HHS Public Access

Author manuscript

J Pediatr. Author manuscript; available in PMC 2021 March 01.

Published in final edited form as:

J Pediatr. 2020 March ; 218: 178–183.e2. doi:10.1016/j.jpeds.2019.11.010.

Estimating the Relevance of Historical Red Flags in the Diagnosis of Abusive Head Trauma

Kent P. Hymel, MD[1], **Gloria Lee, MD**[1], **Stephen Boos, MD**[2], **Wouter A. Karst, MD**[3], **Andrew Sirotnak, MD**[4], **Suzanne B. Haney, MD**[5], **Antoinette Laskey, MD, MPH**[6], **Ming Wang, PhD**[7], **Pediatric Brain Injury Research Network (PediBIRN) Investigators***

[1]Department of Pediatrics, Penn State College of Medicine, Penn State Health Children's Hospital, Hershey, PA; [2]Department of Pediatrics, Baystate Medical Center, Springfield, MA [3]Department of Forensic Medicine, Netherlands Forensic Institute, The Hague, The Netherlands; [4]Department of Pediatrics, University of Colorado School of Medicine, Denver, CO; [5]Department of Pediatrics, University of Nebraska Medical Center, Children's Hospital and Medical Center, Omaha, NE; [6]Department of Pediatrics, University of Utah School of Medicine, Primary Children's Hospital, Salt Lake City, UT; [7]Department of Public Health Sciences, Penn State College of Medicine, Hershey, PA

Abstract

Objective: To replicate the previously published finding that "having no history of trauma"—in the face of a child's obvious traumatic head injuries—demonstrates high specificity and positive predictive value (PPV) for abusive head trauma (AHT).

Study design: Secondary analysis of a de-identified, cross-sectional dataset containing prospective data regarding 346 young, acutely head-injured children hospitalized for intensive care across 18 sites between 2010 and 2013, to estimate the diagnostic relevance of a caregiver's specific denial of any trauma, changing history of accidental trauma, or history of accidental trauma inconsistent with the child's gross motor skills. Cases were categorized as definite or not definite AHT based solely on patients' clinical and radiologic findings. For each presumptive historical "red flag", we calculated sensitivity, specificity, predictive values, and likelihood ratios (LR), with 95% confidence intervals (CI), for definite AHT—in all patients, and in cohorts with normal, abnormal, and persistent abnormal neurological status.

Results: A caregiver's specific denial of any trauma demonstrated specificity 0.90 (95% CI: 0.84–0.94), PPV 0.81 (95% CI: 0.71–0.88), and LR+ 4.83 (95% CI: 3.07–7.61) for definite AHT

Corresponding Author: Kent P. Hymel, MD, Penn State Health Milton S. Hershey Medical Center, Department of Pediatrics, Division of Child Abuse Pediatrics, 500 University Drive, MC H085, Hershey PA, 17033, Work phone: 717-531-5158 or 717-531-0003, extension 281519, khymel@pennstatehealth.psu.edu.

*List of additional members of the PediBIRN investigators is available at www.jpeds.com (Appendix).

We thank the additional PediBIRN investigators who helped to capture the data used in this secondary analysis (Appendix).

in all patients. Specificity and LR+ were lowest—not highest—in patients with persistent neurologic abnormalities. The 2 other historical red flags revealed similar trends.

Conclusions: A caregiver's specific denial of any trauma, changing history of accidental trauma, or history of accidental trauma that is developmentally inconsistent, are each highly specific (>0.90), but may provide weaker support than previously reported for a diagnosis of AHT in patients with persistent neurologic abnormalities.

Keywords

abusive head trauma; child abuse; non-accidental trauma; diagnosis; history

Multiple child abuse medical professionals have opined that some caregiver explanations for their child's traumatic injuries raise concern for child physical abuse.[1,2,3] Examples of these presumptive historical "red flags" include a caregiver's specific denial of any trauma in the face of their child's obvious traumatic injuries, a changing history of accidental trauma, and a history of accidental trauma that is developmentally inconsistent with the child's known or expected gross motor skills.

Objective evidence of these historical red flags' positive predictive value is surprisingly limited. Multiple studies purporting to demonstrate a strong association between no history of trauma and abusive head trauma (AHT) adopted definitional criteria for AHT and non-AHT that were based (at least in part) on the history of present illness (HPI), thus facilitating the introduction of circular reasoning and bias.[4,5,6] In their 2011 systematic review of features that distinguish inflicted from non-inflicted brain injury, Maguire et al concluded that "It was not possible to analyze the value of history given as a predictor, as a number of studies had used absence of a history of trauma or inconsistent explanation as part of their definitional criteria."[7]

A single study, designed specifically to estimate the diagnostic relevance of the caregiver's history, adopted methodology ensuring that the history did not contribute to sorting of AHT vs non-AHT. In their retrospective, single institutional study of 163 young children hospitalized with acute intracranial injury, Hettler and Greenes reported that "having no history of trauma" was highly specific (0.97) and predictive (0.92) of definite AHT, and perfectly specific (1.00) and predictive (1.00) in patients with persistent neurologic abnormalities.[3]

