Dedicated Retinal Examination in Children Evaluated for Physical Abuse without Radiographically Identified Traumatic Brain Injury

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Objective To determine the rate of retinal hemorrhages in children evaluated for physical abuse without traumatic brain injury (TBI) by diagnostic imaging.

Study design This study was a prospectively planned, secondary analysis of the Examining Siblings to Recognize Abuse (ExSTRA) research network, and included only index children who presented with concerns for abuse. Subjects were eligible for the parent study if they were less than 10 years old and evaluated by a Child Abuse Physician for concerns of physical abuse. Child Abuse Physicians recorded results of all screening testing and determination of the likelihood of abuse in each case. For this analysis, we examined the results of dedicated retinal examinations for children with neuroimaging that showed no TBI. Isolated skull fractures were not considered to be TBI.

Results The original ExSTRA sample included 2890 index children evaluated for physical abuse. Of this group, 1692 underwent neuroimaging and 1122 had no TBI. Of these 1122 children, 352 had a dedicated retinal examination. Retinal hemorrhages were identified in 2 (0.6%) children. In both cases, there were few (defined as 3-10) hemorrhages isolated to the posterior poles; neither was diagnosed with physical abuse. The presence of facial bruising, altered mental status, or complex skull fractures was neither sensitive nor specific for retinal hemorrhage identification.

Conclusions Forensically significant retinal hemorrhages are unlikely to be found in children evaluated for physical abuse without TBI on neuroimaging, and such children may not require routine dedicated retinal examination. *(J Pediatr 2013;163:527-31)*.

Abusive head trauma (AHT) is the leading cause of mortality in abused children.[1] Proper diagnosis of AHT is important for many reasons, including to ensure the protection of the child from repeated abusive events.[2] Making the diagnosis of AHT, however, can be complicated because young victims are unable to provide their own history and the history offered by caregivers is often incomplete or misleading. The identification of occult injuries, including retinal hemorrhages, can improve the detection of abuse in children who present with concerning injuries.[3-8]

Retinal hemorrhages are present in 80%-85% of cases of AHT and are uncommon in non-AHT.[6,9,10] The detection of characteristic retinal hemorrhage, defined as numerous, multilayered, and extending to the periphery, is considered to be forensically significant as a cardinal sign of the acceleration-deceleration injuries that can be associated with AHT.[11,12] Other patterns of retinal hemorrhage can be seen in a variety of conditions, including accidental and inflicted injury. Few retinal hemorrhages clustered around the posterior pole have been identified in children with non-AHT and in critically ill children without trauma, and are therefore not specific for AHT.[12,13] Retinal examinations performed by physicians who are not pediatric ophthalmologists are not sufficiently sensitive to detect retinal hemorrhage and, as a result, dedicated retinal examination by a pediatric ophthalmologist is recommended for all children in whom there is concern for AHT.[14]

However, controversy exists about whether the retinal exam is useful in children with concern for abuse when neuroimaging does not reveal intracranial hemorrhage. In 2004, Morad et al described 9 children with altered mental status who were diagnosed with physical abuse and in whom there was retinal hemorrhage despite a normal initial computed tomography (CT) scan.[15] Since then, experts have debated which children with concern for abuse require dedicated retinal examination in the absence of brain injury on neuroimaging.[16-18] Some physicians obtain dedicated retinal examination for some or all children with concerns for physical abuse even when brain injury is not present (ie, in the setting of children with multiple non-cranial injuries).[16]

AHT	Abusive head trauma
CAP	Child Abuse Physician
CT	Computed tomography
ExSTRA	Examining Siblings to Recognize Abuse research network
TBI	Traumatic brain injury

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A retrospective review of data from a multi-center study found that less than 1% of 282 children with concern for physical abuse without brain injury on neuroimaging had characteristic retinal hemorrhage.[16] The authors suggested that a dedicated retinal examination may not be necessary in a child with normal mental status, no facial injury, and no radiographic evidence of brain injury. This study was limited because details of the patients with retinal hemorrhage were not described, and the determination of which retinal hemorrhage were considered to be "characteristic" may have varied between investigators.[16] A consecutive case series of children from a single center found two cases of non-characteristic retinal hemorrhage in 194 children without brain injury on neuroimaging, both of whom had facial bruising.[17] This study also suggested that complex or occipital skull fractures should join facial bruising or altered mental status as an indication for dedicated retinal examination in the absence of brain injury.

