

Performance of the PECARN cervical spine injury prediction rule based on EMS clinician observations

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BACKGROUND:	Pediatric cervical spine injury (CSI) is associated with substantial morbidity and mortality. The Pediatric Emergency Care Applied Research Network (PECARN) developed a CSI prediction rule for evaluating children after blunt trauma in the emergency department (ED). The objective of this study was to evaluate the performance of the PECARN CSI prediction rule using emergency medical services (EMS) clinician observations.
METHODS:	We conducted a multicenter prospective observational study of children younger than 18 years with blunt trauma who were transported to one of 18 participating PECARN EDs by EMS. A convenience sample of EMS clinicians completed case report forms regarding CSI risk factors based on their clinical observations. We then evaluated rule performance with 95% confidence intervals (CI) by applying the PECARN prediction rule using the EMS clinical observations with the primary outcome of CSI. We also calculated rates of spinal motion restriction (SMR) had the algorithm been followed for the study population.
RESULTS:	Emergency medical services clinicians completed case report forms for 7,721 (57.4%) patients. Using these EMS cohort data, the PECARN CSI prediction rule had a sensitivity of 88.5% (95% CI, 82.9–94.2%), specificity of 63.1% (95% CI, 62.0–64.2%), positive predictive value of 3.7% (95% CI, 3.0–4.4%), and negative predictive value of 99.7% (95% CI, 99.6–99.9%). The proportion of children placed in SMR would have decreased from 41.5% to 37.7%, and longboard use would have decreased from 17.0% to 9.8% had the rule been applied to this cohort.
CONCLUSION:	The PECARN CSI prediction rule based on EMS clinician observations had good accuracy for CSI in children experiencing blunt trauma. Application of the prediction rule to our EMS patient population would have reduced both SMR and longboard use. (<i>J Trauma Acute Care Surg.</i> 2025;00: 00–00. Copyright © 2025 Wolters Kluwer Health, Inc. All rights reserved.)
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Traumatic injuries are common in children receiving care by emergency medical services (EMS) clinicians and accounted for over 600,000 pediatric EMS encounters in the United States

in 2023.^{1,2} Cervical spine injury (CSI), while uncommon in children, is associated with substantial morbidity and mortality.^{3–5} Emergency medical services clinicians must evaluate for CSI in

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children experiencing blunt trauma. The current standard of care involves spinal motion restriction (SMR), including rigid cervical collar application, in all children for whom EMS clinicians cannot rule out CSI.^{6,7} However, in practice, the application of a rigid cervical collar in children is variable. Placement of a rigid cervical collar is also associated with important adverse effects, including neck pain and discomfort, use of potentially harmful diagnostic radiation for CSI clearance, and hospital admission cascading from placement of SMR.^{8–10} Previous research demonstrated that implementing a selective prehospital SMR protocol reduced hospital admission rates in injured children.¹¹ Because of both the risks of missing CSI and not placing SMR on one hand, and the risks and adverse consequences of applying SMR when it is not indicated on the other, EMS clinicians require a robust and accurate clinical prediction rule to determine which children are most at risk for CSI following blunt trauma.^{12,13}

Two CSI prediction rules are widely used in the prehospital setting to assess risk for CSI: the Canadian Cervical Spine Rule (CCSR) and the National Emergency X-ray Utilization Study (NEXUS).^{14,15} Derived and validated mainly in adult patients, the current body of literature shows that EMS clinicians can accurately apply these prediction rules to determine CSI risk and the need for SMR in adult patients.^{16,17} However, children were underrepresented and absent in both the NEXUS and the CCSR derivation, respectively. Emergency medical services clinician observations were also not included in either study; therefore, the ability to determine the risk of CSI for pediatric patients in the prehospital setting is unknown. In a prospective observational study of more than 22,000 children, investigators in the Pediatric Emergency Care Applied Research Network (PECARN) derived and validated a CSI prediction rule for evaluating children in the emergency department (ED) after blunt trauma.¹⁸ In the pilot study preceding the PECARN CSI prediction rule, EMS clinicians exhibited high levels of agreement with ED clinicians in identifying the historical, mechanistic, and physical examination variables necessary for evaluating the risk of CSI. This suggested a pediatric CSI rule derived in the ED setting could be applied by EMS clinicians in prehospital care.^{19–21} That study, however, was limited by its pilot design, so there was an insufficient sample size for derivation of a definitive prehospital pediatric CSI prediction rule.

