HHS Public Access

Author manuscript

Pediatr Emerg Care. Author manuscript; available in PMC 2023 June 01.

Published in final edited form as:

Pediatr Emerg Care. 2022 June 01; 38(6): 269–272. doi:10.1097/PEC.0000000000002670.

External validation of the PediBIRN screening tool for abusive head trauma in pediatric emergency department settings

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Abstract

Objective: The screening performance of the PediBIRN (Pediatric Brain Injury Research Network) abusive head trauma (AHT) 4-variable clinical decision rule (CDR) has been validated in the pediatric intensive care unit (PICU) setting and in a broader setting of all hospitalized, acutely head-injured children. To further broaden the rule's clinical applicability, we sought to validate its AHT screening performance in pediatric Emergency Department (ED) settings.

Methods: We conducted a retrospective, secondary analysis of an existing, de-identified, prospective dataset captured to derive a bruising CDR. Subjects were patients under three years with bruising and confirmed acute head trauma. An expert medical panel had previously identified patients with AHT. Measures of the CDR's AHT screening performance (sensitivity, specificity, likelihood ratios) were calculated with 95% confidence intervals (CI).

Results: Expert medical panel members had classified 78 (67%) of 117 eligible patients as AHT, 38 (33%) as non-AHT, and one as indeterminate. Excluding the indeterminate case, the PediBIRN-4 demonstrated sensitivity of 0.96 (95% CI: 0.88–0.99), specificity 0.29 (95% CI: 0.16–0.46), positive likelihood ratio 1.35 (95% CI: 1.10–1.67), and negative likelihood ratio 0.13 (95% CI: 0.04–0.46). Close inspection of the data revealed that one of the CDR's predictor variables had lowered specificity without impacting sensitivity. Eliminating this variable would have increased specificity to 0.84 (95% CI: 0.68–0.93).

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Conflicts of Interest: My coauthors and I have no potential, real or perceived, personal or financial, conflicts of interest to report related to this analysis or this manuscript.

Conclusions: The PediBIRN 4-variable CDR demonstrated AHT screening sensitivity in the pediatric ED equivalent to PICU and other inpatient settings, but lower specificity. Further study of a simplified 3-variable PediBIRN AHT screening tool for the ED setting is warranted.

Keywords

abusive head trauma; child abuse; non-accidental trauma; decision rule; screening tools

INTRODUCTION

Abusive head trauma (AHT) is the leading cause of traumatic death and disability during early childhood, with an estimated annual incidence of 20–30 cases per 100,000 infants or young children.[1–7] To prevent further abusive trauma, physicians caring for young, acutely head-injured children must recognize AHT masquerading as accidental head trauma. Unfortunately, physicians continue to miss AHT and have demonstrated significant disparity and bias in their assessments of child maltreatment.[8–21]

To minimize cases of missed AHT, PediBIRN (Pediatric Brain Injury Research Network) investigators derived and validated an evidence-based AHT screening tool for application in pediatric intensive care unit (PICU) settings.[22–23] The 'PediBIRN-4' AHT screening tool comes in the form of a 4-variable clinical decision rule (CDR). It directs physicians to complete thorough abuse evaluations of all young, acutely head-injured, 'higher risk' patients who present for intensive care with any one or more of the CDR's four predictor variables (Table 1). The PediBIRN-4 performed with sensitivity of 0.96 and specificity of 0.43 in both its original PICU-based validation study[23] and in a more recent external validation study that applied broader inclusion criteria of all young children admitted with head injuries.[24]

To investigate bruising patterns in young children, Pierce and Kaczor directed the capture of multicenter, prospective, clinical and radiological data regarding 2161 children across five pediatric emergency departments (ED). In this manuscript, we present the results of a novel, secondary, retrospective analysis of their existing, de-identified dataset. Our objective was to externally validate the PediBIRN-4's AHT screening performance in pediatric ED settings. We hypothesized that it would perform with sensitivity and specificity similar to that observed in pediatric inpatient settings.