Because adults who physically abuse children are unlikely to seek out centers of excellence in child abuse evaluation, abused children are often seen initially in community emergency departments, and outside of normal business hours, where access to pediatric ophthalmological evaluation may require transfer or admission to the hospital, each of which carry increased cost to the patient. By better targeting this limited resource, we can help to ensure that children most likely to benefit from dedicated retinal examination will receive it.

We sought to prospectively determine rates of retinal hemorrhage in a multi-center sample of children evaluated for physical abuse who did not have brain injury on neuroimaging and to determine the significance of abnormal mental status, facial bruising, and complex or occipital skull fractures.

Methods

This is a prospectively planned secondary analysis of the Examining Siblings to Recognize Abuse (ExSTRA) research network, the complete methods of which have been described previously.[19] Briefly, the ExSTRA research network prospectively collected data from January 15, 2010-April 30, 2011 on all children <10 years old who underwent subspecialty consultation for concerns of physical abuse by 20 US child abuse teams. Each participating center enrolled more than 90% of eligible subjects as determined by monthly audits. Each participating center and the data coordinating center obtained approval for the parent study with a waiver of informed consent from their local institutional review board. This secondary analysis of de-identified data was determined to be exempt from review as human subjects research.

Subjects were included in this secondary analysis if they were less than 120 months (10 years) old and received subspecialty consultation by a Child Abuse Physician (CAP) to determine likelihood of physical abuse. Although the main objective of the parent study was to determine rates of injury among contact children, this analysis included only index children, and no siblings or contacts were eligible. For eligible subjects, CAPs indicated whether neuroimaging was performed and the results of any neuroimaging completed. Traumatic brain injury (TBI) was defined as any radiologic evidence of intracranial trauma, including subdural, subarachnoid, or epidural hemorrhage, brain contusions, and/or brain edema. Patients with isolated scalp contusions and/or skull fractures did not qualify as having TBI. CAPs documented whether a dedicated retinal examination was obtained and if retinal hemorrhage were found. When retinal hemorrhage were reported, CAPs recorded the number of hemorrhages (grouped as 1-2, 3-10, 10-30, 30-100, or >100), whether single or multiple layers of the retina were involved, distribution of hemorrhages (posterior pole only, to periphery, to ora serrate, or other), and presence or absence of retinoschisis. Characteristic retinal hemorrhage was defined as retinal hemorrhage that is numerous, multilayer, and extends to the periphery.[11,12] CAPs also recorded their perceived likelihood of abuse based on a previously published 7-point scale; a score of 6 or 7 was considered 'high likelihood.'[20]

Results

Of the 2890 children, 1692 (58.5%) underwent neuroimaging and 1122 (38.8%) did not have TBI. Of the 1122 children without TBI, 352 (31.4%) from 19 centers underwent dedicated retinal examination; they form the main cohort for this analysis. Children who had retinal examination were younger than those who did not (Table I). Rates of injuries that were suggestive of physical abuse are shown in Table II. Among the 352 children who underwent neuroimaging and did not have TBI, only 2 (0.6%, 95% CI 0.1-2.0) children had any retinal hemorrhage identified (Figure). These cases are summarized below:

Case 1

A 2.9-month-old male presented to the emergency department after being found unresponsive with no history of trauma. His Glasgow Coma Score was 3 and he was admitted to the pediatric intensive care unit where he later died. He had no cutaneous injuries, no fractures on skeletal survey, and no TBI. His dedicated retinal exam revealed a few (3-10) single-layer retinal hemorrhages in the posterior pole of the right eye. These retinal hemorrhages were felt by the CAP to be nonspecific for abuse. Autopsy results were not

Table I. Demographics of the ExSTRA cohort and study group

	ExSTRA cohort (n = 2890)	Study subjects without TBI with dedicated retinal examination (n = 352)	Subjects without TBI without dedicated retinal examination (n = 770)
White (%)	1821 (63.0)	216 (61.4)	503 (65.3)
Male (%)	1687 (58.4)	221 (62.8)	447 (58.1)
Age in mo, median (range)	21.9 (0-118)	8.5 (2-92)	11.9 (0-100)

