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Risk factors associated with retinal hemorrhage in suspected abusive head trauma

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Abstract

Purpose—To determine risk factors associated with retinal hemorrhage (RH) in pediatric abusive head trauma (AHT) suspects.

Methods—Records of children aged 0–3 years hospitalized for suspected AHT from January 2007 to November 2011 were retrospectively reviewed in this case–control study. Children were classified into case and control groups based on RH presence. Medical history, presenting symptoms, reasons, and characteristics of injury were recorded. Logistic regression analysis was performed to identify risk factors.

Results—A total of 168 children (104 males) were included. Of these, 103 were classified as cases and 65 as controls. The mean age (with standard deviation) was 9.3 ± 8.3 months (range, 1 day-36 months). Of the 103 cases, 22 (21%) had subretinal hemorrhage, 9 (9%) had retinoschisis, and 1 (1%) had vitreous hemorrhage. Children presenting with lethargy or altered mental status ($P < 0.0001$), subdural hemorrhage ($P < 0.0001$), and other radiologic findings (eg, cerebral ischemia, diffuse axonal injury, hydrocephalus, or solid organ injury; $P = 0.01546$) were likely to have RH. All 23 children with skull or nonskull fracture without intracranial hemorrhage did not have RH ($P < 0.0001$ both categories).

Conclusions—Retinal hemorrhages were almost never found in the absence of intracranial hemorrhage and not found in the setting of fracture without intracranial hemorrhage.

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In the United States, abusive pediatric head injury is estimated to occur at an annual incidence of 15–20 victims per 100,000 children younger than 2 years, with similar numbers reported internationally.[1–3] Characteristics traditionally thought to place children at particularly high risk for violent abuse are male sex, multiple gestation, minority ethnic status, history of chronic medical problems or developmental delay, premature birth, and young maternal age. Mortality is high in these groups, with reported rates of 20% to 30%.[2,4,5]

In 1974 Dr. John Caffey described a mechanism he termed “whiplash shaken infant syndrome,” characterized by a triad of subdural hematoma, multiple traction changes of the long bones, and retinal hemorrhage (RH) that could all be attributed to the same violent shaking mechanism.[6] The shaking mechanism was noted to coincide with the presentation of abused infants, in whom physical examination findings suggestive of trauma (bruising, abrasions, and lacerations) are often absent.[4,5,7] Routine dilated fundus examination was proposed for the evaluation of suspected physical abuse in children[6] and today is part of the standard work-up, which also typically includes computed tomography (CT) imaging of the head and radiologic skeletal survey.

The terms *shaken baby syndrome*, *nonaccidental trauma*, and *abusive head trauma* (AHT) have replaced *whiplash shaken infant syndrome*, but the pathogenesis of the characteristic injuries have been an ongoing topic of research. Investigations into the pathogenesis of RH in AHT have implicated vitreoretinal traction secondary to repeated acceleration and deceleration during shaking as the primary causative factor.[8] Studies investigating coagulopathy, increased intrathoracic pressure (Purtscher retinopathy), and increased intracranial pressure (Terson syndrome) as possible etiologies of severe RH have not shown significant relationships.[9], [10] The prevailing opinion is that bilateral, diffuse retinal hemorrhages extending beyond the macula, especially associated with macular retinoschisis or retinal folds, are virtually pathognomonic for abuse in the absence of known major accidental trauma.[11–14] The rate of RH in confirmed abuse cases in various studies ranges from 50% to 100%, and severity of RH tends to correlate well with severity of brain injury and mortality rate.[5,9,15]

The most common intracranial injury in AHT is subdural hemorrhage (up to 93% in some large series).[4,7,9,16] Other intracranial findings, such as epidural hematoma and shear injury, on the other hand, have been very rarely associated with inflicted trauma, although common in accidental trauma.[4,17] Less severe injuries, including bruises and lacerations, skeletal fractures, and skull fractures, have been noted to occur with similar frequency in accidental and inflicted trauma. The concurrence of RH and intracranial injury is extraordinarily high in AHT; however, in the absence of intracranial injury, RH is rare. One large series documented a <1% RH rate in patients with negative neuroimaging at admission.[18] However, radiographic misinterpretation, initially absent, slow-developing intracranial bleeds, and imperfect sensitivity of CT and magnetic resonance imaging (MRI) are potential reasons for dilated fundus examination in suspicious cases despite “negative imaging.”[19] Many previous studies in the area of pediatric AHT have cited the lack of a comparison group as a weakness. The purpose of this study was to determine potential risk factors associated with retinal hemorrhage in AHT by performing a case–control study of RH in the setting of AHT.