Our primary objective was to replicate the work of Hettler and Greenes as closely as possible.[3] Specifically, we sought to estimate the AHT diagnostic relevance of a caregiver's specific denial of any trauma, history of accidental head trauma that changed substantively with repetition over time, and history of accidental head trauma inconsistent with the child's known (or expected) gross motor skills; through analysis of a larger, existing, prospective, multicenter dataset. We hypothesized that all three historical red flags would demonstrate high specificity, positive predictive value (PPV), and positive likelihood ratio (LR+) for definite AHT, especially in patients with persistent neurologic abnormalities.

METHODS

This was a retrospective secondary analysis of the de-identified, cross-sectional, PediBIRN (Pediatric Brain Injury Research Network) dataset. Detailed methods have been described previously.[8,9] Clinician investigators at all 18 participating sites obtained approval for the parent PediBIRN studies with waivers of informed consent from their local institutional review board. This secondary analysis was deemed exempt from review by the Institutional Review Board at Penn State Health Hershey Medical Center.

All data used for this analysis were captured prospectively between 2010 and 2013 in two strictly observational studies of consecutive, previously healthy children under three years of age hospitalized for intensive care of acute head injuries confirmed on neuroimaging.[8,9] Prospective study design facilitated capture of uniform, complete, historical, clinical, and radiological data. Victims of motor vehicle collisions and patients with pre-existing brain abnormalities were excluded. All 500 patients in the dataset were diagnosed with closed head trauma. None were diagnosed with a medical mimic.

In both parent PediBIRN studies,[8,9] a patient's "primary caregiver" was defined a priori as "the person responsible for the patient when he/she was acutely head-injured or first became clearly and persistently ill with clinical signs linked to his/her acute head trauma." In the absence of an "unbiased independent" witness to the child's head injury event, physician investigators were directed to obtain the HPI solely from the patient's primary caregiver. Per protocol, treating and consulting physicians entered a consensus impression regarding the caregiver's HPI by answering the following question: "Which of the following statements best summarizes the caregiver's explanation for the child's head injuries and acute clinical presentation?" Their answer options were: (1) "The caregiver described an accidental or nonabusive head injury event," (2) "The caregiver clearly admitted inflicted or abusive head trauma," (3) "The caregiver specifically denied that the child experienced any head trauma before he/she became symptomatic," or (4) "The caregiver refused to explain what happened."

If treating and consulting physicians' response to this question was that the primary caregiver admitted AHT, denied any head trauma, or refused to explain what happened, PediBIRN investigators captured no additional historical information. If, on the other hand, their consensus impression was that the caregiver described accidental head trauma, they were required to further characterize the HPI. Specifically, a caregiver's explanation of the accidental event for their child's head injury was considered historically inconsistent if it "changed substantively with repetition over time", and was considered developmentally inconsistent if it "included a requirement for the child to have utilized developmental skills that he or she had not yet demonstrated". Investigators did not capture data regarding caregivers' preliminary denials of trauma, or inconsistent histories of accidental trauma, in cases of admitted AHT or head trauma observed by an unbiased independent witness.

Fifty of 500 patients in the PediBIRN dataset who did not manifest intracranial hemorrhage (ICH) were excluded because they failed to meet Hettler and Greenes[3] eligibility criteria, adapted for this analysis (Table I). Thirty (30) patients were excluded because the primary

caregiver was unavailable (n=26) or refused to discuss the child's head injury event (n=4). Deeming the HPI to be reasonably definitive, we also excluded 74 cases in which the historical red flags were not captured because the child's abusive (n=5) or accidental (n=36) head injury event had been witnessed independently or the caregiver had admitted AHT (n=33).

The remaining 346 PediBIRN patients became the subjects of this study (Figure). They included 214 (62%) males and 132 (38%) females. Their average (median, range) age was 8.7 (6, 0–34) months. Study patients' races and ethnicities were 192 (55%) white, non-Hispanic or Latino; 83 (24%) white, Hispanic or Latino; 47 (14%) black; and 23 (7%) of "other" or "mixed" race/ethnicity.

Seeking to replicate the methodology of Hettler and Greenes[3] as closely as possible, we: [1] applied the definitional criteria listed in Table 1 to categorize these 346 patients as definite AHT *vs.* not definite AHT, [2] sorted patients into relevant subpopulations for each analysis (Figure, footnotes 2 and 3), and [3] constructed contingency tables to calculate each historical red flag's sensitivity, specificity, predictive values, and likelihood ratios for definite AHT, with 95% confidence intervals, based on asymptotic or exact methods as appropriate. These outcome measures were calculated for all patients, and for subgroups of patients with normal, abnormal, and persistently abnormal neurologic status. Lacking the equivalent data used by Hettler and Greenes[3], we categorized neurologic abnormalities that lasted >24 hours as persistent.

