of retinal hemorrhage and the likelihood of abuse as determined by child abuse specialists.

Subjects and Methods

Clinical information was retrospectively collected on children admitted to the Children's Hospital of Philadelphia between July 13, 2001, and January 3, 2005, meeting the following criteria. All children were 15 months of age or younger, evaluated by the hospital's child abuse evaluation team, and referred to the department of ophthalmology for evaluation. Reasons for referral during this time period included the specific suspicion of abusive head trauma due to the presence of intracranial hemorrhage, with or without other injuries, and no known medical cause of intracranial hemorrhage; intracranial hemorrhage even in the setting of likely accidental head trauma; and, occasionally, a general concern for child abuse without known intracranial hemorrhage or head trauma. Examples of the last might include unexplained apparent life-threatening event or seizure. Children were included only if they had undergone a funduscopic examination by an ophthalmologist using an indirect ophthalmoscope within 72 hours of presentation. Subjects were not excluded from the study on the basis of conditions predisposing to retinal hemorrhages, such as coagulopathy or anemia, as the target study population was children referred to the ophthalmology department while being evaluated for child abuse.

Data collected included age, reported mechanism of injury, physical examination findings, radiographic and laboratory studies, and subspecialty consultant findings, including details of the ophthalmologic examination. The child abuse specialist's summary judgment as to the likelihood of abuse was graded as definite accident, probable accident, probable abuse, or definite abuse. This determination was made independent of ophthalmologic examination results, using a previously published algorithm based on the types of injuries (eg, skull fractures, especially multiple, stellate, or basilar; craniofacial blunt trauma; intradural hemorrhage; or epidural hemorrhage), history (no history of trauma, history of trivial or remote trauma, changing history, or developmentally incompatible history), and associated nonocular findings (eg, unexplained long-bone or old fractures).[13] The algorithm did not include the presence or absence of retinal hemorrhages. Retinal hemorrhage severity was scored (RH score) on a 12-point scale (6 points possible for each eye) based upon type, size, location and

extent (Table 1). The scale was adopted from a clinical form in use at our institution during part of the study period. Retinal hemorrhages were considered present if the RH score was greater than zero; higher scores reflected increased severity of findings.

Statistical analysis was completed using STATA version 10.0 (StataCorp, College Station, TX). Group means of continuous variables were compared with *t*-test. Multivariate logistic regressions were used to calculate odds ratios. Adjustment was made for age in months. To determine the presence or absence of confounding by age, a 10% change from the crude to adjusted odds ratios was considered to be significant, and a Mantel-Haenszel test of homogeneity was used to identify effect modification by age. Strata were defined as age less than 6 months and greater than or equal to 6 months. The Wilcoxon rank-sum test (Mann-Whitney test) was used as a nonparametric test to compare samples of the ordinal variable retinal hemorrhage score among subjects diagnosed and not diagnosed with abuse. Spearman coefficient was used to assess the association between the ordinal variable retinal hemorrhage score and the 4-category ordered variable likelihood of abuse.

The study had approval of the Children's Hospital of Philadelphia Institutional Review Board and was conducted in compliance with the federal Health Insurance Portability and Privacy Act.

Results

One hundred eighteen children met the inclusion criteria. Complete records were available for 110 children, the subjects of this study. Mean age was 4.1 months (SD 3.5), and the median age was 3 months (range, 1 week to 15 months) (Figure 1). Seventy-four percent of the children were younger than 6 months of age. There was no significant difference in age between subjects with and without retinal hemorrhages ($p = 0.20$). All children were examined within 24 hours of presentation, except for 2 children examined 3 days after initial presentation. Neither of these children had retinal hemorrhages. Only one subject's funduscopic examination was through undilated pupils; this child was diagnosed with definite abuse and was not found to have any eye findings.

The child-abuse specialist diagnosis of abuse for the study sample appears in Table 2. The majority of children were classified as definite abuse (45%) or definite accident (37%): 57 children were felt to have been subjected to definite or probable abuse, and 53 children were felt to have had a definite or probable accident.

The prevalence of retinal hemorrhages among the study population was 31% (34 of 110 subjects). Among these children, retinal hemorrhages were bilateral in 24 subjects (69%) and unilateral in 11 subjects (31%) (Table 2). Additional findings on ophthalmologic examination included subconjunctival hemorrhage (3 subjects), optic nerve head swelling (3), periorbital swelling (2), orbital fractures (1), and an epibulbar dermoid (1). All of these patients had associated retinal hemorrhages. One additional child diagnosed with definite accident had both a corneal abrasion and a sixth (abducens) nerve palsy but no retinal findings.