MATERIALS and METHODS

We conducted a novel, retrospective, secondary analysis of de-identified data captured prospectively between December 2011 and March 2016 across five participating sites to derive a bruising clinical decision rule (BCDR). Eligibility criteria for enrollment in the parent BCDR study included age less than four years and skin bruising on physical examination. Enrollment in the parent BCDR study occurred via two pathways: parental informed consent during pre-scheduled periods of active ED recruitment, and waived consent in ED patients undergoing formal child abuse consultations. Clinician investigators at all five participating sites obtained approval for the parent BCDR study from their local institutional review boards. This retrospective, secondary analysis of the BCDR dataset

was deemed exempt from review by the Institutional Review Boards at Penn State Health Hershey Medical Center and Lurie Children's.

All BCDR patients under three years of age who had neuroimaging findings of acute closed head trauma were considered for inclusion in this secondary analysis. The investigators who directed the BCDR study (MP and KK) identified the subpopulation of their BCDR subjects eligible for inclusion, reviewed each patient's relevant clinical data, and achieved complete consensus regarding the presence or absence of the PediBIRN-4's first two predictor variables (Table 1). Thereafter, two different reviewers (AF and KH) independently reviewed the neuroradiological report(s) regarding each of these acutely head-injured children and achieved complete consensus regarding the presence or absence of the PediBIRN-4's last two predictor variables (Table 1). Patients lacking sufficient data to apply the PediBIRN-4 as an AHT screening tool were excluded from analysis. The remaining head-injured BCDR patients became the subjects of this study.

All patients eligible for inclusion in the secondary analysis had previously been classified as having AHT, head trauma that was not abusive (non-AHT), or head trauma of indeterminate cause, by an expert medical panel.[25] For this secondary analysis, subjects were sorted independently into higher *vs.* lower risk cohorts based on application of the PediBIRN-4 CDR (Table 1)[23]. A contingency table was created that excluded indeterminate case(s), and measures of the PediBIRN-4's AHT screening performance (sensitivity, specificity, likelihood ratios) were calculated with 95% confidence intervals. Predictive values were not calculated, as they are prevalence-dependent, and we deemed AHT prevalence in our study population of young children with both head trauma and bruising to be non-representative of AHT patients at large.

RESULTS

Among the 2161 patients in the BCDR dataset, neuroimaging reports confirmed findings of acute closed head trauma in 143 (7%) patients. Twenty-six patients who were over three years of age; presented with isolated facial, tooth, or scalp injuries; and/or lacked data needed to apply the PediBIRN-4 CDR were excluded. Of the remaining 117 patients, expert medical panel members had previously classified 78 (67%) as AHT, 38 (33%) as non-AHT, and 1 as indeterminate (Figure 1). Excluding the indeterminate case, the final study population of 116 patients included 58 males (50%) and 58 (50%) females. Study patients' races and ethnicities were 63 (54.3%) White, non-Hispanic or Latino; 22 (19.0%) White, Hispanic or Latino; 18 (15.5%) African American; and 13 (11.2%) of "other" or "mixed" race/ethnicity.

Applied to this pediatric ED population (N=116) as an AHT screening tool, the PediBIRN-4 would have demonstrated sensitivity of 0.96 (95% CI: 0.88–0.99), specificity 0.29 (95% CI: 0.16–0.46), positive likelihood ratio 1.35 (95% CI: 1.10–1.67), and negative likelihood ratio 0.13 (95% CI: 0.04–0.46)(Table 2).

The PediBIRN-4 categorized 27 (71%) of 38 patients with non-AHT as higher risk (Table 2). Close inspection of the data regarding these 27 false positive cases revealed that 21

(78%) presented with “skull fracture(s) other than an isolated, unilateral, nondiastatic, linear, parietal skull fracture” (i.e., the CDR’s fourth predictor variable), but none of its first three predictor variables (Table 1). Sensitivity analysis revealed that application of a simplified CDR—based solely on the PediBIRN-4’s first three predictor variables—would have increased AHT specificity to 0.84 (95% CI: 0.68–0.93) without compromising sensitivity (Table 3).

DISCUSSION

Physicians’ failures to recognize, diagnose, and report AHT place their young, acutely head-injured patients at substantial risk for additional inflicted trauma when they are returned to their abusive caregiver(s).[8] For this reason, an effective AHT screening test must perform with high sensitivity, to cast a broad net, and to miss as few cases as possible. Ideally, an effective AHT screening test will also demonstrate reasonable specificity, to minimize unnecessary abuse evaluations of patients with non-abusive head trauma.