Although the PECARN CSI rule performs well when using ED clinician observations to identify children at low risk for CSI after blunt trauma,¹⁸ it is not known how the rule performs with use of EMS clinician observations. Understanding the performance of the PECARN CSI rule is essential to determine its appropriateness of use in the prehospital setting. The primary objective of this study was to determine the accuracy of the PECARN CSI prediction rule using EMS clinician observations of risk factors associated with CSI in children. Our secondary objective was to determine the potential impact of this rule on prehospital SMR when compared with the observed use of SMR in our study population.

METHODS

Study Design, Setting, and Inclusion Criteria

The current study was a planned secondary analysis of the parent PECARN CSI study. The parent study was a prospective

observational study of children younger than 18 years who experienced blunt trauma and were evaluated at one of 18 participating PECARN EDs between December 2018 and December 2021. Children presenting after blunt trauma were eligible for enrollment in the parent study if they were transported from the scene of injury via EMS, underwent trauma team evaluation, and/or had cervical spine imaging. We excluded children with solely penetrating trauma and those secondarily transferred to a study ED. We included all EMS transports agnostic to the transporting agency or level of prehospital certification given that SMR is within the scope of practice of all EMS clinicians. Complete details of the parent study methods have been published previously.^{18,20} This study was approved by a single centralized institutional review board. Our study adhered to STROBE reporting guidelines (see checklist in Supplemental Digital Content 1, <http://links.lww.com/TA/E749>).

Data Collection and Variables

In the parent study, trained research coordinators administered electronic case report forms (CRFs) to ED physicians to confirm patient eligibility and to ED physicians and trauma surgeons to capture clinical observations regarding the presence or absence of CSI risk factors. For this secondary analysis, we also administered similar electronic CRFs to a convenience sample of EMS clinicians immediately following the transfer of their patients to the ED staff. Variables included on the report forms had been previously shown to have high clinical plausibility to be associated with CSI and to have high degrees of interrater reliability.^{19,20} These variables included patient demographic factors, predisposing medical conditions, patient complaints, physical examination findings, mechanisms of injury, and markers of mechanism severity.

Outcome

The primary outcome was CSI, defined by cervical spine fractures or ligamentous injuries, cervical intraspinal hemorrhage or vertebral artery injury, and/or cervical spinal cord injury, including changes in the cervical spine cord on magnetic resonance imaging or cervical spinal cord injury without radiographic association.¹⁵ Research coordinators reviewed medical records for neck imaging (plain radiography, computed tomography, or magnetic resonance imaging) 21 days to 28 days after the index ED encounter. Imaging reports (if available) were reviewed for CSIs by the site principal investigators. If no imaging was obtained, or the reports unavailable, research coordinators contacted guardians of the study patients 21 days to 28 days after the index ED encounter to determine if a CSI was diagnosed in another clinical setting after the index ED visit. The study co-investigator, a pediatric spine surgeon, who served as the adjudicator reviewed imaging reports and surgical consultation notes to verify the presence of a CSI. The adjudicator was blinded to CRF results completed by the EMS clinician and patient outcomes.

