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ORIGINAL RESEARCH

Trauma

External validation of a pediatric decision rule for blunt abdominal trauma

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Abstract

Introduction: Blunt traumatic injuries are a leading cause of morbidity and mortality in the pediatric population. Contrast-enhanced multidetector computed tomography is the best imaging tool for screening patients at risk of blunt abdominal injury. The Pediatric Emergency Care Applied Research Network (PECARN) abdominal rule was derived to identify patients at low risk for significant abdominal injury who do not require imaging.

Methods: We conducted a retrospective review of pediatric patients with blunt trauma to validate the PECARN rule in a non-pediatric specialized hospital from February 3, 2013, through December 31, 2019. We excluded those with penetrating or mild isolated head injury. The PECARN decision rule was retrospectively applied for the presence of a therapeutic intervention, defined as a laparotomy, angiographic embolization, blood transfusion, or administration of intravenous fluids for pancreatic or gastrointestinal injury. Sensitivity and specificity analysis were conducted along with the negative and positive predictive values.

Results: A total of 794 patients were included in the final analysis; 23 patients met the primary outcome for an acute intervention. The PECARN clinical decision rule (CDR) had a sensitivity of 91.3%, a negative predictive value of 99.5, and a negative likelihood ration of 0.16.

Conclusion: In a non-pediatric specialty hospital, the PECARN blunt abdominal CDR performed with comparable sensitivity and negative predictive value to the derivation and external validation study performed at specialized children's hospitals.

KEYWORDS
blunt abdominal injury, clinical decision rule, intervention, low risk, pediatric, trauma

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1 | INTRODUCTION

1.1 | Background

Traumatic injuries are the number 1 cause of death from ages 1–18 years.[1] In 2015, >140,000 patients aged <19 years were injured, resulting in 3400 deaths. More than 73% of these injuries occurred by blunt mechanisms, with most being falls or motor vehicle accidents. Abdominal injuries were documented in almost 13% of these patients.[2] American College of Surgeons Committee on Trauma (ACS COT). notes that a contrast-enhanced, multidetector computed tomography (CT) scan is the best imaging tool for screening the patient with blunt abdominal trauma, especially for identifying active hemorrhage and hepatobiliary, splenic, pancreatic, and genitourinary injuries.[3] The use of CT imaging in evaluating pediatric traumas has resulted in a shift to non-operative management. A normal CT after blunt abdominal trauma has a high negative predictive value (NPV) for intra-abdominal injuries (IAIs) requiring intervention (IAIs-I).[4,5]

1.2 | Importance

Unfortunately, the use of CT scans in children, especially when the cumulative dose becomes greater than 50 mGy, increases the risk of cancer development.[6] This observation has led the ACS-COT to recommend minimizing unnecessary imaging in pediatric patients.[3] The Pediatric Emergency Care Applied Research Network (PECARN) was established to translate research results into clinical practice. In 2013, the network derived a clinical decision rule (CDR) to identify children at very low risk for IAIs that would require intervention, obviating the need for CT scans of the abdomen and pelvis (Table 1).[7,8]

1.3 | Goals

The initial CDR was derived using specialized trauma centers with pediatric trauma expertise.[8] It has undergone external validation also at a pediatric emergency department (ED) in an academic tertiary care children's hospital with an ACS level 1 trauma designation.[9] Our objective was to determine the sensitivity of the PECARN CDR in a non-pediatric specialty care hospital.

2 | METHODS

2.1 | Study design and setting

We conducted a retrospective review of all pediatric trauma patients (aged <19 years) from February 3, 2013, through December 31, 2019. The study took place at a large community ED with an annual census of 134,000 patients, 20% of which are pediatric patients, defined as age <19 years. The hospital is also a level 1 designated trauma center with 1500 trauma activations, of which 6.6% are pediatric patients, defined as age <15 years per ACS-COT. In February 2019, a separate pediatric ED section opened within the main ED, which is staffed by a combination of emergency physicians, pediatric emergency physician assistance and nurse practitioners. The Institutional Review Board reviewed and approved the study protocol.

The Bottom Line

In this retrospective review of the Pediatric Emergency Care Applied Research Network (PECARN) blunt abdominal trauma clinical decision rule, Dr. Sigal et al found the sensitivity of the rule was somewhat lower than the original prospective cohort (91.3%). However, the authors found the negative predictive value of a patient being PECARN negative was quite high (99.5), although the overall prevalence of serious injury in the cohort was small. This article adds to the growing body of literature on clinical decision rules for pediatric injury.