Subjects and Methods

The medical records of children between the ages of 0 and 3 years who underwent dilated fundus examination as part of an AHT work-up between January 2007 and November 2011 at Children's Memorial Hermann Hospital in Houston, Texas, were retrospectively reviewed. All patients were referred to our service for evaluation for RH; therefore, the sample would inevitably contain children in whom abuse was suspected. The University of Texas Health Science Center at Houston Committee for the Protection of Human Subjects deemed this study exempt from review. Memorial Hermann Hospital approved access to medical records. This study conformed to the requirements of the US Health Insurance Portability and Accountability Act of 1996.

All examinations were initially performed by an ophthalmology resident and confirmed by an attending ophthalmologist. All patients received dilated fundus examination for potential AHT. Indirect ophthalmoscopy was performed at the bedside after instillation of age-appropriate dilating eyedrops (cyclopentolate 1% and phenylephrine 2.5% or cyclopentolate 0.2% and phenylephrine 1%). Patients were divided into a case group (at least one RH) and a control group (no RH) based on examination findings.

The following data were collected : sex, age, and race; presence or absence of subretinal hemorrhage, retinoschisis, and vitreous hemorrhage; medical history, including gestation in weeks, history of maltreatment (present or absent, if indicated in the record by previous providers or investigations), history of chronic medical problems, and twin gestation; reason for and date of consult; presenting signs and symptoms (lethargy or altered mental status, respiratory distress or apnea, seizure, vomiting); history given by caretaker (whether injury was the result of trauma or otherwise); presence of RH and severity of hemorrhages; and characteristics of injury: presence or absence of subdural hemorrhage, other radiologic findings (including cerebral ischemia, diffuse axonal injury, hydrocephalus, or solid organ injury), bruising or swelling, skull fracture, nonskull fracture (most commonly rib, femur, and humerus), other intracranial hemorrhage (most commonly intraventricular hemorrhage, lobar hematoma, subgaleal hematoma, and germinal matrix hemorrhage), subarachnoid hemorrhage, epidural hemorrhage, burns, evidence of sexual abuse, nonskull fracture without intracranial hemorrhage, skull fracture without intracranial hemorrhage, and acute or chronic morbidity.

Descriptive statistics, mean and standard deviation, were calculated for continuous variables, that is, age, gestation in weeks, and so on, and frequency and percentage were calculated for discrete variables, that is, sex, race, presence of vitreous hemorrhage, and so on. The two-sample *t*-test or the Fisher exact test were used to compare groups. Estimated effect sizes (differences for continuous variables and odds ratio for discrete variables) and their 95% confidence intervals were reported along with *P* values. A variable with a P value of <0.3 from the two-sample *t* test or the Fisher exact test was considered to indicate a potential risk factor and was further analyzed in a stepwise logistic regression model. A stepwise logistic regression was used to identify risk factors associated with presence of RH. All statistical analyses were performed using SAS v9.2 (SAS Institute Inc, Cary, NC). *P* values of ≤0.05 were considered statistically significant.

Results

A total of 168 children (104 [62%] males) were included in the study, 103 in the case group and 65 in the control group. The mean age was 9.3 ± 8.3 months (range, 1 day to 36 months). Of 103 children with RH, 22 (21%) had subretinal hemorrhage, 9 (9%) had retinoschisis, and 1 (1%) had vitreous hemorrhage.

Table 1 summarizes demographics, medical history, presenting signs and symptoms, history given by caretaker, and characteristics of injury for each group. Age (difference = 3.0 months; 95% CI, −5.4 to 0.6; *P* = 0.0122) was found to be statistically significantly different between groups using the two-sample *t*-test. The Fisher exact test found that the symptoms of lethargy or altered mental status (OR = 9.56; 95% CI, 4.64–19.67; *P* <0.0001), seizure (OR = 2.41; 95% CI, 1.01–5.70; *P* = 0.0494), and vomiting (OR = 3.45; 95% CI, 1.24–9.60; *P* = 0.0182) as well as characteristics of injury including subdural hemorrhage (OR = 12.43; 95% CI, 5.78–26.72; *P*<0.0001), other radiologic findings (OR = 2.87; 95% CI, 1.47–5.61; *P* = 0.0022), skull fracture without intracranial hemorrhage (OR = N/A; *P* < 0.0001), and nonskull fracture without intracranial hemorrhage (OR = N/A; *P*<0.0001) were statistically different between groups.