Statistical Analysis

We categorized the study population by mode of arrival (EMS transport vs. private vehicle) and then described each group with means, medians, counts, and percentages. We further separated participants transported by EMS based on the presence or absence of a completed EMS electronic CRF. We

dichotomized all data for clinical predictors either as present or absent or grouped into discrete categories. We assessed associations between candidate risk factors and CSI in the prehospital cohort via Pearson's χ^2 tests or Fisher's exact test of independence. For the purposes of deriving the CSI prediction model, a moderate alpha-level of 0.15 was used in the parent study. We maintained use of this cutoff when assessing associations in this prehospital analysis.

Next, we applied the PECARN CSI prediction rule to EMS clinician observations (Fig. 1), initially derived using the clinical observations of treating ED clinicians. This prediction rule includes four high-risk variables: Glasgow Coma Scale (GCS) score of 3 to 8; unresponsiveness on the Alert, Verbal, Pain, Unresponsive level of consciousness scale (AVPU); abnormal airway, breathing, or circulation; or focal neurologic deficit, including paresthesia, numbness, or weakness. The prediction rule also includes five additional variables associated with an increased risk of CSI: self-reported neck pain; GCS score 9 to 14, best response of verbal or pain on AVPU or other signs altered mental status; substantial torso injury; substantial head injury; and neck tenderness upon examination.

We calculated measures of rule performance (sensitivity, specificity, positive predictive value [PPV], and negative predictive value [NPV]) with associated 95% confidence intervals by applying the PECARN CSI prediction rule to the EMS clinician observations of the risk factors. Risk factors were obtained from the electronic CRFs completed by the EMS clinician before neck imaging results were available. In the derivation of the prediction rule, the presence of any risk factor was considered to render the prediction rule positive for CSI.¹⁸ We defined sensitivity as the proportion of children with CSIs with at least one of the rule's risk factors, specificity as the proportion of children without CSIs who did not have any of the rule's risk factors, PPV as the proportion of children with at least one of the rule's risk factors who have CSIs, and NPV as the proportion of children who did not have any of the rule's risk factors that do not have a CSI. We reviewed all CRFs completed by ED clinicians and trauma surgeons during the parent study for participants with CSI in the EMS cohort who lacked prediction rule risk factors documented on EMS clinician completed CRFs.

To assess the potential effect of the PECARN CSI prediction rule on the use of SMR, we developed a hypothetical clinical care algorithm for managing potential CSI after blunt trauma in the prehospital setting. This algorithm triages children to the application of a rigid cervical collar with any of the nine PECARN CSI prediction rule risk factors and application of a longboard for children with any of the four high-risk factors. Children with no PECARN CSI prediction rule risk factors could forego SMR. This aligns with The American College of Surgeons Committee on Trauma, the American College of Emergency Physicians, and the National Association of EMS Physicians position statement that discourages the indiscriminate use of longboards for patient transport.⁵ We calculated the associated SMR rates if the hypothetical algorithm was followed for the prehospital study population. We performed all analyses in SAS 9.4 (SAS Institute, Inc., Cary, NC).

RESULTS

Participants

Of the 22,430 children enrolled in the parent study, EMS transported 13,453 who were thus eligible for this subanalysis. Emergency medical services clinicians completed an electronic CRFs for 7,721 (57.4%) of these children (Fig. 2). Table 1 presents the characteristics of children in the cohort stratified by mode of arrival and by availability of an EMS CRF. When compared with the cohort of children who had no EMS involvement, the children transported by EMS were slightly older and were more likely to be Black or African American race. Children transported by EMS directly from the scene to the participating ED were also more likely to have been involved in motor vehicle collisions or to be struck by cars or other motor vehicles, more likely to be discharged home from the ED, and less likely to be admitted to the intensive care unit when compared with those who had no EMS contact or who arrived as an interfacility transport from a referral ED. The rate of CSI was higher for children not transported primarily from the scene by EMS (2.7%; 95% CI, 2.3–3.0%) compared with those with primary EMS scene transport (CSI rate of 1.6%; 95% CI, 1.3–1.9%). Eligible children with and without completed CRFs were comparable in