2.2 | Data collection

A total of 2 researchers (SW, EM) reviewed all pediatric trauma patients evaluated in either the trauma bay, ED, or in the pediatric ED and removed all of those with penetrating injury or isolated head injury. Charts excluded represented patients with obvious isolated injury or a mechanism thought very unlikely to cause a blunt abdominal injury. A total of 3 abstractors (FG, MB, AS) then reviewed each chart and manually entered variables in Research Electronic Data Capture (REDCap). A total of 2 investigators (AS, TD) reviewed their first 10 charts for accuracy. Any charts with abstracting questions were reviewed by 2 of 4 reviewers (APS, TD, CV, AO), and a consensus was reached. Study data were collected and managed using REDCap electronic data capture tools hosted at Reading Hospital.[10,11] REDCap is a secure, web-based software platform designed to support data capture for research studies, providing (1) an intuitive interface for validated data capture, (2) audit trails for tracking data manipulation and export procedure, (3) automated export procedures for seamless data downloads to common statistical packages, and (4) procedures for data integration and interoperability with external sources.

2.3 | Analysis

Statistical analysis between categorical variables was performed with a chi-square test of fit association, and analysis between groups on continuous variables was performed using a group *t* test. Sensitivity and specificity analyses were conducted for the CDR variables indicating appropriateness of imaging and the need for an acute intervention

TABLE 1 PECARN criteria for obtaining a Computed Tomography (CT) scan of the abdomen and pelvis for blunt abdominal trauma and definition of an intervention

Imaging is appropriate if any of the following are present	
Evidence of abdominal wall trauma or a "seat belt" sign	Glasgow Coma Scale ≤13
Abdominal tenderness	Evidence of thoracic wall trauma
Complaints of abdominal pain	Decreased breath sounds
Vomiting	
Criteria for acute intervention	
Death	Therapeutic intervention at laparotomy
Angiographic embolization to treat bleeding from the intra-abdominal injury	Blood transfusion for anemia attributed to hemorrhage
Intravenous fluids for ≥2 nights for pancreatic or gastrointestinal injury	

as defined by the rule (Table 1). In addition, we calculated the positive predictive value (PPV) and NPV for the CDR.

During the review, we included pediatric trauma patients with blunt mechanisms of injury, such as falls, bicycle accidents, pedestrian versus motor vehicle accidents, and motor vehicle crashes. We excluded patients with minor isolated head trauma, transfers from other hospitals, those with CT imaging before arrival, and non-blunt mechanisms of injury such as drowning. We also excluded charts with missing data.

Any P value <0.05 was considered significant for analysis. Because of the exploratory nature of this analysis, there were no corrections applied to the data for multiple comparisons. No missing value imputations were performed for any data variable, and missing subject data were deleted on a case-by-case, variable-by-variable basis.

All statistical analyses for this research were performed using SPSS version 25.0 (IBM Corp). Data were downloaded from an Excel file and uploaded into SPSS format. Descriptive data involving discreet variables were reported as counts and percentages within categories. Continuous data were reported as means (averages) and SDs.

3 | RESULTS

A total of 1953 pediatric patients with traumatic injuries or a traumatic mechanism of injury were reviewed during the study period. After exclusions, a total of 794 patients were included in the final analysis, and 23 met criteria for needing an acute intervention (Figure 1).

There was no significant difference between patients who received a CT scan and those who did not regarding sex or the use of the focused assessment with sonography for trauma (FAST) exam. Those patients who received a CT scan during the trauma evaluation were more likely to have experienced a motor vehicle accident or crash (40.8% vs 22.7%; $P < 0.001$) and to be older (13.9 vs 9.2 years; $P < 0.001$; Table 2).

To identify patients with possible missed injuries, we reviewed the PECARN-negative charts without imaging for follow-up ED visits 1 week after the index visit. Of the 264 patients who were PECARN negative and did not have a CT scan performed, none returned within 7 days to the ED for a re-evaluation. Of the 157 patients who were PECARN negative who had a CT scan performed, 2 patients had blood transfusions. Patient 1 was a 17-year-old victim of a motor vehicle crash with a pelvic fracture that required a transfusion and orthopedic surgery. Patient 2 was a 15-year-old with a lower extremity penetrating injury near the inguinal region with active bleeding. The patient underwent operative control. Although a grade II liver laceration was identified, the blood loss anemia was thought secondary to the extremity injury. A review of the 129 patients who were PECARN positive without CT imaging did not identify any additional patients requiring intervention within the week after the index visit (Table 2).