There were 13 factors with *P* values <0.3 in Table 1 that were considered for further analysis. However, “skull fracture without intracranial hemorrhage” and “nonskull fracture without intracranial hemorrhage” could not be entered into stepwise logistic regression analysis because the incidence for both in the case group was zero. The remaining 11 factors were age, sex, respiratory distress or apnea, seizure, lethargy or altered mental status, vomiting, history given by caretaker, subdural hemorrhage, subarachnoid hemorrhage, skull fracture, and other radiologic findings.

The results of stepwise logistic regression analysis with the 11 risk factors mentioned above are given in Table 2. Lethargy or altered mental status were the only presenting signs that correlated strongly with the presence of RH (OR = 9.66; 95% CI, 3.71–25.18; *P* < 0.0001). In the area of radiologic findings, presence of subdural hemorrhage was found to be a potential predictive factor for RH (OR = 22.35; 95% CI, 7.92–63.10; *P* < 0.0001), as was the presence of other radiologic findings (OR = 3.45; 95% CI, 1.28–9.32; *P* = 0.0146). In the setting of fractures, skull or otherwise, patients without intracranial hemorrhage were not found to have RH in our study (*P* < 0.0001).

The outcomes of these children are presented in Table 3. Mortality was approximately 4 times higher in the case group (24%) than in the control group (6%; OR = 4.89; 95% CI, 1.62–14.79; *P* = 0.0028). In the area of morbidity, 18 children (18%) with RH suffered permanent traumatic brain injury, while no children (0%) in the control group suffered permanent traumatic brain injury (*P* < 0.0001). Case group patients were also more likely to undergo feeding tube placement (13 patients [13%]) than controls (2 patients [3%]; OR = 4.55; 95% CI, 0.99–20.87; $P = 0.0494$).

Discussion

While there has been a neurosurgical case-control study regarding AHT,[20] an ophthalmologic study has been lacking. To our knowledge, this is the first case–control study examining risk factors associated with retinal hemorrhage in traumatic AHT cases. The major strength of our study is the comparison control group, which has been absent in previous studies of RH and cited as a weakness of those studies.[4] These previous studies have shown increased abuse risk for younger children, males, minorities, twins, children born prematurely, and children with chronic medical problems,[2–5,11] but the present study did not find these factors to be predictive of RH. Our data supports the long-standing association between subdural hemorrhage and RH in AHT suspects.[4,9] However, we found that the presence of fractures was potentially not predictive of RH in the absence of intracranial hemorrhage. In fact, we found a negative correlation between skull fractures and RH. Other radiologic findings, consisting mostly of solid organ injury and severe nonhemorrhagic intracranial injury, are potentially predictive of RH, a finding we might attribute to the fact that all are markers of severe trauma. The present study also found the complete absence of RH in patients with fracture (skull or nonskull) without intracranial hemorrhage. This may be due to differences in the mechanism of injury between a direct blow versus the repetitive acceleration-deceleration caused by shaking.[21] This finding raises questions regarding RH in the setting of fractures without intracranial bleed and the need for future studies in the area.

Regarding patient presentation, we found that the presence of lethargy and altered mental status are potentially predictive of RH is consistent with prior studies,[4,5,7] but it was somewhat surprising that vomiting and respiratory distress or apnea did not reach statistical significance, because these factors have been traditionally linked to AHT.

Questioning the utility of dilated fundus exams when certain specific characteristics are present in AHT cases has been debated in the literature previously. Thackery and colleagues found that out of 282 children without traumatic brain injury, only 2 had retinal hemorrhages that were consistent with abuse.[18] Li and colleauges[22] found no RHs in patients presenting with what the authors described as “low-risk criteria,” that is, no intracranial injury, normal mental state, and no bruising to the face or head. Additionally, Griener and colleagues[23] also found only 2 children with RH out of 352 with no traumatic brain injury. All 3 of these studies suggest that a dedicated retinal examination may not be necessary unless there is traumatic brain injury. The results of these studies support ours as our patients did not have RH with skull or nonskull fractures without traumatic brain injury.

There are a number of limitations in our study. First, we would need a much larger sample size to be more conclusive with our data. Additionally, the end point in this study was the presence or absence of RH, not the presence or absence of AHT. Therefore, whereas we can draw conclusions about what patient characteristics are predictive of RH and which patients would benefit from ophthalmologic consultation, we cannot draw conclusions about patient characteristics that are predictive of AHT. Also, because this is a retrospective study, there are limitations inherent to the design for which we could not control.