RESULTS

Of 346 study patients, 160 (46%) were categorized as definite AHT. The remaining 186 patients (54%) were categorized as not definite AHT. In 98 (28%) of 346 cases, the primary caregiver specifically denied the patient had experienced any head trauma. In the remaining 248 cases (72%), the primary caregiver reported the patient had experienced accidental head trauma. In 41 (17%) of these 248 cases, the primary caregiver's history of accidental head trauma changed substantively with repetition over time. In 22 (9%) of 248 cases, the primary caregiver's history of accidental head trauma was deemed inconsistent with the child's known or expected gross motor skills.

Patients categorized as not definite AHT tended to undergo more frequent abuse evaluations when caregivers specifically denied any trauma than when caregivers described accidental head trauma (Table 2). A primary caregiver's specific denial of any trauma demonstrated overall sensitivity 0.49 (95% CI: 0.41–0.57), specificity 0.90 (95% CI: 0.84–0.94), positive predictive value (PPV) 0.81 (95% CI: 0.71–0.88), negative predictive value 0.67 (95% CI: 0.61–0.73), positive likelihood ratio (LR+) 4.83 (95% CI: 3.07–7.61), and negative likelihood ratio 0.56 (95% CI: 0.48–0.66) for definite AHT, in all patients (n=346)(Table 3). A caregiver's history of accidental head trauma that changed substantively with repetition over time, or was inconsistent with the child's known or expected gross motor skills, demonstrated similar results (Table 4 and Table 5; available at www.jpeds.com).

Equivalent analyses in patient cohorts with normal, abnormal, and persistently abnormal neurologic status revealed surprising results that did not conform to our original hypotheses. Unlike the findings of Hettler and Greenes[3], for each historical red flag: (1) specificity and LR+ for definite AHT were lowest in patients with persistent neurologic abnormalities, and (2) PPV—though higher in patients with neurologic abnormalities—remained imperfect (<1.00) (Tables 3–5).

DISCUSSION

A diagnosis of AHT requires the capture and examination of extensive clinical, radiological, historical, and social data. In most cases, the diagnosis cannot—or should not—rest on historical data alone. We suspect that many physicians routinely assign some degree of diagnostic weight to historical elements they presume to be strongly associated with AHT. Our finding that a caregiver's specific denial of any trauma triggered more frequent abuse evaluations than a history of accidental head trauma supports this impression (Table 2). Unfortunately, HPI interpretation can be difficult, context-specific, and/or influenced by our own implicit biases.[10–16]

In this study, we estimated the diagnostic relevance of three, presumptive, historical red flags of AHT, through analysis of a large, cross-sectional, prospective, multicenter dataset. Using positive likelihood ratios to express our overall results, we found that each of the historical red flags was approximately 4 to 6 times more likely to be observed in cases of definite AHT than in cases of not definite AHT (LR+ in Table 3, and in Tables 4 and 5 online: "In all patients"). Although a LR+ in the range of 4 to 6 provides relatively weak evidence in support of a specific diagnosis[17–18], these results should not be discounted as clinically or forensically insignificant. Applied specifically to this study population (N=346), where the prevalence (pretest probability) of definite AHT was 0.46, LR+s in the range of 4 to 6 translate into posttest estimates of definite AHT probability between 77% and 84%.

Hettler and Greenes reported that having no history of trauma was highly specific (0.97) and predictive (0.92) of definite AHT, and perfectly specific (1.00) and predictive (1.00) in patients with persistent neurologic abnormalities at hospital discharge.[3] Very likely, physicians are inclined to accept these results as valid and generalizable because we associate persistent neurologic abnormalities more closely with AHT, and normal neurologic status with non-AHT. Accordingly, we hypothesized that the three historical red flags would each demonstrate high specificity, PPV, and LR+ for definite AHT, especially in patients with abnormal neurologic status lasting >24 hours. Although these overall trends were reproduced in this study, we found that: (1) specificity and LR+ for definite AHT were lowest—not highest—in patients with persistent neurologic abnormalities, and (2) PPV—though higher in patients with neurologic compromise—remained imperfect (<1.00) (Tables 3–5).

These unexpected results have potential clinical relevance. Whereas physicians have experienced abusive caregivers who specifically denied any trauma or falsified the HPI and caregivers unaware of another's abusive actions, our results remind us that some caregivers may falsify the HPI in cases of non-abusive trauma. We speculate that this occurs when

caregivers find it difficult to admit that their own inattention, imprudent behavior, or lapsed judgment resulted in head trauma with neurologic compromise.

Defining AHT for research purposes is challenging. There is no gold standard, and the selection of specific AHT definitional criteria both defines and limits the hypotheses that can be tested. For example, the AHT definitional criteria used in our parent PediBIRN studies[8,9] could not be adopted for this analysis because they too rely on historical data. Instead, we adapted Hettler and Greenes' somewhat conservative definitional criteria, precisely because historical data had been excluded.