The PECARN (CDR) performed with a sensitivity of 91.3% (95% confidence interval [CI], 72.0–98.9) and a NPV of 99.5 (95% CI, 98.2–99.9; Table 2). A total of 2 patients identified as PECARN negative had an intervention. Both patients required a blood transfusion and the interventions described previously. The specificity was 54.4% (95% CI, 50.8–57.9), and the PPV was 5.63 (95% CI, 4.9–6.5; Table 3).

Of the charts reviewed, 21% were not included as a result of missing data. Compared with those included in the analysis who were PECARN negative and positive, patients with missing data were younger (mean age, 9.9 years vs 13.94 and 12.46, respectively), less likely to have a FAST performed (39.2% vs 62.4% and 63.6%, respectively), and more likely to have a fall as the mechanism of injury (52.8% vs 35.6% and 40.3%, respectively). Children aged ≤5 years represented 61% of the charts with not enough data for abstraction. Glasgow Coma Score, the presence of abdominal pain, and abdominal tenderness were the variables most likely to have missing documentation (Tables 2 and 4).

3.1 | Limitations

This study has several limitations. The study is from a single institution and is a retrospective review. Inherent in retrospective reviews are missing data, and in our review 212 patients had missing data. In addition, because it was a single-site review, the prevalence of disease was low, with only 23 patients requiring an intervention. However, the utility of the CDR is in identifying low-risk patients without disease. Our results using data external to the original cohort and occurring at a non-pediatric hospital are similar to prior studies.

As part of the retrospective review, we excluded patients from analysis whose charts described isolated head injury or penetrating injury in whom abdominal injury was not considered. There is the risk that the treating clinicians mentally reviewed PECARN variables and incorporated them into the medical decision making without documenting their medical decision making. We also did not review these charts for subsequent return visits for missed IAIs or IAIs-I. This review setting was done at a regional trauma center and not a specialized pediatric

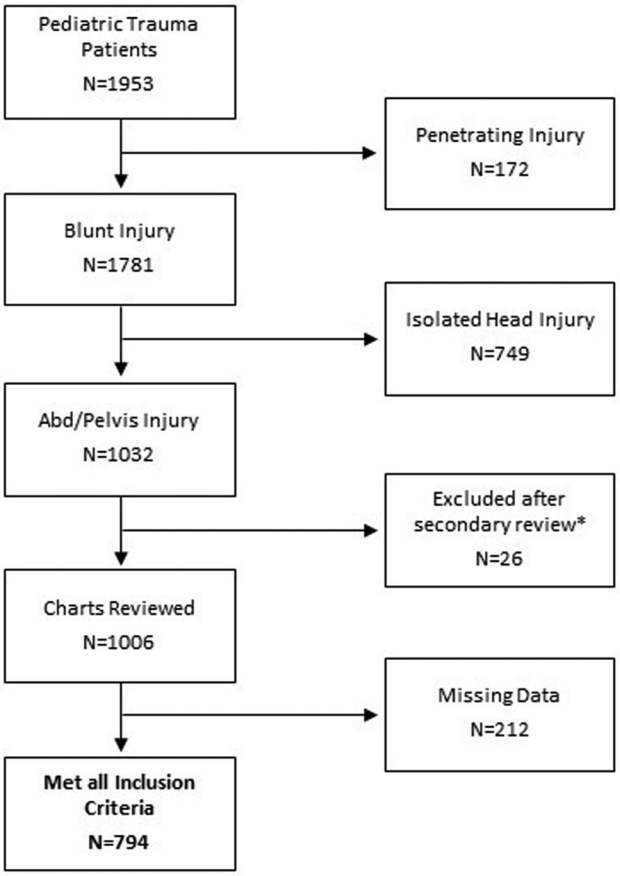

FIGURE 1 Inclusion of pediatric trauma patients in final analysis. Abd, abdominal

tertiary trauma center. Emergency medicine service units may preferentially defer higher acuity patients to pediatric specialty centers in our region.

