Derivation & Validation of a Pediatric Cervical Spine Injury Prediction Rule

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Disclosures

- Project supported by Eunice Kennedy Shriver National Institute of Child Health & Human Development 5R01HD091347 *Development and Testing of a Pediatric Cervical Spine Injury Risk Assessment Tool*
- PECARN supported by the Health Resources and Services Administration (HRSA) of the U.S. Department of Health and Human Services (HHS), in the Maternal and Child Health Bureau (MCHB), under the Emergency Medical Services for Children (EMSC) program through the following cooperative agreements: DCC-University of Utah (UJ5MC30824), GLEMSCRN-Nationwide Children's Hospital (U03MC28844), HOMERUN-Cincinnati Children's Hospital Medical Center (U03MC22684), PEMNEWS- Columbia University Medical Center (U03MC00007), PRIME-University of California at Davis Medical Center (U03MC00001), CHaMP node- State University of New York at Buffalo (U03MC33154), WPEMR- Seattle Children's Hospital U03MC33156), and SPARC- Rhode Island Hospital/Hasbro Children's Hospital (U03MC33155). This information or content and conclusions are those of the author and should not be construed as the official position or policy of, nor should any endorsements be inferred by HRSA, HHS or the U.S. Government

Patient Encounter

- 16 year-old female boarding school student in Hawaii, had just won her track state championship and was going to the beach with friends to celebrate. Involved in a highway speed motor vehicle crash. Thrown out of car into a median and paralyzed. EMS ground scene response with air transport to the University of Washington

Clinical Scenario: Cervical Spine Injury

- Rare event
- Common interventions
  - Spinal motion restriction
  - Radiographic clearance
- Efficacy of interventions unknown
- Adverse effects of intervention
  - Mispositioning
  - Pain
  - Radiation exposure
  - Cancer

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Potential Adverse Effects of Spinal Motion Restriction in Children

TABLE 2. Effects of Spinal Immobilization in Children

	Spine-Immobilized Prior to Evaluation ($n = 173$)	Not Spine-Immobilized but Met ACS Guidelines for Spinal Immobilization ($n = 112$)	Odds Ratio/ Hazard Ratio (95% CI)
Pain score—median (range)	3 (0–4)	2 (0–4)	2.2 (1.4–3.4)*
Cervical spine imaging, % (95% CI)†	56.6 (49.0–64.2)	13.4 (7.6–21.1)	8.2 (4.5–15.4)‡
ED length of stay—median (range), hours	2.8 (0.3–15.1)	2.8 (0.3–10.8)	0.96 (0.76–1.2)
ED disposition, % (95% CI)			
Home	58.4 (50.7–65.8)	85.7 (77.8–91.6)	*Reference*
Floor or transfer	31.8 (24.9–39.3)	11.6 (6.3–19.0)	4.0 (2.1–7.8)‡
ICU or OR	9.8 (5.8–15.3)	2.7 (0.6–7.6)	5.3 (1.5–19.0)*

*$p < 0.05$.
†Adjusted for Glasgow Coma Scale (GCS) score.
‡$p < 0.0001$.
ACS = American College of Surgeons; CI = confidence interval; ED = emergency department; ICU = intensive care unit; OR = odds ratio.