There was a significant association between the presence of any retinal hemorrhage and a diagnosis of definite or probable abuse versus definite or probable accident. The age-adjusted odds ratio (OR) was 5.4 (95% CI, 2.1-13.6), and the unadjusted odds ratio was similar (5.0, 95% CI, 2.0-12.6). Forty-seven percent of children with definite or probable abuse had retinal hemorrhages, while 15% of children with definite or probable accidents had retinal hemorrhages. Excluding children with probable abuse or accident, the association between abuse versus accident and the presence of any retinal hemorrhage persisted (age-adjusted OR 8.5; 95% CI, 2.7-26.3). Dividing all 110 subjects into two groups based on age, the odds ratio between any retinal hemorrhage and definite or probable abuse (versus definite or probable

accident) in children under age 6 months (n = 85) was 11.7 (95% CI, 2.9-66.8), while among subjects 6 months or older, the odds ratio was 1.2 (95% CI, 0.2-7.2).

Retinal hemorrhage grading scores appear in Figure 1. RH scores were significantly higher in children diagnosed with definite or probable abuse than in children diagnosed with definite or probable accidental trauma ($p < 0.0001$, Wilcoxon Rank-Sum). Increasing RH score correlated positively with abuse (Spearman $r = 0.367$, $p < 0.0001$). RH scores of 9 or higher (maximum is 12) were only seen in children diagnosed with abusive head trauma. The highest RH score among the accidental trauma group was in an 11-month-old child who was witnessed to have slipped out of his grandmother's arms and fallen down ten wooden steps. He had a RH score of 8 but also an orbital roof fracture and periorbital ecchymoses. RH scores of 5 or higher were seen in 23 (40%) subjects diagnosed with abuse and in 5 (9%) subjects with accidental trauma.

Discussion

We found an overall prevalence of retinal hemorrhages among referred children being evaluated for possible abusive head trauma of 31%. While other eye findings were identified, retinal hemorrhages were present in all but one of the subjects with eye pathology. In settings where child abuse specialists or ophthalmologists are not as readily available for consultation and referrals are subsequently less frequent, the rate of positive consults may be higher. There is limited information in the literature addressing this issue. In one recent cross-sectional retrospective study of inpatient ophthalmology consultations at a major tertiary care children's hospital, 11 of 55 patients (20%) evaluated for suspected nonaccidental trauma had retinal hemorrhages.[14] In contrast, retinal hemorrhages were present in 29 of 57 children (51%) evaluated for nonaccidental trauma at another children's hospital (Curtis TH et al, Pediatric ophthalmology inpatient consultations, J AAPOS 2007;11:87). We speculate that higher rates might indicate less frequent consults, but further study is necessary to evaluate this hypothesis. In general, we recommend casting the net wide by consulting ophthalmologists for any infant with intracranial hemorrhage, even in the setting of likely accidental trauma. Doing so may increase the identification of child abuse, help reduce potential bias in the interpretation of ocular findings when referrals are consistently made only for a strong suspicion of abusive head trauma, and lead to discovery of other findings, such as papilledema. Finally, identifying the presence of retinal hemorrhages in a variety of injury and disease states could also help to elucidate the pathophysiology of retinal hemorrhages in infants.

Once a diagnosis of child abuse has been made, the role of the physician is to inform authorities and effectively communicate the basis for the diagnosis. Ophthalmologists are in large part aware that bilateral, extensive hemorrhages, in the absence of major accidental trauma or factors such as coagulopathy, are highly correlated with abusive head trauma. However, it is important to quantify this relationship with a measure of association in order to communicate to non-ophthalmologists and non-physicians. We found a strong association between retinal hemorrhages and a diagnosis of abuse head trauma (adjusted OR 5.4). While previous investigators have not explicitly reported such a measure of association, one may be derived from published data. For example, based on a report by Bechtel and colleagues[15] on 15 children with abuse and 77 children with accidental trauma, the odds ratio between retinal hemorrhage and abuse would have been 12.85 (95% CI, 2.9-57.2). Studies such as this and ours demonstrate a strong association between retinal hemorrhage and a determination of child abuse. With regards to the effect of age on this association, limiting the analysis to children under 6 months of age suggested an even more robust effect (OR 11.7), but the lesser number of infants 6 months or older decreases the statistical power and limits the conclusions that can be drawn.

