

Nonaccidental trauma in pediatric patients: evidence-based screening criteria for ophthalmologic examination

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BACKGROUND

Ophthalmologic examination is included in the work-up for pediatric nonaccidental trauma (NAT) when there is concern for retinal hemorrhage. However, dilated fundus examination entails patient discomfort and prohibition of assessment of pupillary response. Previous studies have suggested that patients without neuroimaging abnormalities are unlikely to have retinal hemorrhage. The purpose of the current study was to analyze the findings in patients who received NAT evaluation with eye examination at our institution, and to propose screening criteria for inclusion of ophthalmologic examination in NAT evaluation.

METHODS

The medical records of patients who received NAT evaluation with ophthalmologic examination at The Johns Hopkins Children's Center Pediatric Emergency Department from August 2014 to July 2018 were reviewed retrospectively. Data collected included demographics, presenting symptoms, imaging findings, and ophthalmologic examination findings. The main outcome measure was presence of retinal hemorrhage.

RESULTS

A total of 192 evaluations with ophthalmologic examination were included, representing 190 unique individuals of mean age 8.4 ± 9.5 months at presentation. In approximately half (54%) of the evaluations, there were abnormal findings on neuroimaging. Fifteen children (8%) had retinal hemorrhage, all of whom also had abnormal neuroimaging. Abnormal neuroimaging was associated with presence of retinal hemorrhage, with an odds ratio of 21.0 (95% CI, 3.47- ∞ ; $P < 0.001$). Of the 15 children with retinal hemorrhage, 14 had subdural hemorrhage.

CONCLUSIONS

When neuroimaging abnormalities are present, ophthalmologic examination should be performed as part of the pediatric NAT evaluation. When there is no evidence of head injury on neuroimaging, ophthalmologic examination should not be routine. (J AAPOS 2020; ■:1.e1-1.e5)

Abuse and neglect affected 674,000 children in the United States in 2017. Of those children, 18.3% experienced physical abuse, or nonaccidental trauma (NAT).¹ Many emergency departments have developed protocols to identify and manage suspected victims of

NAT,² especially infants and toddlers. These protocols include neuroimaging, skeletal survey, social work consultation, and ophthalmologic examination.³ At some centers, ophthalmologic examination to detect retinal hemorrhage (RH) is performed for all infants and toddlers receiving NAT evaluation. When present, RH is an important feature in interpreting the likelihood of nonaccidental head injury, sometimes referred to as "shaken baby syndrome" or "abusive head trauma."⁴⁻⁷ RH associated with NAT is often bilateral, extensive, and present in all retinal layers and extending to the periphery; however, not all RH in the setting of NAT follows this pattern.^{8,9} When absent, the lack of RH does not rule out NAT.⁸ As such, ophthalmologic examination in a patient who ultimately does not have retinal findings is less helpful to the clinician evaluating the probability of child abuse.

Ophthalmologic examination in the setting of suspected NAT is not without costs. First, the examination involves indirect ophthalmoscopy through dilated pupils,⁴ which may be inappropriate in a setting where pupillary checks

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are needed to monitor neurologic status. Second, the examination may be stressful for the patient. Third, physician resources are expended when ophthalmologists are consulted. Non-ophthalmologists often do not attempt or are unable to perform the examination,¹⁰ and expert evaluation and documentation of findings is important for court proceedings.¹¹ It would thus be valuable to distinguish the patients who would benefit from ophthalmologic examination from those for whom the benefits are unlikely to outweigh the costs.

Previous studies have recommended that ophthalmologic examination may not be needed in certain subpopulations of suspected NAT patients because of the low likelihood of retinal findings. These reports have found that the prevalence of RH is very low in selected patients who fulfill criteria such as lack of traumatic brain injury on neuroimaging, lack of facial bruising, and normal mental status.¹²⁻¹⁵ To our knowledge, this topic had not been discussed extensively in the ophthalmology literature. The purpose of the current study is to examine the findings in patients who received NAT evaluation with included eye examination at our institution over a 4-year period. Based on presenting symptoms, neuroimaging and skeletal imaging, and ophthalmologic findings, we propose screening criteria for including ophthalmologic examination as part of NAT evaluation.

Subjects and Methods

This study adhered to the tenets of the Declaration of Helsinki and was conducted with approval of the Johns Hopkins Hospital Institutional Review Board. The study complied with the US Health Insurance Portability and Accountability Act of 1996. Because all patient data were deidentified, individual parent/guardian consent was not required. The medical records of all patient encounters involving ophthalmologic examination as a part of a NAT evaluation at The Johns Hopkins Children's Center Pediatric Emergency Department, which is the regional Child Maltreatment Center, between August 2014 and July 2018 were reviewed retrospectively. Possible encounters were identified by a senior clinical information technology analyst by screening for the terms *NAT*, *nonaccidental*, *shaken*, *abuse*, and *hemorrhage* in the ophthalmology consult orders within the electronic medical record. Patient records were manually reviewed to exclude irrelevant encounters, for example, patients presenting with blood disorders and patients with subconjunctival hemorrhage or other eye abnormality un concerning for NAT. Encounters in which ophthalmologic examination was requested but not ultimately performed because of lack of head trauma and low suspicion for RH were also excluded.