4 | DISCUSSION

We retrospectively applied the PECARN abdominal CDR in a non-pediatric community hospital. We obtained sensitivity slightly lower but a NPV comparable with the derivation and externally validated study.[8,9] The small negative likelihood ratio of 0.16 in our study suggests that the PECARN rule can safely identify pediatric patients at low risk of an IAI-I, thus obviating the need for CT imaging and the subsequent risks of ionizing radiation exposure. Our sensitivity and NPV results closely mirror those of Ozcan et al in their retrospective application of 3 CDRs for pediatric blunt abdominal trauma (BAT). That study was also conducted at a tertiary pediatric hospital.[12] We estimate that following the PECARN rule would have resulted in a 37% reduction in CT scan use if applied appropriately. The utility of the PECARN CDR is in avoiding unnecessary ionizing radiation exposure in patients with low risk of having an injury requiring intervention.

Physicians should be cognizant that even if a patient meets some or all PECARN CDR criteria, imaging is not mandated. Although obtaining a CT image would have been justified in an almost equal number of pediatric patients based on a positive PECARN rule, the low positive likelihood ratio of the PECARN rule coupled with a low disease prevalence of 2.9% (Table 2) suggest that CT scanning in every patient who is PECARN positive may not be necessary. It is difficult to abstract from the medical records how physician gestalt regarding the presence of a significant blunt abdominal injury influenced the decision not to image this cohort of patients who were PECARN positive. However, clinicians appear to use other factors when caring for younger patients and those with lower energy mechanisms of injury, as these patients were less likely to receive CT scanning compared with other patients. The poor reliability of the history from younger patients coupled with a difficult exam may explain the lack of documentation for these categories.

We did not evaluate the utility of various laboratory screening tests or point-of-care ultrasound and their ability to identify trauma patients at low risk for clinically significant abdominal injury. Streck et al retrospectively evaluated a prediction rule for clinically significant injuries using the following 6 high-risk variables: hypotension for age, abnormal exam, elevated aspartate aminotransferase (AST), decreased

TABLE 2 Comparison of CT image use and PECARN criteria

		PECARN negative			PECARN positive		
		CT performed	CT not performed		CT performed	CT not performed	
Variable	Category	Count (%)	Count (%)	*P* value	Count (%)	Count (%)	*P* value
Sex	Female	55 (35)	88 (33.3)	0.722	82 (33.6)	54 (41.9)	0.115
	Male	102 (65)	176 (66.7)		162 (66.4)	75 (58.1)	
Etiology	Fall	26 (16.6)	94 (35.6)	<0.001	22 (9)	52 (40.3)	<0.001
	MVA	64 (40.8)	60 (22.7)		104 (42.8)	30 (23.3)	
	MCA	17 (10.8)	10 (3.8)		26 (10.7)	7 (5.4)	
	Ped accident	33 (21)	56 (21.2)		36 (14.8)	9 (7)	
	Other	17 (10.8)	44 (16.7)		56 (23)	31 (24)	
FAST performed	No	59 (37.6)	103 (39)	0.77	90 (36.9)	47 (36.4)	0.931
	Yes	98 (62.4)	161 (61)		154 (63.1)	82 (63.6)	
FAST negative/positive	Positive	0 (0)	0 (0)	N/A	13 (8.4)	0 (0)	0.003[a]
	Negative	98 (100)	161 (100)		141 (91.6)	82 (100)	
Continuous variable		Mean (SD)	Mean (SD)	*P* value	Mean (SD)	Mean (SD)	*P* value
Age, years		13.94 (3.67)	9.16 (5.1)	<0.001	12.46 (4.36)	7.5 (4.99)	<0.001

Abbreviations: CT, computed tomography; FAST, focused assessment with sonography for trauma; MCA, motor cycle accident, MVA, motor vehicle accident; N/A, not applicable; PECARN, Pediatric Emergency Care Applied Research Network; PED, pedestrian.
[a]Fisher's exact test.