Another informative way to communicate the basis for a diagnosis of child abuse is to report the severity of eye findings. We found that the association between retinal hemorrhages and

abusive head trauma was higher with increasing severity of retinal hemorrhages. RH scores were higher in subjects diagnosed with abuse, and increasing scores correlated positively with increasing likelihood of abuse on the four-category scale ranging from definite accident to definite abuse. These findings are consistent with the clinical experience of physicians and pathologists who examine such children and with the related literature.[8,15-21] Our findings also support the contention that the most severe retinal findings, as represented by the highest RH scores among our subjects, are strong indicators of abuse. In fact, scores from 9 to 12 were seen only in cases of abuse, and the single child with accidental trauma and a RH score of 8 had a history of confirmable, witnessed significant trauma and external signs of blunt eye injury that are not typically seen in abusive head trauma. Our retinal hemorrhage scale was adopted from a clinical form used previously in our hospital. We believe the scale has face validity as a general summary statistic of retinal hemorrhage severity, based upon extent, type, etc. However, it does not include the number of hemorrhages or the presence of hemorrhagic macular retinoschisis, features commonly cited as relevant to abusive head trauma, and it is not yet clear which factors should be weighted the most heavily to maximize a RH score's sensitivity and specificity as a “test” for abuse. Future work using modeling and regression techniques on a larger data set should be used to build a more robust model and establish construct validity for the instrument.

Our targeted study population was children being evaluated for possible abuse. Therefore, we did not exclude children who had conditions known to be potential causes of retinal hemorrhages, such as coagulopathy or significant witnessed trauma.[9] However, the inclusion of these children likely results in a bias toward an odds ratio of 1.0, and their exclusion would therefore have strengthened the observed association between retinal hemorrhage and a diagnosis of abuse. Similarly, we did not exclude children under 3 weeks of age, even though birth is a well-recognized cause of retinal hemorrhages in the immediate neonatal period.[22,23] None of these subjects, however, had retinal hemorrhage on examination. Finally, the one child with an undilated funduscopic examination was diagnosed with definite abuse and no ocular findings. Therefore, if peripheral retinal hemorrhages were missed, there would be a slight underestimation of the odds ratio.

We found that approximately one-third of ophthalmology consultations for suspected child abuse in infants reveal ocular findings, most commonly retinal hemorrhages. Retinal hemorrhages were highly associated with a diagnosis of abusive head trauma made independently of eye findings, particularly in children under 6 months of age, and increasing severity of retinal hemorrhages, expressed through a RH score, was correlated with increasing likelihood of abuse. It is important for physicians to communicate these associations and qualitative descriptions with the individuals who are responsible for making legal determinations of abuse and for providing protection for children at risk for further abuse.