Despite the limitations, this study demonstrates a potential negative correlation between skull and nonskull fractures without intracranial hemorrhage and RH. Additionally, although we found a negative correlation between fracture without intracranial hemorrhage and RH, it is important to remember that the conditions are not mutually exclusive.

Literature Search

PubMed was searched, without language or date restriction, on December 8, 2014, using the following terms: *shaken baby syndrome*, *ophthalmology*, *nonaccidental trauma*, *abusive head trauma*, *risk factors*, *retinal hemorrhage*, and *eye* in multiple combinations. All articles that examined retinal injury in the context of abusive head trauma were assessed for similarity to the present study.

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Table 1

Summary statistics for each risk factor by group

Variable	Controls (N = 65)	Cases (N = 103)	*P* value
Demographics			
Sex, no. male (%)	44 (68)	60 (58)	0.2551
Age in months, mean ± SD	7.2 ± 7.2	10.2 ± 7.9	0.0122
Race or ethnicity,[a] no. (%)			1.0000
Hispanics	22 (36)	37 (37)	
Black	16 (26)	26 (26)	
White	15 (25)	26 (26)	
Others	6 (10)	9 (9)	
Asian	2 (3)	3 (3)	
Unknown	4	2	
Medical History			
Gestation in weeks, mean ± SD	38.0 ± 3.2	38.1 ± 3.4	0.9478
History of maltreatment, no. (%)	11 (17)	20 (19)	0.8386
History of chronic medical problems, no. (%)	7 (11)	8 (8)	0.5823
Twin gestation, no. (%)	2 (3)	5 (5)	0.7075
Presenting signs and symptoms			
Lethargy or altered mental status, no. (%)	16 (25)	78 (76)	<0.0001
Respiratory distress or apnea, no. (%)	10 (15)	28 (27)	0.0895
Seizure, no. (%)	8 (12)	26 (25)	0.0494
Vomiting, no. (%)	5 (8)	23 (22.3)	0.0182
History given by caretaker			
History of trauma, no. (%)	35 (54)	46 (45)	0.2699
Short fall, no. (%)	20 (31)	34 (33)	0.8656
Characteristics of injury			
Subdural hemorrhage, no. (%)	12 (19)	76 (74)	<0.0001
Other radiologic findings, no. (%)	18 (28)	54 (52)	0.0022
Bruising or swelling, no. (%)	30 (46)	50 (49)	0.8741
Skull fracture, no. (%)	25 (39)	28 (27)	0.1300
Non-skull fracture, no. (%)	15 (23)	25 (24)	1.0000
Other intracranial hemorrhage, no. (%)	7 (11)	16 (16)	0.4913
Subarachnoid hemorrhage, no. (%)	5 (8)	16 (16)	0.1568
Epidural hemorrhage, no. (%)	4 (6)	8 (8)	0.7681
Burns, no. (%)	0 (0)	2 (2)	0.5227
Evidence of sexual abuse, no. (%)	0 (0)	1 (1)	1.0000
Non–skull fracture without intracranial hemorrhage, no. (%)	13 (20)	0 (0)	<0.0001
Skull fracture without intracranial hemorrhage, no. (%)	10 (15)	0 (0)	<0.0001

SD, standard deviation.

[a]Missing 4 controls and 2 cases.

Table 2

Risk factors identified by stepwise logistic regression analysis

Variable	OR (95% CI)	*P* value
Lethargy or altered mental status	9.66 (3.71–25.18)	<0.0001
Subdural hemorrhage	22.35 (7.92–63.10)	<0.0001
Other radiologic findings	3.45 (1.28–9.32)	0.0146

CI, confidence interval; *OR*, odds ratio.

Table 3

Outcomes

Outcomes	Controls (n = 65)	Cases (n = 104)	OR (95% CI)	*P* value
Mortality, no. (%)	4 (6)	25 (24)	4.89 (1.62–14.79)	0.0028
Permanent traumatic brain injury,[a] no. (%)	0 (0)	18 (18)	N/A[b]	<0.0001
New seizure, no. (%)	3 (5)	15 (15)	3.52 (0.98–12.69)	0.0703
Feeding tube, no. (%)	2 (3)	13 (13)	4.55 (0.99–20.87)	0.0494

CI, confidence interval; *OR*, odds ratio.

[a]Missing 3 cases.

[b]The odds ratio cannot be estimated due to the absence of permanent traumatic brain injury in the control group.