Retrieved data included information on patient demographics (age, sex, race, insurance status), recorded history of Child Protective Services (CPS) involvement in the family, presenting signs and symptoms (altered mental status, seizures, vomiting, bruising, burns, scalp hematoma/swelling), neuroimaging findings obtained from head computed tomography or magnetic resonance imaging (epidural hemorrhage, subdural hemorrhage, subarachnoid

hemorrhage, nonspecific extra-axial hemorrhage, parenchymal hemorrhage/contusion, hypoxia/ischemia/infarct, cerebral edema, axonal/white matter injury, skull fracture, scalp hematoma), other radiological imaging findings (rib fracture, other fracture), and ophthalmologic examination findings (presence of RH). Altered mental status was defined broadly as any sleepiness, lethargy, change in level of consciousness, or seizures. Neuroimaging was defined as positive if there was presence of any finding other than scalp hematoma.

Statistical Analysis

All statistical analyses were performed using Stata version 15.1 (Stata Corp, College Station, TX). To derive odds ratios, univariable exact logistic regression was performed. The reported odds ratio is the conditional maximum likelihood estimate, except when the patient characteristic predicts the presence or the absence of RH perfectly, in which case the median unbiased estimate is reported. For percentage values, binomial exact 95% confidence intervals are reported.

Results

During the study period, 192 patient encounters met inclusion criteria, representing 190 unique patients (2 patients had repeat visits to the emergency department). [Table 1](#) describes patient demographics. Mean age at presentation was 8.4 ± 9.5 months (range, 6 days to 6 years), and 59% of patients were male. 53% were black or African American, 36% were white, 4% were Hispanic or Latino, 1% were Asian, and 6% were either unspecified or "other." With regard to insurance, 68% of patients had public insurance, 23% had private insurance, 4% were uninsured, and 5% did not have insurance status specified. A family history of Child Protective Services involvement was noted in 20% of patients.

Table 1. Demographics of patients receiving nonaccidental trauma evaluation with ophthalmologic examination

Variable	Frequency (%)
Total no. patients	192
Sex	
Male	114 (59)
Age	
Mean \pm SD (months)	8.4 ± 9.5
Range	6 days-6 years
Race	
Black or African American	101 (53)
White	69 (36)
Hispanic or Latino	8 (4)
Asian	2 (1)
Other/unspecified	12 (6)
Insurance	
Public	131 (68)
Private	44 (23)
Uninsured	7 (4)
Unspecified	10 (5)
History of CPS involvement with family	39 (20)

CPS, Child Protective Services.

A total of 171 patient encounters (89%) involved dedicated neuroimaging. In patients without neuroimaging, the patient was evaluated for other injuries, but suspicion of head trauma was low. Of the entire cohort of 192, 103 encounters (54%) featured positive neuroimaging; the remaining 89 patients, representing 46% of our cohort, received ophthalmologic examination in their NAT evaluation despite lack of neuroimaging evidence of head injury.

Of 192 patients encounters for suspected NAT, 15 (8%) had retinal hemorrhages. Thus the diagnostic yield of ophthalmologic examination for RH within our cohort was 8%. Patients with RH were 1-28 months of age. Notably, all 15 patients also had positive neuroimaging. Table 2 lists the frequency of clinical findings and odds ratio of each finding for RH in our cohort. Positive neuroimaging was associated with presence of retinal hemorrhage with odds ratio 21.0 (95% CI, 3.47-∞; $P < 0.001$). In particular, 14 of the 15 patients with RH had specifically subdural hemorrhage on neuroimaging. Subdural hemorrhage had an odds ratio of 54 for RH (95% CI, 7.7-2334; $P < 0.001$), and the diagnostic yield of RH among patients with subdural hemorrhage was 28% (14 of 50 patients with subdural hemorrhage). Other findings associated with RH included any extra-axial hemorrhage (OR = 28.3; 95% CI, 4.1-1224; $P < 0.001$), seizures (OR = 15.8; 95% CI, 3.96-64; $P < 0.001$), any altered mental status including

seizures (OR = 8.3; 95% CI, 2.40-33.0; $P < 0.001$), brain parenchymal hypoxia/ischemia/infarct (OR = 10.1; 95% CI, 1.82-51; $P = 0.008$), and vomiting (OR = 4.4; 95% CI, 1.18-15.5; $P = 0.03$).