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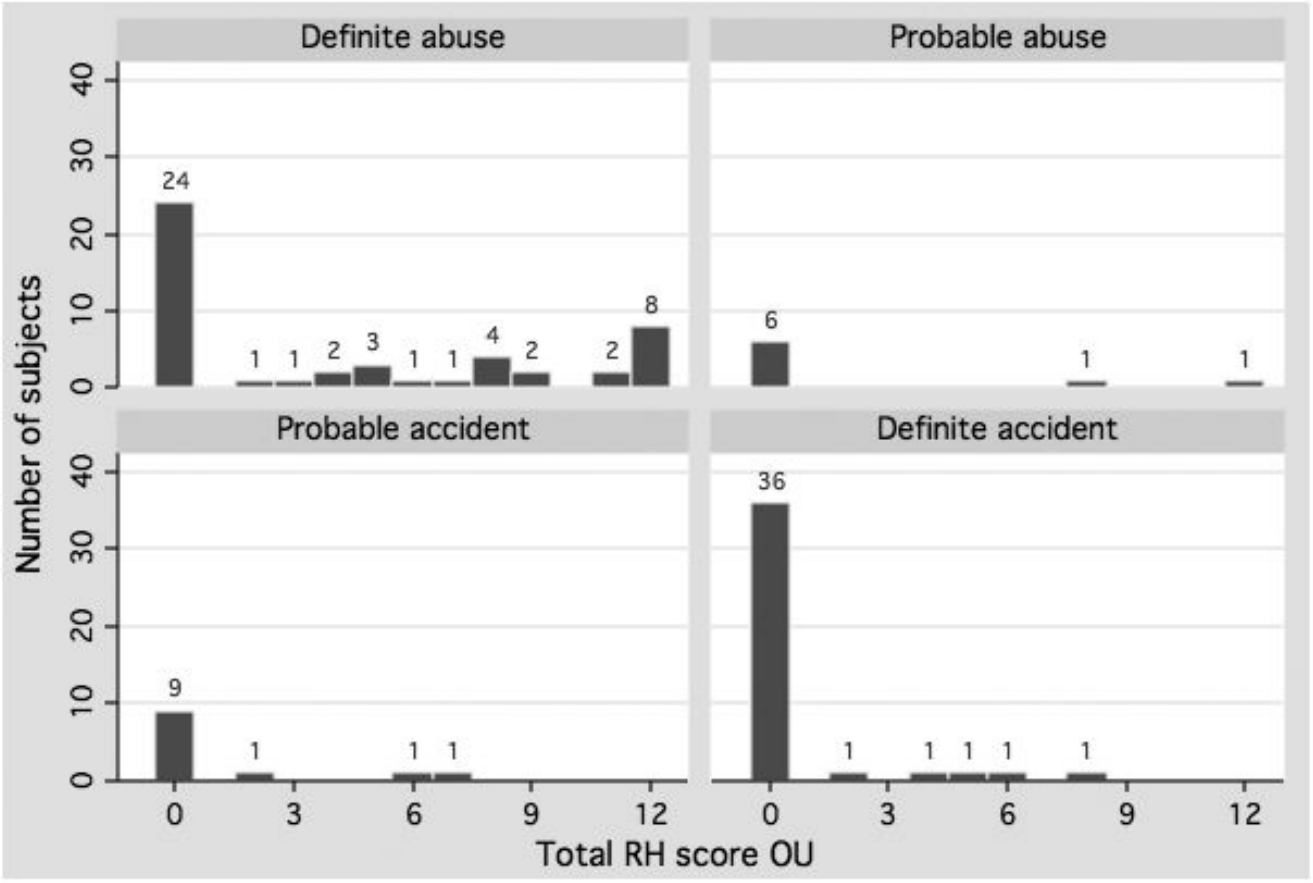

Figure 1.
Distributions of retinal hemorrhage scores grouped by the child-abuse pediatrician's assessment of the mechanism of injury for 110 infants being evaluated for abusive head trauma.

Table 1

Retinal hemorrhage grading scale. Left and right eyes are assessed separately. Overall score is calculated by combining the total scores for each eye. Maximum score is 6 points per eye or 12 points overall. *DD*, disk diameter.

Hemorrhage	Points
Type and size (only one category chosen)	
Mild—intraretinal hemorrhages only	1
Moderate—subhyaloid hemorrhage present, all lesions less than two disk areas in size	2
Severe—subhyaloid hemorrhage, vitreous hemorrhage, or any lesion greater than two disk areas in size	3
Extent (sum of categories)	
Any hemorrhage within the following areas	
Macula (>1 DD from disk, within 2 DD of fovea)	1
Peripapillary (within 2 DD of disk, excluding macula)	1
Periphery (outside above regions)	1

DD, disk diameter.

Table 2

Age distribution of 110 infants evaluated for abusive head trauma (A) and likelihood of abuse ascertained by the child abuse specialist team and retinal hemorrhage findings for the 110 subjects (B).

A. Subject age

Age in months	**n**	**(%)**
0-2	47	(43)
3-5	34	(31)
6-8	14	(13)
9-12	15	(14)
Total	110	(100.0)

B. Likelihood of abusive head trauma

Diagnosis	**n**	**(%)**	**Retinal hemorrhages**					
			None		Unilateral		Bilateral	
			n	(%)	n	(%)	n	(%)
Definite abuse	49	(45)	24	(49)	7	(14)	18	(37)
Probable abuse	8	(7)	6	(75)	0	(0)	2	(25)
Probable accident	12	(11)	9	(75)	1	(8)	2	(17)
Definite accident	41	(37)	36	(87)	3	(7)	2	(5)
Total	110	(100.0)	75	(68)	11	(10)	24	(22)