Applied at the time of PICU admission as an AHT screening tool, the PediBIRN 4-variable CDR directs providers to complete thorough abuse evaluations of their young, acutely head-injured patients who present with any one or more of its four predictor variables. In its original, prospective, multicenter, PICU-based validation study, it performed with sensitivity of 0.96 (95% CI: 0.90–0.99).[23] In a subsequent, independent, external validation study conducted by the PREDICT (Pediatric Research in Emergency Department International Collaborative) research network in Australia and New Zealand, it performed with sensitivity 0.96 (95% CI: 0.82–0.999) when applied more broadly to all young, hospitalized children with head trauma.[24] In this secondary, retrospective analysis of the BCDR dataset, the PediBIRN-4 once again demonstrated high sensitivity (0.96, 95% CI: 0.88–0.99) when applied to young, acutely head-injured patients with bruising presenting to pediatric ED settings.

High sensitivity in an effective screening test oftentimes comes at the cost of mediocre specificity. The PediBIRN-4 is no exception. Specificity for AHT was 0.43 (95% CI: 0.35–0.50) in its original PICU-based validation study[23], 0.43 (95% CI: 0.32–0.53) in the external validation study conducted by the PREDICT network[24], and 0.29 (95% CI: 0.16–0.46) in the current, ED-based, external validation study. As reflected in its wide 95% CI, having so few non-AHT patients in the current ED-based study (n=38) rendered estimation of the PediBIRN-4’s AHT specificity imprecise. Nevertheless, such low specificity suggests that the CDR will recommend abuse evaluations for many pediatric ED patients with accidental head trauma. Some ED providers may find this unacceptable and therefore reject its application as an AHT screening tool.

Detailed information regarding all of the PediBIRN-4’s false positive and false negative cases can be found in Table 4. Close inspection of the data regarding its 27 false positive cases (study patients designated higher risk by the PediBIRN-4 but non-AHT by the expert medical panel) revealed that the CDR categorized 21 (78%) of 27 as higher risk based solely on its fourth predictor variable. Based on this observation, we conducted an additional analysis and found that application of a simplified 3-variable AHT screening tool

—based solely on the PediBIRN-4's first three predictor variables (Table 1)—would have increased its specificity from 0.29 (95% CI: 0.16–0.46) to 0.84 (95% CI: 0.68–0.93), without compromising sensitivity (Table 3).

A more complete understanding of the implications of this result is perhaps best achieved by comparing 3- *vs.* 4-variable CDR screening accuracy using their positive likelihood ratios. Applying the PediBIRN-4 as an AHT screening tool in this ED population, a higher risk designation was 1.35 times more likely in patients with AHT, than in patients with non-AHT (Table 2). Applying instead a simplified 3-variable CDR based solely on the PediBIRN-4's first three predictor variables, a higher risk designation was 6.09 times more likely in patients with AHT, than in patients with non-AHT (Table 3). Further study of the accuracy, acceptability, and clinical impact of this simplified, 3-variable, AHT screening tool is clearly warranted.

One of the greatest challenges associated with development of an AHT screening tool is the lack of a gold standard. To address this challenge, in its original validation study[23], PediBIRN investigators demonstrated that the CDR performed with sensitivity ≥0.96 if/when we defined AHT using a priori definitional criteria or physicians' final diagnoses. In its more recent external validation study by the PREDICT network[24], sorting of patients as AHT, non-AHT, or indeterminate head trauma was based on local institutional multidisciplinary review. In this secondary analysis of the BCDR dataset, patients were sorted as AHT, non-AHT, or indeterminate head trauma by an expert medical panel whose members were blinded to the results of psychosocial risk assessment. Robust analysis revealed that this expert medical panel approach was both reliable and accurate.[25]

Validation of the PediBIRN-4's AHT screening sensitivity in multiple clinical settings, applying diverse criteria or methods to define AHT, through analysis of prospective data captured by three independent research networks, and in study populations with divergent AHT prevalence, places the CDR firmly within the "level 2" hierarchy of evidence for clinical prediction rules—that is, "rules that can be used in various settings with confidence in their accuracy".[26] Assessment of the PediBIRN-4's actual impact on relevant patient outcomes and health care costs must await a formal implementation trial.