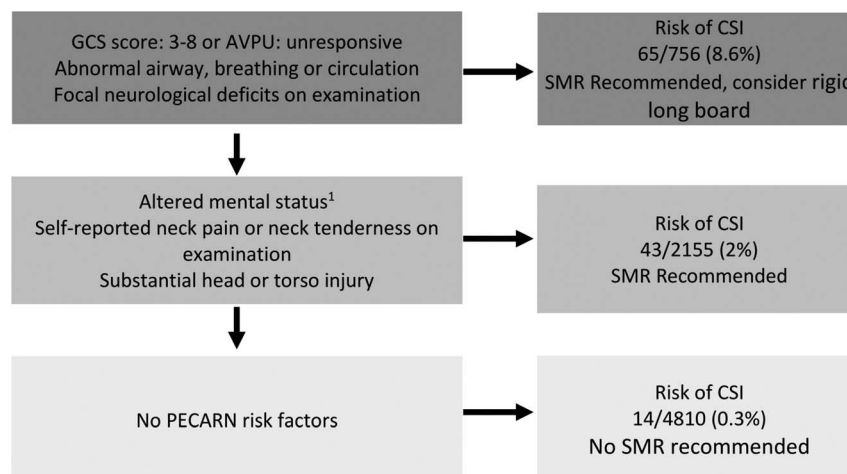


Figure 1. The PECARN CSI prediction rule.

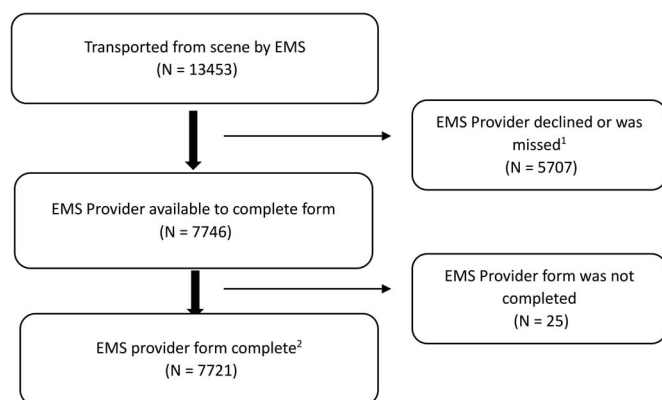


Figure 2. CONSORT diagram.

age, sex, race, ethnicity, mechanism of injury, ED disposition, and presence of CSI (Table 2).

Outcomes

In the bivariable analysis of the candidate variables with the presence of CSI, 71% of candidate variables, including all nine PECARN CSI prediction rule risk factors (Table 2), were

statistically significantly associated ($p < 0.15$). (A Complete list of candidate variables is included in Supplemental Digital Content Table 1, <http://links.lww.com/TA/E750>). When applied to the EMS cohort, the combined set of nine risk factors in the PECARN CSI prediction rule had a sensitivity of 88.5% (95% CI, 82.9–94.2%), specificity of 63.1% (95% CI, 62.0–64.2%), PPV of 3.7% (95% CI, 3.0–4.4%), and NPV of 99.7% (95% CI, 99.6–99.9%) (Table 3). Rule sensitivity varied minimally by age with an observed sensitivity of 87.5 (64.6, 100), 87.8 (77.8, 97.8), and 89 (81.9, 96.2) for children 0 to <2 years, children 2 to <8 years, and children 8 to <18 years, respectively. Negative predictive value of the PECARN CSI prediction rule was essential unchanged by age: 99.9 (99.6, 100) for children 0 to <2 years, 99.7 (99.4, 100) for children 2 to <8 years, and 99.7 (99.5, 99.9) for children 8 to <18 years.