Table II. Study group findings concerning abuse

Finding	Study subjects without TBI with dedicated retinal examination (n = 352)	Subjects without TBI without dedicated retinal examination (n = 770)
Altered mental status (%)	61 (17.3)	76 (9.9)
Facial/head bruising (%)	89 (25.3)	210 (27.3)
Complex skull fracture (%)	25 (7.1)	33 (4.3)
Occipital skull fracture (%)	11 (3.1)	12 (1.6)
Classic metaphyseal lesion(s) (%)	33 (9.4)	56 (7.3)
Posterior rib fracture(s) (%)	58 (16.5)	57 (7.4)
Acute and healing fractures (%)	48 (13.6)	44 (5.7)
Patterned cutaneous injury (%)	22 (6.3)	76 (9.9)

available. The ultimate likelihood of abuse was rated as mildly concerning (3/7) for physical abuse.

Case 2

A 7-month-old male presented to the emergency department after an apparent life threatening event. His mother reported finding him in his crib not breathing 30 minutes after taking a bottle and being put down to bed. The mother gave a rescue breath and a back thrust and he began breathing within 10 seconds. He had normal mental status by the time of presentation and throughout his hospital course. He had no cutaneous injuries, no fractures on skeletal survey, and no TBI on either CT or magnetic resonance imaging. He had a positive rhinovirus/enterovirus polymerase chain reaction. His dedicated retinal examination revealed few (3-10) retinal hemorrhages in the posterior poles bilaterally. These retinal hemorrhages were felt by the CAP to be nonspecific for abuse. The ultimate likelihood of abuse was rated as intermediately concerning (4/7) for physical abuse.

Associated Findings

Of the 352 subjects without TBI who underwent dedicated retinal examination, 198 had at least 1 finding that has been proposed to increase the likelihood of retinal hemorrhage without TBI: complex or occipital skull fracture, altered mental status, or facial bruising (Table II). Although 1 of the children with retinal hemorrhage identified in the above cases had altered mental status, the other had none of these findings.

Discussion

This prospective multi-center study supports previous recommendations that a dedicated retinal examination is not needed when children being evaluated for physical abuse do not have TBI.

Our data show that despite prior recommendations, CAPs continue to order dedicated retinal examinations in children without TBI. Consistent with these prior studies,[16,17] our data indicate the incidence of patients with any retinal hemorrhage in the absence of TBI is exceedingly rare. Our data suggest that it would require approximately 176 dedicated retinal examinations to detect 1 child with retinal hemorrhage, and that the hemorrhages detected would be unlikely to be forensically significant.

Our study is subject to several limitations. The decision to perform a dedicated retinal examination was undertaken at the discretion of the consulting clinical team, and was not guided by protocol. As a result, variability between centers is likely. The previously published studies may have affected clinical practice, decreasing the number of dedicated retinal examinations in children without TBI. Although 31.4% of children without TBI did receive a dedicated eye exam, many children without TBI (770/1122) did not. We did not determine the reasons that retinal examinations were performed in these 352 children, or why they were omitted in the others. We suspect that delay in penetrance of the recommendations by Li and Thackeray may result in substantial variance between CAPs and other physicians. Because CAPs may have used other measured or unmeasured markers of

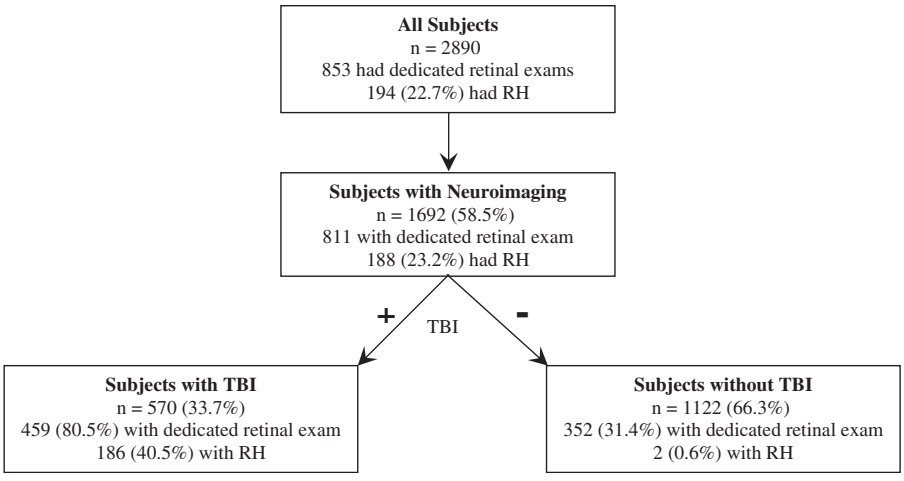

Figure. Patient flow. *RH,* retinal hemorrhage.