Application of their more conservative criteria likely resulted in some patients with AHT being categorized erroneously as not definite AHT. In support of this supposition, we found that treating and consulting physicians ultimately diagnosed AHT in 11 (58%) of 19 patients sorted as not definite AHT whose caregivers denied any trauma. Patient misclassifications of AHT as not definite AHT could explain why a caregiver's specific denial of any trauma demonstrated lower specificity and PPV for definite AHT in this study, compared with the 2003 study by Hettler and Greenes.[3]

On the other hand, physicians' diagnostic reasoning can also be inaccurate. Although a high percentage of these 19 patients underwent thorough abuse evaluations (Table 2), none manifested skin findings with high specificity for abuse, skeletal findings moderately or highly specific for abuse, or retinal findings suspicious for major trauma (Table 1). These observations thus call the following into question: In the absence of such specific findings of abuse, did physicians conclude that these 11 patients had been abused *because* their caregivers had specifically denied any trauma?

This study has limitations. We were unable to precisely replicate Hettler and Greene's definitional criteria for definite AHT and for persistent neurologic abnormalities (Table 1, footnotes).[3] Whereas their single institutional study analyzed data regarding all hospitalized patients under 3 years of age with ICH, the PediBIRN dataset contains data regarding acutely head-injured children hospitalized specifically for intensive care. Very likely, there was significant variation in the timing, structure, circumstances, and content of the HPIs solicited from primary caregivers. We cannot confirm the accuracy or reliability of PediBIRN investigators' final consensus impressions regarding the HPI. Finally, we failed to capture data needed to assess the diagnostic relevance of historical red flags emerging prior to caregivers' admissions of abuse, or prior to revelations that a child's head trauma had been witnessed independently.

This secondary analysis also has strengths. The multicenter patient population used for this analysis was relatively large. Prospective study design facilitated complete capture of all required data. Clinicians' consensus impressions regarding caregivers' HPIs were captured prospectively and sorted consistently in accordance with a specified protocol. The historical red flags of AHT considered in this study were each defined a priori. Finally, the AHT definitional criteria applied in this study—adapted from Hettler and Greenes[3]—were well-suited to our research objective.

Our results confirm that a caregiver's specific denial of any trauma, changing history of accidental head trauma, or history of accidental head trauma that is developmentally inconsistent with the child's gross motor skills, are each highly specific (>0.90) for definite AHT. Although seemingly counterintuitive, in this study these historical red flags were more supportive of a diagnosis of AHT in patients presenting with normal neurologic status than in patients presenting with acute and/or persistent neurologic compromise.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Supported by Dartmouth-Hitchcock Medical Center, a private family foundation, The Gerber Foundation, Penn State University, Penn State Health Milton S. Hershey Medical Center, and the National Institutes of Health (P50HD089922). These funding organizations had no role in the study design; in the collection, analysis and interpretation of the data; in the writing of the report; and in the decision to submit the manuscript for publication. The content of this study is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The authors declare no conflicts of interest.

Abbreviations:

CI	confidence interval
HPI	history of present illness
PediBIRN	Pediatric Brain Injury Research Network
PPV	positive predictive value
NPV	negative predictive value
LR+	positive likelihood ratio
LR−	negative likelihood ratio

REFERENCES

1. Kellogg ND, Committee on Child Abuse and Neglect: Evaluation of suspected child physical abuse. Pediatrics 2007; 119:1232–1241. [PubMed: 17545397]
2. Snyder KR, Currie ML, Stockhammer TF. Interviewing caregivers of suspected child abuse victims In: Jenny C, ed. Child Abuse and Neglect: Diagnosis, Treatment, and Evidence. St. Louis: Elsevier Saunders; 2011 p. 51–9.
3. Hettler J, Greenes DS. Can the initial history predict whether a child with head injury has been abused? Pediatrics 2003; 111:602–7. [PubMed: 12612243]
4. Kelly P, John S, Vincent AL, Reed P. Abusive head trauma and accidental head injury: a 20-year comparative study of referrals to a hospital child protection team. Archives of Disease in Childhood 2015; 100:1123–1130. [PubMed: 26130384]
5. Fujiwara T, Okuyama M, Miyasaka M. Characteristics that distinguish abusive from nonabusive head trama among children who underwent head computed tomography in Japan. Pediatrics 2008; 122:e841–e847. [PubMed: 18762487]
6. Piteau SJ, Ward MGK, Barrowman NJ, Plint AC. Clinical and radiographic characteristics associated with abusive and nonabusive head trauma: a systematic review. Pediatrics 2012; 130:315–323. [PubMed: 22778309]

7. Maguire S, Pickerd N, Farewell D, Mann M, Tempest V, Kemp AM. Which clinical features distinguish inflicted from non-inflicted brain injury? A systematic review. Archives of Desease in Childhood 2011; 94:860–867.