Of the 122 children transported by EMS and subsequently found to have CSIs, 87.7% had some form of SMR applied. The PECARN CSI prediction rule did not capture 14 participants with CSIs (11.5%) in the EMS cohort (Supplemental Digital Content Table 2, <http://links.lww.com/TA/E751>). Of note, 11 of these children had one or more risk factor from the PECARN prediction rule recorded in either the ED clinician CRF, trauma surgeon CRF, or elsewhere in the medical record, and 10 had

TABLE 1. Participant Characteristics by EMS Cohort

	EMS Provider Cohort			
	Overall (N = 22,430)	No Direct EMS Transport From Scene (n = 8,977)	Direct EMS Transport From Scene and CRF <u>Not</u> Complete (N = 5,732)	Direct EMS Transport From Scene and CRF Complete (N = 7,721)
Age: Median [Q1, Q3]	8.0 [2.0, 13.0]	6.0 [1.0, 13.0]	9.0 [3.0, 13.0]	9.0 [4.0, 13.0]
Female	9,362 (41.7%)	3,805 (42.4%)	2,439 (42.6%)	3,118 (40.4%)
Race				
White	10,906 (48.6%)	5,133 (57.2%)	2,414 (42.1%)	3,359 (43.5%)
Black or African American	6,793 (30.3%)	1,724 (19.2%)	2,073 (36.2%)	2,996 (38.8%)
Other	3,539 (15.8%)	1,624 (18.1%)	889 (15.5%)	1,026 (13.3%)
Hispanic or Latino	4,330 (19.3%)	1,739 (19.4%)	1,284 (22.4%)	1,307 (16.9%)
Mechanism of injury				
Motor vehicle crash, driver or passenger	6,358 (28.3%)	1,464 (16.3%)	2,119 (37.0%)	2,775 (35.9%)
Motorcycle/all-terrain vehicle/motorized scooter crash, etc.	1,250 (5.6%)	654 (7.3%)	226 (3.9%)	370 (4.8%)
Hit by car or other motor vehicle (pedestrian, cyclist, other)	1,455 (6.5%)	325 (3.6%)	433 (7.6%)	697 (9.0%)
Fall	7,444 (33.2%)	3,267 (36.4%)	1,808 (31.5%)	2,369 (30.7%)
Diving	38 (0.2%)	18 (0.2%)	6 (0.1%)	14 (0.2%)
Sports or recreation related	2,219 (9.9%)	929 (10.3%)	470 (8.2%)	820 (10.6%)
Suspected child abuse	1,327 (5.9%)	1,133 (12.6%)	134 (2.3%)	60 (0.8%)
Assault/ altercation	535 (2.4%)	175 (1.9%)	170 (3.0%)	190 (2.5%)
ED Disposition				
Home	1,4948 (66.6%)	5,045 (56.2%)	4,304 (75.1%)	5,599 (72.5%)
Admit intensive care unit	1,614 (7.2%)	866 (9.6%)	278 (4.8%)	470 (6.1%)
Admit floor	5,038 (22.5%)	2,716 (30.3%)	940 (16.4%)	1,382 (17.9%)
Operating room	618 (2.8%)	280 (3.1%)	133 (2.3%)	205 (2.7%)
Death in the ED	43 (0.2%)	8 (0.1%)	22 (0.4%)	13 (0.2%)
Other	169 (0.8%)	62 (0.7%)	55 (1.0%)	52 (0.7%)
CSI	433 (1.9%)	239 (2.7%)	72 (1.3%)	122 (1.6%)

Description of participant characteristics using means, medians, counts, and percentages for those who were enrolled in the study with and without complete EMS provider CRFs. The EMS provider CRF could be incomplete because the EMS provider declined, the provider was missed, or the provider was not available.