Discussion

The goal of this study was to characterize the findings in patients who received NAT evaluation with included eye examination at our institution and to use these results to identify screening criteria for inclusion of ophthalmologic examination because of higher likelihood of RH. We found that, of 192 patients in our cohort, only 15 had RH, all of whom also had positive neuroimaging. Nearly half (46%) of our cohort received ophthalmologic examination even though there was no neuroimaging evidence of head injury, despite recent studies in the pediatric literature showing such patients likely do not need eye examination.^{12,13,15} None of the patients with negative neuroimaging ultimately had RH, reinforcing the suggested practice presented in the pediatric literature. The gap between the suggested practice and the reality is likely because physicians tend to err on the side of caution in cases of suspected NAT. We argue that this overabundance of caution is not needed, because cases of RH will still be detected even if

Table 2. Frequency of clinical findings and odds ratio of retinal hemorrhage by univariate exact logistic regression

Variable	Frequency (%)		OR of RH (95% CI) ^a	P value
	Patients with RH (n = 15)	Patients without RH (n = 177)		
Signs and symptoms reported by physician or caregiver				
Altered mental status ^b	11 (73)	34 (19)	8.3 (2.40-33.0)	<0.001
Seizures	7 (47)	9 (5)	15.8 (3.96-64)	<0.001
Vomiting	6 (40)	23 (13)	4.4 (1.18-15.5)	0.03
Bruising	3 (20)	32 (18)	1.13 (0.194-4.5)	1.00
Burns	0 (0)	11 (6)	0.74 (0-4.9) ^c	0.80
Scalp hematoma/swelling	2 (13)	52 (29)	0.371 (0.040-1.73)	0.30
Imaging				
Any abnormal neuroimaging	15 (100)	88 (50)	21.0 (3.47-∞) ^c	<0.001
Any extra-axial hemorrhage	14 (93)	58 (33)	28.3 (4.1-1224)	<0.001
Epidural hemorrhage	1 (7)	11 (6)	1.08 (0.023-8.5)	1.00
Subdural hemorrhage	14 (93)	36 (20)	54 (7.7-2334)	<0.001
Subarachnoid hemorrhage	5 (33)	25 (14)	3.01 (0.75-10.7)	0.13
Parenchymal hemorrhage	2 (13)	16 (9)	1.54 (0.156-7.8)	0.84
Hypoxia/ischemia/infarct	4 (27)	6 (3)	10.1 (1.82-51)	0.008
Cerebral edema	1 (7)	4 (2)	3.06 (0.059-33.9)	0.67
Axonal/white matter injury	1 (7)	2 (1)	6.1 (0.099-125)	0.44
Skull fracture	7 (47)	60 (34)	1.70 (0.50-5.7)	0.47
Any nonskull fracture	2 (13)	46 (26)	0.44 (0.047-2.06)	0.45
Rib fracture	2 (13)	12 (7)	2.10 (0.207-11.2)	0.60
Other fracture	2 (13)	44 (25)	0.47 (0.049-2.19)	0.51
Scalp hematoma	2 (13)	39 (22)	0.55 (0.057-2.57)	0.68

CI, confidence interval; OR, odds ratio; RH, Retinal hemorrhage.

^aAll unmarked odds ratios are conditional maximum likelihood estimates.

^bAltered mental status includes lethargy, sleepiness, seizures, and any other change in level of consciousness reported by a caretaker or noted on presentation.

^cOdds ratio is a median unbiased estimate because the patient characteristic predicts either presence or absence of retinal hemorrhage perfectly.

eye examinations are reserved for patients with neuroimaging abnormalities.

Our proposed paradigm for determining which children need ophthalmologic examination in NAT evaluation is shown in Figure 1. Once a NAT evaluation is initiated due to suspicion of abuse, the care team must decide whether neuroimaging due is needed because of concern for head trauma. The guidelines for making this determination will vary by institution; at our institution, neuroimaging is considered when there are injuries in children <1 year of age that are not consistent with history, injuries as a result of family violence, or history of brief resolved unexplained event (also known as BRUE). If neuroimaging is deemed unnecessary, then ophthalmologic examination should also not be routinely performed. If the care team proceeds with neuroimaging, then the decision to perform ophthalmologic examination depends on the findings. When neuroimaging is positive, ophthalmologic examination should be performed. When neuroimaging is negative, eye examination should not be routine. There may be cases where a physician chooses to consult ophthalmology for eye examination without evidence of neuroimaging abnormalities; however, we suggest that this not be the normal procedure but, rather, reserved for special cases.

If this proposed screening protocol had been followed for the patients in our cohort, 103 patients would have received ophthalmologic examination, decreasing the number of examinations by approximately half from 192. The diagnostic yield of ophthalmologic examination for RH would also have increased from 7.8% (15/192) to

15% (15/103). A significant number of infants and toddlers would have been spared an additional noncontributory test during their hospital course while still allowing the detection of all cases of RH.