abuse likelihood or severity to determine which children underwent dedicated retinal examination, these cohorts may represent children at elevated risk for retinal hemorrhage, and true rates for all children undergoing abuse evaluation may be even lower. We did not record the timing of the dedicated retinal examination relative to neuroimaging. Because even large numbers of superficial retinal hemorrhage can resolve within 24 hours, this may have resulted in an underestimate of the true rate of retinal hemorrhage.[6] We would not expect characteristic retinal hemorrhage to resolve as quickly, however, so this would not be expected to alter rates of forensically significant retinal hemorrhage.

These results appear to run counter to the work of Morad et al, who reported a series of 9 children with retinal hemorrhage (at least 5 of which were characteristic of AHT) without TBI on initial CT.[15] Several possible reasons could explain this difference. First, the series by Morad et al was collected by way of a survey of a worldwide listserve of CAPs, rather than a defined cohort of children with concern for abuse. Because this method has the potential to include any child in the memory of the community of CAPs on the listserve, the denominator of cases is likely to be both extremely large and impossible to define. Second, the series by Morad et al included 4 patients of 9, where subdural hematomas were identified by subsequent neuroimaging, even though the initial CT did not demonstrate TBI. Our methodology did not distinguish between TBI that was identified on initial or subsequent neuroimaging. Finally, the cases reported by Morad et al were published in 2004, but the year during which the children were evaluated was not described and the children may have presented several years earlier. It is possible that improvements in neuroimaging, particularly CT, have resulted in better ability to appreciate smaller or more subtle TBI that would have been missed in prior years.

Because they also included consecutive samples of children evaluated for physical abuse who had normal neuroimaging, the cohorts used by Thackeray[16] and Li[17] are similar enough to the cohort in the current study to allow for combination. Combining the 3 cohorts, these data suggest that the rate of any retinal hemorrhage in children evaluated for physical abuse without TBI is approximately 1.6% (13/828, 95% CI 0.8-2.7) and that the prevalence of retinal hemorrhage likely to forensically impact the case is approximately 0.2% (2/828, 95% CI 0.0-0.8). This implies the need to perform 64 dedicated retinal examinations to find a child with any retinal hemorrhage, and 414 to identify forensically significant retinal hemorrhage. For context, forensically significant information was identified in at least 1 of 18 skeletal surveys,[21] and abdominal injuries are identified in approximately 1 of every 5-6 potentially abused children with elevated hepatic transaminases.[5,22]

Retrospective studies have suggested factors that may correlate with the presence of retinal hemorrhage in patients without TBI, including abnormal mental status, presence of facial/head bruising, and skull fractures. In our study, altered mental status was present in 1 of the 2 patients with retinal hemorrhage without TBI but facial bruising and skull fractures were not useful. Performing dedicated retinal examination for any of these factors would have led to performing 198 additional dedicated retinal exams to identify 1 new patient with retinal hemorrhage.

These results should not be interpreted to cast doubt on the importance of a thorough retinal examination in the course of an evaluation of AHT. Our data confirm the high rate of retinal hemorrhages in this population and support this recommendation. Indeed, retinal examinations have been shown to identify cases of abuse in other low-risk populations.[23] Nevertheless, a large number of pediatricians, emergency physicians, and other front-line providers who evaluate potentially abused children practice at times and in settings without easy access to pediatric ophthalmological evaluation. Such examinations carry the potential to involve the ophthalmologist in time-consuming and unreimbursed court testimony and contentious clinical circumstances. As such, the front-line providers must be careful stewards of this limited resource, reserving consultation for cases with a reasonable level of concern to identify positive findings. Even though the ultimate decision to pursue dedicated retinal exam will always remain with the treating physician, these data provide support for providers who choose to forego dedicated retinal examination in children without TBI.

Dedicated retinal examination plays a very important role in the diagnosis of AHT. However, in this prospective multicenter study, forensically significant retinal hemorrhages were not found in children without radiographic evidence of TBI. Therefore, children being evaluated for physical abuse without TBI on neuroimaging may not require routine dedicated retinal examination. ■

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Appendix

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