This secondary analysis has numerous limitations. The study population was small, and the results may not be generalizable to larger patient populations, to other clinical settings, and/or to acutely head-injured patients who present for pediatric ED care without bruising. Two otherwise eligible BCDR patients had to be excluded from the analysis because they lacked data regarding one or more of the PediBIRN-4's predictor variables. Finally, although initially interpreted by neuroradiologists, neuroimaging studies were not directly re-examined to ascertain the presence or absence of the CDR's last two predictor variables (Table 1). Instead, their neuroimaging reports were reviewed by non-radiologists (AF and KH).

CONCLUSION

The PediBIRN 4-variable CDR demonstrated AHT screening sensitivity in the pediatric ED equivalent to PICU and other inpatient settings, but lower specificity. Further study of a simplified 3-variable PediBIRN AHT screening tool for the ED setting is warranted.

Acknowledgement:

The authors would like to thank Douglas Lorenz, PhD, for his careful critique of this manuscript and his insightful suggestions.

Sources of Funding:

Research reported in this publication was supported in part by the National Institutes of Health, Eunice Kennedy Shriver National Institute of Child Health and Human Development under Award Numbers P50HD089922 [PI: Noll] and R01HD060997 [PI: Pierce]. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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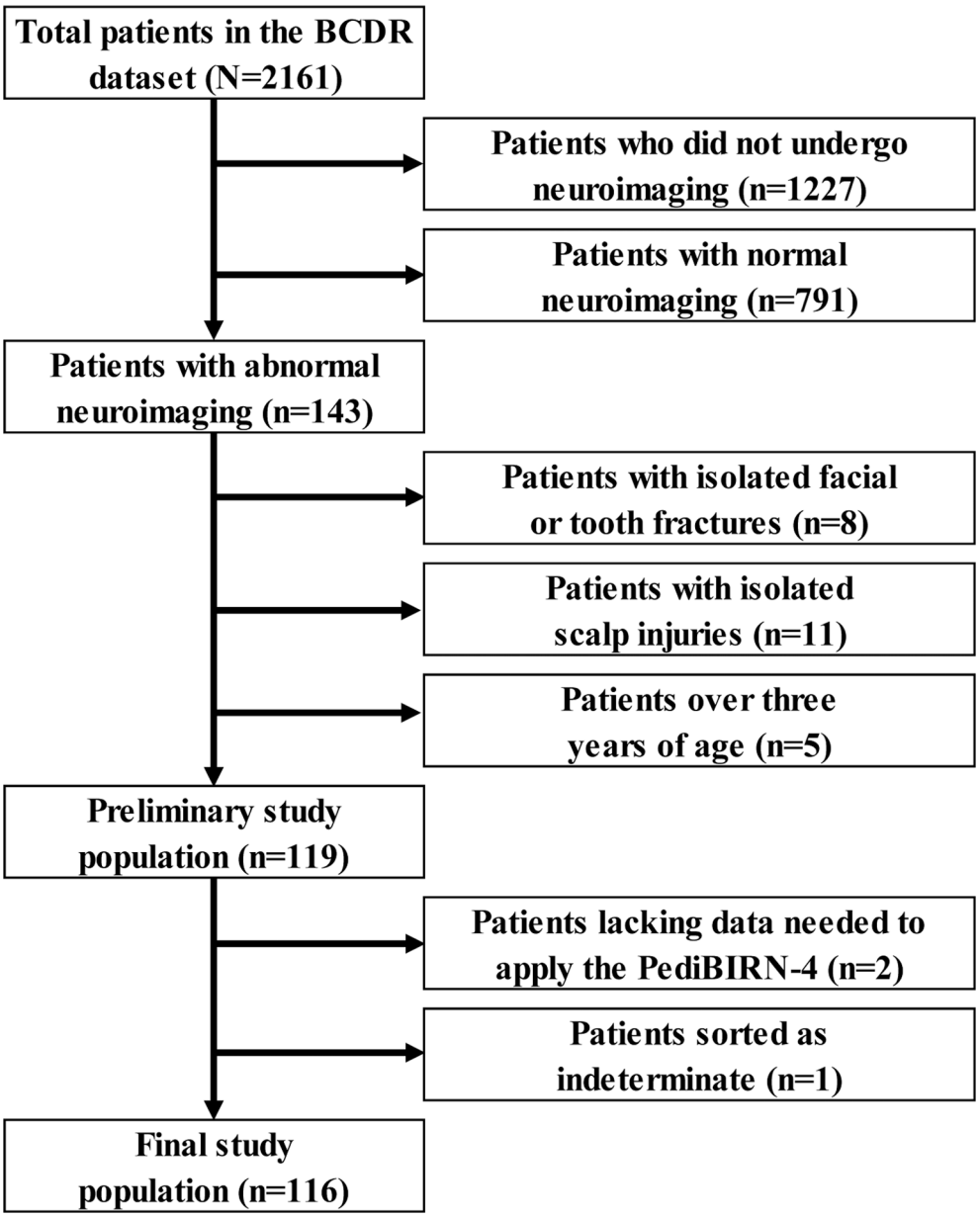