Other than abnormal neuroimaging in general, there were specific clinical findings that were statistically significantly associated with RH. These were subdural hemorrhage, any extra-axial hemorrhage, seizures, altered mental status including seizures, hypoxia/ischemia/infarct, and vomiting. These are similar to the characteristics previously reported to be associated with RH.^{8,16,17} Notably, all but one of the patients with RH also had subdural hemorrhage, and the diagnostic yield of RH among patients with subdural hemorrhage was 28%. This suggests that subdural hemorrhage is a noteworthy finding that is associated with RH. This finding is consistent with the “classic triad” of signs of NAT head injury, where diffuse brain swelling, subdural hemorrhage, and RH are often found together.¹⁸

A major advantage of the proposed screening protocol is that it can easily be incorporated into the emergency department workflow. Neuroimaging typically occurs prior to ophthalmologic examination when there is suspicion of head trauma because it is critical for identifying injuries that require immediate attention.^{3,19} Emergency department physicians could certainly delay ordering an ophthalmology consult until after review of the neuroimaging results. Another strength of our study is that, to our knowledge, it is among the first in the ophthalmology literature to consider the question of when ophthalmologic examination should be performed in NAT evaluation.

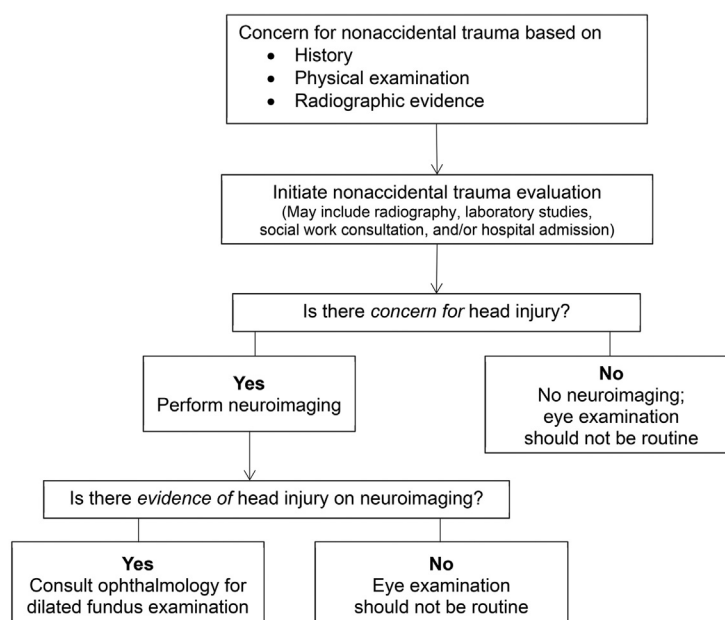


FIG 1. Proposed decision tree for obtaining ophthalmologic examination in the setting of suspected nonaccidental trauma. Once nonaccidental trauma evaluation is initiated, the clinician must determine whether neuroimaging is necessary due to concern for head injury. If so, then neuroimaging is performed. If abnormalities are present on neuroimaging, then ophthalmology should be consulted to perform dilated fundus examination. In all other circumstances, eye examination should not be routine.

In addition to the limitations inherent to a retrospective study, several particular limitations should be noted. First, the outcome measure in this study was RH, *not* NAT. Presence of RH is highly suggestive of NAT, but not all individuals who experience NAT develop RH, and vice versa.²⁰⁻²³ Accordingly, we cannot draw conclusions about whether abnormal neuroimaging is an effective criterion for detecting NAT. Second, the practice of obtaining neuroimaging as a decision tool for subsequent ophthalmologic examination is only possible in high-resource settings, where computed tomography or magnetic resonance imaging is readily available and routinely performed as part of NAT evaluation, such as at tertiary referral centers. This screening protocol is not as applicable in less-equipped hospitals. Third, the data relied on information recorded in patients' medical charts, which may have been incomplete or incorrect in some points. Additionally, the retinal findings were established based on written descriptions of ophthalmologic examinations rather than on fundus photography, because most patients did not ultimately receive fundus imaging. Finally, the data in this study was gathered from a single, tertiary-referral, academic institution and may not be generalizable.

In conclusion, abnormal neuroimaging is an effective screening criterion for determining which children need ophthalmologic examination as part of NAT evaluation. When neuroimaging abnormalities are present, ophthalmologic examination should be performed. When there is no evidence of head injury on neuroimaging, eye examination should not be routine. Utilizing this screening protocol reduces the number of noncontributory examinations. Prospective studies will be needed to confirm these findings.

Literature Search

PubMed was searched for English-language results in May 2019 and again in July 2019 using the term *child abuse retinal hemorrhage*. All results were evaluated for relevance based on their abstracts.

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