8. Hymel KP, Willson DF, Boos SC, Pullin DA, Homa K, Lorenz DJ, et al. for the Pediatric Brain Injury Research Network (PediBIRN) Investigators. Derivation of a clinical prediction rule for pediatric abusive head trauma. Pediatric Critical Care Medicine 2013; 14:210–220. [PubMed: 23314183]

9. Hymel KP, Armijo-Garcia V, Foster R, Frazier TN, Stoiko M, Christie LM, et al. for the Pediatric Brain Injury Research Network (PediBIRN) Investigators. Validation of a clinical prediction rule for pediatric abusive head trauma. Pediatrics 2014; 134:e1537–44. [PubMed: 25404722]

10. Amagasa S, Matsui H, Tsuji S, Moriya T, Kinoshita K. Accuracy of the history obtained from the caregiver in infantile head trauma. American Journal of Emergency Medicine 2016; 34:1863–7. [PubMed: 27422215]

11. Chadwick DL, Chin S, Salerno C, Landsverk J, Kitchen L. Death from falls in children: how far is fatal? Journal of Trauma 1991; 31:1353–5. [PubMed: 1942142]

12. Keenan HT, Cook LJ, Olson LM, Bardsley T, Campbell KA. Social intuition and social information in physical child abuse evaluation and diagnosis. Pediatrics 2017; 140:e20171188. [PubMed: 29074609]

13. Hymel KP, Laskey AL, Crowell KR, Wang M, Armijo-Garcia V, Frazier TN, et al. for the Pediatric Brain Injury Research Network (PediBIRN) Investigators. Racial/Ethnic disparities and bias in the evaluation and reporting of abusive head trauma. Journal of Pediatrics 2018; 198:137–43. [PubMed: 29606408]

14. Lane WG, Dubowitz H. What factors affect the identification and reporting of child abuse-related fractures? Clinical Orthopaedics and Related Research. 8 2007; 461:219–25. [PubMed: 17415005]

15. Lane WG, Rubin DM, Monteith R, Christian CW. Racial differences in the evaluation of pediatric fractures for physical abuse. Journal of the American Medical Association 2002; 288:1603–9. [PubMed: 12350191]

16. Wood JN, Hall M, Schilling S, Keren R, Mitra N, Rubin DM. Disparities in the evaluation and diagnosis of abuse among infants with traumatic brain injury. Pediatrics 2010; 126:408–414. [PubMed: 20713477]

17. Association of Forensic Science Providers. Standards for the formulation of evaluative forensic science expert opinion. Science and Justice 2009; 49:161–4. [PubMed: 19839414]

18. Arscott E, Morgan R, Meakin G, French J. Understanding forensic expert evaluative evidence: a study of the perception of verbal expressions of the strength of evidence. Science and Justice 2017; 57:221–7. [PubMed: 28454631]