Figure 1. Selection of the final study population.

Abbreviations: BCDR=bruising clinical decision rule, PediBIRN=Pediatric Brain Injury Research Network

Table 1.

The PediBIRN 4-variable CDR for pediatric AHT.

To minimize missed cases, every acutely head-injured infant or young child hospitalized for intensive care who presents with one or more of these 4 predictor variables should be thoroughly evaluated for abuse.
• Any clinically-significant respiratory compromise at the SOI, during transport, in the ED, or PTA
• Any bruising involving the child's ear(s), neck or torso
• Any subdural hemorrhage(s) or fluid collection(s) that are bilateral OR involve the interhemispheric space
• Any skull fracture(s) other than an isolated, unilateral, nondiastatic, linear, parietal skull fracture

Abbreviations: AHT, abusive head trauma; CDR, clinical decision rule; ED, emergency department; PediBIRN=pediatric brain injury research network; PTA, prior to admission; SOI, scene of injury

Table 2.

AHT screening performance of the PediBIRN-4 CDR in pediatric ED settings.

		Sorting by the multidisciplinary expert panel in the parent BCDR study[1]	
Applying the PediBIRN-4		***Abusive head trauma***	***Accidental head trauma***
Higher Risk		75	27
Lower Risk		3	11
			Value (95% CI)
		Sensitivity	0.96 (0.88–0.99)
		Specificity	0.29 (0.16–0.46)
		Prevalence	0.67 (0.58–0.75)
		Positive likelihood ratio	1.35 (1.10–1.67)
		Negative likelihood ratio	0.13 (0.04–0.46)

Abbreviations: AHT=abusive head trauma; BCDR=bruising clinical decision rule; CDR=clinical decision rule; CI=confidence interval; ED=emergency department; PediBIRN=pediatric brain injury research network

[1]Excluding the single patient that the multidisciplinary expert panel sorted as indeterminate.

Table 3.

AHT screening performance of a simplified, 3-variable PediBIRN CDR in pediatric ED settings.

Applying a simplified 3-variable PediBIRN CDR[2]	**Sorting by the multidisciplinary expert panel in the parent BCDR study**[1]	
	Abusive head trauma	***Accidental head trauma***
Higher risk	75	6
Lower risk	3	32
		Value (95% CI)
	Sensitivity	0.96 (0.88–0.99)
	Specificity	0.84 (0.68–0.93)
	Prevalence	0.67 (0.58–0.75)
	Positive likelihood ratio	6.09 (2.92–12.71)
	Negative likelihood ratio	0.05 (0.01–0.14)

Abbreviations: AHT=abusive head trauma; BCDR=bruising clinical decision rule;

CDR=clinical decision rule; CI=confidence interval; ED=emergency department;

PediBIRN=pediatric brain injury research network

[1]Excluding the single patient that the multidisciplinary expert panel sorted as indeterminate.

[2]Excluding the PediBIRN-4's fourth predictor variable.

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resonance imaging, PedIBIRN=pediatric brain injury research network

Pediatr Emerg Care. Author manuscript; available in PMC 2023 June 01.