TABLE 3 PECARN performance in a non-pediatric specialty care hospital

		Intervention	No Intervention	
Variable	Category	Count (%)	Count (%)	*P* value
PECARN	Yes	21 (91.3)	352 (45.7)	<0.001
	No	2 (8.7)	419 (54.3)	
Statistic			**% (95% CI)**	
Sensitivity			91.3 (71.96–98.93)	
Specificity			54.35 (50.75–57.9)	
Positive likelihood ratio			2 (1.73–2.32)	
Negative likelihood ratio			0.16 (0.04–0.6)	
Disease prevalence			2.9 (1.84–4.31)	
Positive predictive value			5.63 (4.89–6.47)	
Negative predictive value			99.52 (98.23–99.87)	
Accuracy			55.42 (51.88–58.91)	

Abbreviations: CI, confidence interval; PECARN, Pediatric Emergency Care Applied Research Network.

hematocrit, elevated amylase, and microhematuria. They also had a high NPV of 98.8%. In addition, they noted that elevated AST, low hematocrit, an abnormal abdominal exam and an abnormal chest x-ray as being independently associated with an IAI.[13] A follow-up prospective study using the same 4 variables plus the report of abdominal pain had a NPV of 99.4% for identifying an IAI and 100% for an IAI-I.[14] The prediction rule was subsequently validated with similar NPVs for IAIs and IAIs-I as defined by PECARN.[15] The PECARN CDR may have the

TABLE 4 Characteristics of patients excluded as a result of missing data

	All	Age ≤5 years
	n = 212	n = 129
PECARN variable (count/%)		
Seat belt sign or abdominal wall trauma	11 (5)	7 (63)
Glasgow Coma Score	80 (38)	45 (56)
Abdominal tenderness	40 (19)	23 (57)
Thoracic wall trauma	6 (3)	4 (66)
Complaint of abdominal pain	113 (53)	88 (78)
Decreased breath sounds	6 (3)	2 (33)
Vomiting	92 (43)	51 (55)
Age	9.9 (6.7)[a]	
Mechanism of Injury		
Fall	112 (52)	
MVC	64 (40.8)	
Ped accident	17 (10.8)	
Other	17 (10.8)	
FAST		
Yes	83 (39)	
No	129 (61)	

Abbreviations: FAST, focused assessment with sonography for trauma; MVC, motor vehicle crash; PECARN, Pediatric Emergency Care Applied Research Network; PED, pedestrian.
Data presented as n (% of all) unless otherwise indicated.
[a]Values are presented as mean (SD).

most utility in those cases in which the treating physician does not think laboratory testing is indicated.

Other strategies to decrease the need for CT scans and ionizing radiation include monitoring children with hemodynamic stability and an initial benign physical exam. In 1 prospective study at a single center, the development of abdominal pain after a period of observation or the presence of abnormal selected laboratory studies would prompt imaging acquisition. Absence of concerning developments would result in family continuing to monitor the child at home with close follow-up phone calls from the ED. No complications were noted on children managed in the conservative pathway.[16]

The PECARN CDR was designed to identify patients at sufficiently low risk for blunt IAIs-I in whom ionizing radiation diagnostic studies could be eliminated. As such, emphasis was placed on having a high sensitivity. It was not designed to identify patients at risk for IAIs-I. Other studies have evaluated the significance of mechanisms of injury, physical exam findings, laboratory abnormalities, and the role of FAST to predict the need for IAIs-I.[17–22]

Implementing the CDR has proven to be difficult despite its validation. A pediatric referral center has noted a poor compliance with the PECARN head rule for identifying patients at low risk for significant traumatic brain injury.[23] Both a level 1 trauma center and a pediatric trauma center did not find any improvement in the use of CT imaging after publication of both the PECARN head and abdominal rules.[24,25] Further studies are needed on effective strategies to implement the CDR to decrease unnecessary ionizing radiation in children with blunt abdominal trauma.

This study supports the use of the PECARN CDR to identify patients at very low risk of IAIs-I. This study is the first to validate the rule in a non-pediatric specialty center. When applying the PECARN CDR in settings beyond that of the original derivation, clinicians must understand the rule limitations as well as how their individual experiences with pediatric trauma patients impact their clinical gestalt. A prospective application of the CDR in this similar setting is needed to for widespread adaption.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Adam P. Sigal, Traci Deaner, Alison L. Muller, Anthony Martin, Adrian Ong, Thomas Geng, Tom Wasser, Brian Lahmann, and Christopher Valente developed the research project, analyzed the data, and wrote and edited manuscript and approved the final version. Sam Woods, Elizabeth Mannarelli, Alexis Schoener, McKenna Brower, and Felipe Guillen acquired and analyzed data and edited and approved the final manuscript. Adam P. Sigal, Traci Deaner, Adrian Ong, and Christopher Valente also verified data abstraction.

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