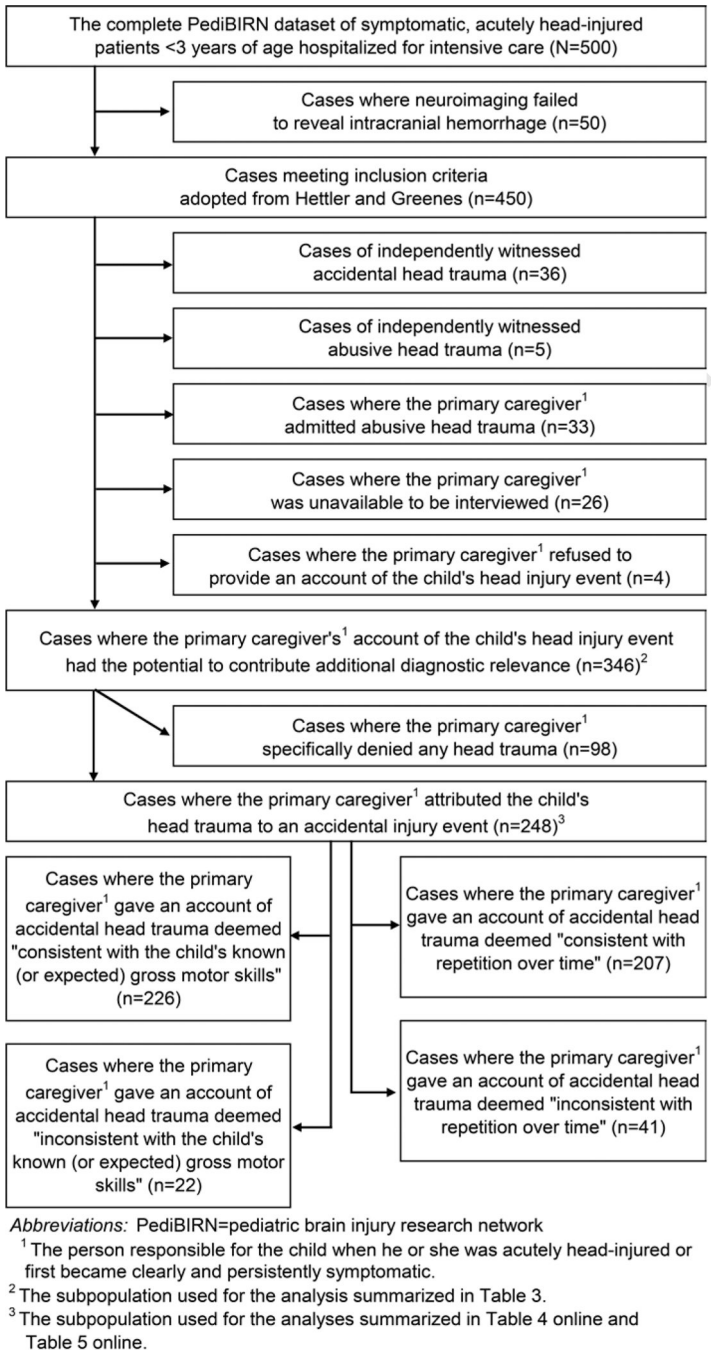

Figure 1.

Sorting of PediBIRN patients to estimate the diagnostic relevance of three, presumptive, historical “red flags” of pediatric abusive head trauma.

Table 1.

Eligibility and definitional criteria applied in these secondary analyses, adapted from Hettler and Greenes.

Criterion	Defined as…
Eligibility	Previously healthy children under three years of age hospitalized for intensive care at one of 18 participating PediBIRN sites between 2010 and 2013 for treatment of acute head trauma with intracranial hemorrhage confirmed on neuroimaging
Definite AHT[1]	Eligible patients with intracranial hemorrhage AND one or more of the following: retinal findings consistent with abuse, high-specificity skin findings, OR moderate or high-specificity fractures.
Intracranial hemorrhage	Head CT- or MRI finding(s) of epidural, subdural, or subarachnoid hemorrhage(s); brain contusion(s), laceration(s) or hemorrhage(s); OR diffuse traumatic axonal injury
Retinal findings consistent with abuse	Ophthalmologist findings of retinoschisis OR retinal hemorrhages described as dense, extensive, covering a large surface area, and/or extending to the ora serrata
High-specificity skin findings	Bruising involving the ear(s), neck, or torso; patterned skin bruising or dry contact burns; OR scalding burns with clear lines of demarcation, uniform depth, and a paucity of splash marks
Moderate or high-specificity fractures	Rib fracture(s); classic metaphyseal lesion fracture(s); epiphyseal separation(s); fracture(s) of the scapula or sternum; fracture(s) of digit(s); vertebral body fracture(s) or dislocation(s); OR fracture(s) of spinous process(es)
Abnormal neurologic status	A clear impairment or loss of consciousness
Persistent abnormal neurologic status[2]	A clear impairment or loss of consciousness lasting >24 hours.
Not definite AHT	All remaining hospitalized children 0 to 3 years of age who did not meet criteria for definite AHT

Abbreviations: AHT=abusive head trauma, CT=computed tomography, MRI=magnetic resonance imaging, PediBIRN=pediatric brain injury research network

[1]Hettler and Greenes' definitional criteria for definite AHT also included patients with intracranial hemorrhage and caregiver admissions of AHT. Deeming caregiver admissions of AHT to be reasonably definitive, PediBIRN investigators captured no data regarding presumptive historical red flags in equivalent cases. The resulting absence of analyzable data necessitated the elimination of this specific criterion for definite AHT in the current study. Because Hettler and Greenes' analysis included only a single patient with intracranial hemorrhage and admitted abuse, we deemed this modification to be both necessary and reasonable.

[2]Hettler and Greenes labeled a patient's abnormal neurological status as "persistent" if/when neurologic abnormalities were present at hospital discharge.

Table 2.

Completed abuse evaluations in patients with normal, abnormal, and prolonged abnormal neurological status.

In patients with normal neurologic status (n=161)…	**Skeletal survey**	**Retinal exam**
Definite AHT(n=39), and primary caregiver…	38 (97%)	37 (95%)
History of accidental head trauma (n=22)	21 (95%)	20 (91%)
Specific denial of any head trauma (n=17)	17 (100%)	17 (100%)
Not definite AHT (n=122), and primary caregiver…	75 (61%)	59 (48%)
History of accidental head trauma (n=114)	68 (60%)	54 (47%)
Specific denial of any head trauma (n=8)	7 (88%)	5 (63%)
In patients with abnormal neurologic status (n=185)…	**Skeletal survey**	**Retinal exam**
Definite AHT (n=121), and primary caregiver…	115 (95%)	116 (96%)
History of accidental head trauma (n=59)	56 (95%)	55 (93%)
Specific denial of any head trauma (n=62)	59 (95%)	61 (98%)
Not definite AHT (n=64), and primary caregiver…	41 (64%)	38 (59%)
History of accidental head trauma (n=53)	32 (60%)	27 (51%)
Specific denial of any head trauma (n=11)	9 (82%)	11 (100%)
In patients with abnormal neurologic status >24 hours (n=103)…	**Skeletal survey**	**Retinal exam**
Definite AHT (n=80), and primary caregiver…	76 (95%)	76 (95%)
History of accidental head trauma (n=34)	32 (94%)	31 (91%)
Specific denial of any head trauma (n=46)	44 (96%)	45 (98%)
Not definite AHT (n=23), and primary caregiver…	14 (61%)	18 (78%)
History of accidental head trauma (n=16)	8 (50%)	11 (69%)
Specific denial of any head trauma (n=7)	6 (86%)	7 (100%)