TABLE 2. Bivariable Associations Between Risk Factors and CSI Injury in the EMS Cohort Based on EMS Provider Observations (*Variables Considered for Entry to the Prediction Rule Modeling Process)

	CSI		p*
	Overall (N = 7721)	No (n = 7599)	Yes (n = 122)
GCS score**			<0.001
3–8**	178 (2.3%)	142 (1.9%)	36 (29.5%)
9–13†	360 (4.7%)	338 (4.4%)	22 (18.0%)
14–15	7183 (93.0%)	7119 (93.7%)	64 (52.5%)
AVPU category**			<0.001
(A) The patient is awake or alert or oriented	7,100 (92.0%)	7,042 (92.7%)	58 (47.5%)
(V) The patient is responsive to verbal stimuli†	295 (3.8%)	280 (3.7%)	15 (12.3%)
(P) The patient is responsive to pain†	218 (2.8%)	194 (2.6%)	24 (19.7%)
(U) The patient is unresponsive to pain**	108 (1.4%)	83 (1.1%)	25 (20.5%)
Abnormal airway, breathing, or circulation findings**	463 (6.0%)	416 (5.5%)	47 (38.5%)
Self-reported paresthesia (abnormal tactile sensation)**	214 (2.8%)	202 (2.7%)	12 (9.8%)
Self-reported numbness**	404 (5.2%)	388 (5.1%)	16 (13.1%)
Self-reported extremity weakness**	770 (10.0%)	753 (9.9%)	17 (13.9%)
Self-reported neck pain†	1,398 (18.1%)	1,366 (18.0%)	32 (26.2%)
Neck tenderness upon examination†	817 (10.6%)	794 (10.4%)	23 (18.9%)
Signs of substantial head injury†	627 (8.1%)	585 (7.7%)	42 (34.4%)
Substantial torso injury†	234 (3.0%)	221 (2.9%)	13 (10.7%)

* χ^2 test.

**High-risk variable in the PECARN CSI prediction rule.

†Additional variables in the PECARN CSI prediction rule.

mechanism of injury of motor vehicle collisions. Only 1 study participant from the EMS cohort had a missed CSI by the prediction rule and subsequently required operative stabilization. This participant, a 6-year-old child injured in a motor vehicle crash, would have been detected by the PECARN CSI prediction rule if using observations from the ED clinician. The electronic CRF completed by the ED clinician and medical records both noted self-reported neck pain, neck tenderness on examination, a substantial torso injury, and abnormal airway, breathing, or circulation findings.

Application of the Clinical Prediction Rule to the Study Cohort

Table 4 illustrates the hypothetical use of the PECARN CSI prediction rule as a clinical care algorithm for the application of SMR by EMS clinicians. If this algorithm had been followed in the prehospital care of our study cohort, the proportion of children placed in SMR would have decreased from 41.5% to 37.7%. Longboard use, if used only for those with a high-risk factor, would have been reduced from 17.0% to 9.8%.

DISCUSSION

In this planned secondary analysis of the performance of the PECARN CSI prediction rule using EMS clinician observations, we found the sensitivity and negative predictive value of this novel rule to be acceptable; however, an evaluation of the patients with CSI who were not captured by the rule indicates improvements may be possible. While some were missed because the EMS clinicians did not appreciate risk factors that were likely present, 12 of 14 children with CSIs missed by the rule were injured when struck by motor vehicles or when involved in motor vehicle collisions, suggesting that inclusion of mechanism of

injury may increase sensitivity of the prediction rule when used in the prehospital setting (see Supplemental Digital Content Table 2, <http://links.lww.com/TA/E751>). However, inclusion of mechanism of injury in a CSI prediction rule will likely reduce its specificity and result in an increase in use of prehospital SMR. The sensitivity of 88.5% for CSI indicates that EMS clinicians can observe clinical and historical features associated with CSI in children in the prehospital environment. A near-perfect NPV suggests the rule is discriminatory for most children without CSI. Application of the PECARN prediction rule to our study's EMS population demonstrated the potential to reduce the proportion of children requiring SMR from 41.5% to 37.7%. In comparison, the proportion of children with CSIs placed in SMR increased modestly from 87.7% to 88.5%.