Abbreviations: AHT=abusive head trauma

Table 3.

Diagnostic relevance of a primary caregiver's[1] "specific denial of any trauma" for identifying cases of definite AHT[2].

Specific denial of any trauma?	In patients presenting with normal neurologic status (n=161)		In patients presenting with abnormal neurologic status[3] (n=185)		In patients presenting with abnormal neurologic status[3] that lasted >24 hours (n=103)		In all patients[4] (n=346)	
	Definite AHT[2]	*Not Definite AHT*	*Definite AHT*[2]	*Not Definite AHT*	*Definite AHT*[2]	*Not Definite AHT*	*Definite AHT*[2]	*Not Definite AHT*
Yes	**17**	**8**	**62**	**11**	**46**	**7**	**79**	**19**
No	**22**	**114**	**59**	**53**	**34**	**16**	**81**	**167**
		Value (95% CI)		***Value (95% CI)***		***Value (95% CI)***		***Value (95% CI)***
Sensitivity		0.44 (0.28–0.60)		0.51 (0.42–0.60)		0.58 (0.46–0.68)		**0.49 (0.41–0.57)**
Specificity		0.93 (0.87–0.97)		0.83 (0.71–0.91)		0.70 (0.47–0.86)		**0.90 (0.84–0.94)**
PPV		0.68 (0.46–0.84)		0.85 (0.74–0.92)		0.87 (0.74–0.94)		**0.81 (0.71–0.88)**
NPV		0.84 (0.76–0.89)		0.47 (0.38–0.57)		0.32 (0.20–0.47)		**0.67 (0.61–0.73)**
Prevalence		0.24 (0.18–0.32)		0.65 (0.58–0.72)		0.78 (0.68–0.85)		**0.46 (0.41–0.52)**
LR+		6.65 (3.11–14.20)		2.98 (1.69–5.25)		1.89 (0.99–3.60)		**4.83 (3.07–7.61)**
LR−		0.60 (0.46–0.80)		0.59 (0.49–0.71)		0.61 (0.46–0.82)		**0.56 (0.48–0.66)**

Abbreviations: AHT=abusive head trauma, CI=confidence interval, LR+=positive likelihood ratio, LR-=negative likelihood ratio, PPV=positive predictive value, NPV=negative predictive value

[1]Defined as the person responsible for the child when he or she was acutely head-injured or first became clearly and persistently symptomatic.

[2]Defined as eligible patients with intracranial hemorrhage and one or more of the following: retinal hemorrhages consistent with abuse, high-specificity skin findings, OR moderate-high specificity fracture(s).

[3]Defined as a clear impairment or loss of consciousness. (NOTE: These two patient subpopulations with abnormal neurological status are not mutually exclusive.)

[4]Excludes PediBIRN patients lacking intracranial hemorrhage (n=50), and patients where "a specific denial of any trauma" contributed no additional diagnostic utility [e.g., cases of independently witnessed abusive (n=5) or accidental head trauma (n=36), cases with primary caregiver admissions of abuse (n=33), and cases where the primary caregiver was unavailable (n=26) or refused to provide an account of the child's head injury event (n=4)].

Table 4.

Diagnostic relevance of a primary caregiver's[1] "history of accidental trauma that changed substantively with repetition over time" for identifying cases of definite AHT[2].

History of accidental head trauma that…	In patients presenting with normal neurologic status (n=136)		In patients presenting with abnormal neurologic status[3] (n=112)		In patients presenting with abnormal neurologic status[3] that lasted >24 hours (n=50)		In all patients[4] (n=248)	
Changed substantively?	***Definite AHT*[2]**	***Not Definite AHT***	***Definite AHT*[2]**	***Not Definite AHT***	***Definite AHT*[2]**	***Not Definite AHT***	***Definite AHT*[2]**	***Not Definite AHT***
Yes	**7**	**5**	**24**	**5**	**16**	**4**	**31**	**10**
No	**15**	**109**	**35**	**48**	**18**	**12**	**50**	**157**
		Value (95% CI)		***Value (95% CI)***		***Value (95% CI)***		***Value (95% CI)***
Sensitivity		0.32 (0.15–0.55)		0.41 (0.28–0.54)		0.47 (0.30–0.65)		**0.38 (0.28–0.50)**
Specificity		0.96 (0.90–0.98)		0.91 (0.79–0.96)		0.75 (0.47–0.92)		**0.94 (0.89–0.97)**
PPV		0.58 (0.29–0.84)		0.83 (0.64–0.93)		0.80 (0.56–0.93)		**0.76 (0.59–0.87)**
NPV		0.88 (0.81–0.93)		0.58 (0.46–0.68)		0.40 (0.23–0.59)		**0.76 (0.69–0.81)**
Prevalence		0.16 (0.11–0.24)		0.53 (0.43–0.62)		0.68 (0.53–0.80)		**0.33 (0.27–0.39)**
LR+		7.25 (2.53–20.79)		4.31 (1.77–10.49)		1.88 (0.75–4.73)		**6.39 (3.30–12.38)**
LR−		0.71 (0.54–0.95)		0.66 (0.53–0.81)		0.71 (0.49–1.01)		**0.66 (0.55–0.78)**

Abbreviations: AHT=abusive head trauma, CI=confidence interval, LR+=positive likelihood ratio, LR-=negative likelihood ratio, PPV=positive predictive value, NPV=negative predictive value

[1]Defined as the person responsible for the child when he or she was acutely head-injured or first became clearly and persistently symptomatic.

[2]Defined as eligible patients with intracranial hemorrhage and one or more of the following: retinal hemorrhages consistent with abuse, high-specificity skin findings, OR moderate-high specificity fracture(s).

[3]Defined as a clear impairment or loss of consciousness. (NOTE: These two patient subpopulations with abnormal neurological status are not mutually exclusive.)

[4]Includes the 248 of 500 cases in the PediBIRN dataset where the only historical element with the potential to yield diagnostic relevance was the primary caregiver's history of accidental head trauma.

Table 5.

Diagnostic relevance of a primary caregiver's[1] "history of accidental trauma that is inconsistent with the child's known (or expected) gross motor skills" for identifying cases of definite AHT[2].

History of accidental head trauma that is…	In patients presenting with normal neurologic status (n=136)		In patients presenting with abnormal neurologic status[3] (n=112)		In patients presenting with abnormal neurologic status[3] that lasted >24 hours (n=50)		In all patients[4] (n=248)	
Developmentally inconsistent?	***Definite AHT*[2]**	***Not Definite AHT***	***Definite AHT*[2]**	***Not Definite AHT***	***Definite AHT*[2]**	***Not Definite AHT***	***Definite AHT*[2]**	***Not Definite AHT***
Yes	**6**	**5**	**8**	**3**	**3**	**2**	**14**	**8**
No	**16**	**109**	**51**	**50**	**31**	**14**	**67**	**159**
	Value (95% CI)		***Value (95% CI)***		***Value (95% CI)***		***Value (95% CI)***	
Sensitivity	0.27 (0.12–0.50)		0.14 (0.06–0.26)		0.09 (0.02–0.25)		**0.17 (0.10–0.28)**	
Specificity	0.96 (0.90–0.98)		0.94 (0.83–0.99)		0.88 (0.60–0.98)		**0.95 (0.90–0.98)**	
PPV	0.55 (0.25–0.82)		0.73 (0.39–0.93)		0.60(0.17–0.93)		**0.64 (0.41–0.82)**	
NPV	0.87 (0.80–0.92)		0.50 (0.39–0.60)		0.31 (0.19–0.47)		**0.70 (0.64–0.76)**	
Prevalence	0.16 (0.11–0.24)		0.53 (0.43–0.62)		0.68 (0.53–0.80)		**0.33 (0.27–0.39)**	
LR+	6.22 (2.08–18.60)		2.39 (0.67–8.56)		0.71 (0.13–3.82)		**3.61 (1.58–8.25)**	
LR−	0.76 (0.59–0.98)		0.92 (0.83–1.02)		1.04 (0.92–1.18)		**0.87 (0.79–0.96)**	

Abbreviations: AHT=abusive head trauma, CI=confidence interval, LR+=positive likelihood ratio, LR-=negative likelihood ratio, PPV=positive predictive value, NPV=negative predictive value

[1]Defined as the person responsible for the child when he or she was acutely head-injured or first became clearly and persistently symptomatic.

[2]Defined as eligible patients with intracranial hemorrhage and one or more of the following: retinal hemorrhages consistent with abuse, high-specificity skin findings, OR moderate-high specificity fracture(s).

[3]Defined as a clear impairment or loss of consciousness. (NOTE: These two patient subpopulations with abnormal neurological status are not mutually exclusive.)

[4]Includes the 248 of 500 cases in the PediBIRN dataset where the only historical element with the potential to yield diagnostic relevance was the primary caregiver's history of accidental head trauma.