Previous studies have demonstrated the value of applying the CCSR and NEXUS c-spine rules to adults in the EMS setting.^{16,17} These studies, however, were inclusive of adult trauma patients. The exclusion of children in these studies is

TABLE 3. Clinical Prediction Rule Performance Based on EMS Provider Observations

Any Factor Observed	CSI	
	No (n = 7,599)	Yes (n = 122)
No	4,796	14
Yes	2,803	108
Performance		
Sensitivity	88.5% (82.9–94.2%)	
Specificity	63.1% (62–64.2%)	
PPV	3.7% (3–4.4%)	
NPV	99.7% (99.6–99.9%)	

logical given that they were underrepresented in the derivation of both the CCSR and NEXUS criteria.^{14,15,22} Of note, the NEXUS study did include more than 3,000 children and exhibited excellent sensitivity and NPV for CSI across the pediatric age group. However, the study only included 30 children with CSIs and there were no observed CSIs in children younger than 2 years, thus limiting the application of the NEXUS criteria in pediatrics.^{14,15}

In the pilot study preceding our main prospective study, we showed that CSI risk factors such as high-risk injury mechanisms, altered mental status, neck pain, decreased neck mobility, and neurologic deficits were positively associated with CSI in children when independently observed by EMS clinicians.¹⁹ We also demonstrated that EMS clinicians and ED clinicians exhibited high inter-rater reliability for many variables plausibly related to CSI, including those in the PECARN CSI Prediction Rule.^{18,19} These studies, together with the findings of the current sub-analysis, show promise in the prehospital application and performance of pediatric-specific CSI prediction rules such as the PECARN CSI prediction rule.

When based on prospective observations by ED clinicians from the parent study, the PECARN prediction rule exhibited better discrimination for CSI than our observed results when based on prospective observations by EMS clinicians.¹⁸ When comparing our results based on EMS clinician observations of CSI risk factors to those of the parent study based on ED clinician observations, we observed slightly lower sensitivity, slightly better specificity, and nearly identical PPV and NPV. While there is inherent value in using the same rule for both ED and EMS CSI risk stratification, the observed differences in rule performance suggests that there may be additional value in deriving and validating a CSI prediction rule from EMS observations that is specific to the prehospital setting.

The ability to stratify high-, low-, and very low-risk for CSI in injured children may also provide an opportunity to inform prehospital destination decision-making. Children with any of the PECARN CSI prediction rule variables likely warrant immediate transfer to the closest appropriate Level I trauma center for primary evaluation. Those without PECARN CSI prediction rule variables may not require Level I trauma center evaluation solely for potential CSI. Accurately stratifying CSI risk in the prehospital setting may also allow for appropriate distribution of patients throughout a region's health system, decrease medical cost, and keep children closer to their medical home.

This study is limited by both the demographics of the study sites and the sizable missed eligible population. We performed this study at 18 Level I Pediatric Trauma Centers, which, while geographically diverse and allowing for the capture of a sizeable population of injured children, are more homogenous than all EDs that provide care to injured children. While the observed PECARN CSI Prediction Rule test performances can be confidently applied to the type of patients typically transported directly from the scene by EMS to tertiary care pediatric trauma centers, the homogeneity of participating EDs introduces difficulty in extrapolating those test performances to community EDs and nonpediatric trauma centers. These EDs likely receive, on average, a less-injured population via EMS with lower rates of CSI than our participating sites. The observed negative predictive values of the PECARN prediction rule in these sites may decreased compared with those observed in our study cohort. However, we did not exclude any EMS agencies and included all eligible children regardless of the transporting agency or the level of EMS certification. This likely allowed for a greater heterogeneity among EMS clinicians who provided study observations and likely decreased the potential bias introduced by the homogeneity of our study EDs.

Our population of children transported directly from the scene to the participating ED was more likely to be discharged home and less likely to be admitted to the intensive care unit compared with other patients arriving via interfacility transfer or by non-EMS transport. The study sites, all Level I pediatric trauma facilities, serve as tertiary regional receiving centers. It is reasonable to assume that this population of transferred children had substantial injuries or mechanisms of injury identified by the referring ED and were felt to require care at a Level I pediatric trauma center. This characteristic of our enrolled population may have led to overestimating the accuracy of the prediction rule. However, our observed CSI rate of 1.6% in our study population does align with current published rates of pediatric CSI.

There also may be potential bias to our observations based on the rate of eligible patients who were missed for enrollment. To prospectively record EMS clinician observations, the study required EMS clinicians to complete electronic CRFs after patient hand-off in the ED. Due to both the research coordinator and EMS clinician's availability and the willingness of the EMS clinician to complete the form, a sizable portion of eligible patients did not have completed EMS clinician CRFs. Any potential bias, however, should be mitigated by the similarity in

TABLE 4. Observed SMR Rates and Projected SMR Rates With the Application of the PECARN CSI Prediction Rule

	Confirmed CSI (N = 122)	Overall (N = 7721)
	Observed SMR rates	
No spinal motion restriction	15 (12.3%)	4,515 (58.5%)
Rigid long board or vacuum mattress	52 (42.6%)	1,316 (17.0%)
Other or cervical collar	55 (45.1%)	1,890 (24.5%)
	SMR rates with the PECARN clinical prediction rule applied	
No spinal motion restriction	14 (11.5%)	4,810 (62.3%)
Rigid long board or vacuum mattress	43 (35.2%)	756 (9.8%)
Other or cervical collar	65 (53.3%)	2,155 (27.9%)

SMR restriction categories were derived to be mutually exclusive. Rigid long board or vacuum mattress was identified first, then other SMR or cervical collar. If neither form of SMR was found, the participant was determined to be clinically cleared with no SMR. Projected SMR categories were determined by the tiered recommendation from the clinical prediction rule.

characteristics observed between our enrolled and missed subjects and our overall large sample size.

CONCLUSION

The application of the PECARN CSI prediction rule based on EMS clinician observations in a cohort of children experiencing blunt trauma had acceptable accuracy. Future directions should include exploring whether the prediction rule can be improved if primarily derived using EMS clinician observations. The PECARN CSI prediction rule has the potential to identify children in the prehospital setting at risk for CSI who warrant the application of SMR for trauma transport and for destination determination in injured children. Applying this rule may reduce the number of children who receive prehospital SMR unnecessarily while still identifying children with CSI who may benefit from SMR. Future prehospital implementation studies are needed to assess the population impact of the prehospital application of the PECARN CSI prediction rule.

AUTHORSHIP

L.R.B., C.E.W., M.H., J.C.L. participated in the study concept and design. L.R.B., C.E.W., K.M.A., F.A.A., R.B., P.P.C., D.J.G., N.E.W., N.K., L.K.E., L.K.L., J.R.L., S.O., L.C.R., A.J.R., D.M.R., R.E.S., M.A.Z., L.T., K.Y., J.C.L. participated in the acquisition of the data. L.R.B., C.E.W., M.H., L.J.C., J.C.L. participated in the analysis and interpretation of the data. L.R.B., C.E.W., J.C.L. participated in the drafting of the article. L.R.B., C.E.W., K.M.A., F.A.A., R.B., P.P.C., D.J.G., N.E.W., N.K., L.K.E., L.K.L., J.R.L., S.O., L.C.R., A.J.R., D.M.R., R.E.S., M.A.Z., L.T., K.Y., J.C.L. participated in the critical revision of the article for important intellectual content. M.H., L.J.C. participated in the statistical expertise. J.C.L. participated in the acquisition of funding.

DISCLOSURE

Conflicts of Interest: All Journal of Acute Care and Trauma Disclosure Forms have been supplied and are provided as supplemental digital content (<http://links.lww.com/TA/E748>).

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