Leonard JC, Mao J, Jaffe D. Prehospital Emergency Care, 2012

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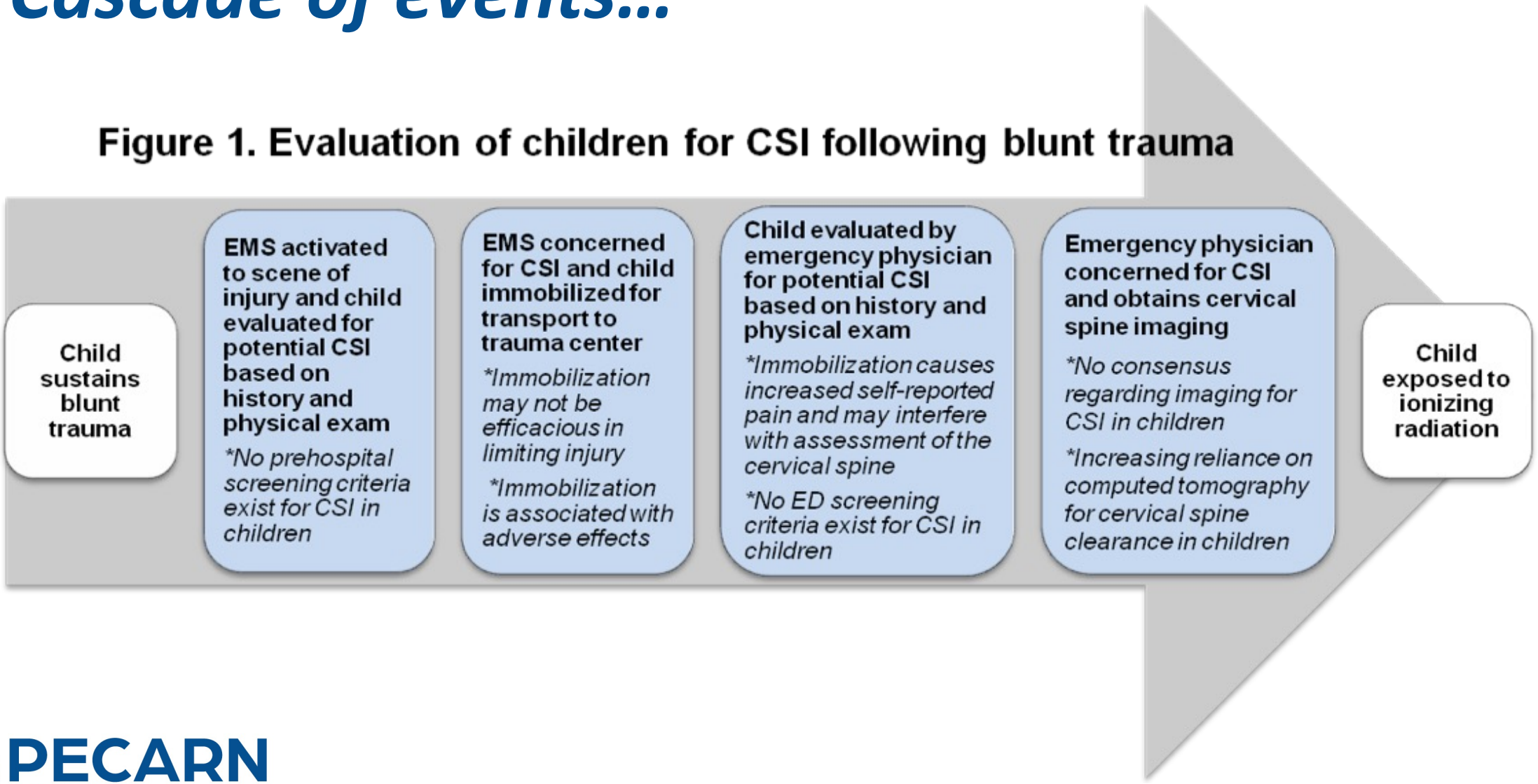
Cascade of events…

Figure 1. Evaluation of children for CSI following blunt trauma



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The Pediatric Emergency Care Applied Research Network (PECARN)

- Funded through DHHS/HRSA/MCHB EMSC for Children since 2001
- 18 Pediatric Children's Hospitals emergency departments
  - Over 1.1 million visits
  - 9 affiliated EMS agencies
- Trauma care
  - Clinical decision support
    - PECARN head and abdomen rules
    - C-spine injury study group
      - HRSA
      - NIH

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Factors Associated With Cervical Spine Injury in Children After Blunt Trauma

Leonard et al. Annals of Emergency Medicine. 2011;58(2):145-55

HRSA/MCHB EMSC Targeted Issues Grant: (1H34MC04372-01-00) "Predicting Cervical Spine Injury in Children"

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Objective

To identify risk factors associated with CSI in children after blunt trauma

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Study Methods

- Retrospective case-control study
- Five years: 2000-2004
- 17 PECARN sites
- 540 children with cervical spine injury
- Multiple control groups (random and matched) of children without cervical spine injury

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Results

CSI Risk Factor	Adjusted Odds-Ratio (95% CI)
Altered Mental Status	3.0 (2.1, 4.3)
Focal Neurological Findings	8.3 (5.6, 12.2)
Complaint of Neck Pain	3.2 (2.3, 4.4)
Torticollis	1.8 (1.1, 2.9)
Substantial Co-morbid Injury: Torso	1.9 (1.1, 3.4)
Predisposing Condition	15.0 (2.9, 78.0)
High Risk Mechanism: MVC	2.5 (1.8, 3.6)
High Risk Mechanism: Diving	73.0 (9.6, 555.6)

Age-stratified models

	All patients	<2 years	2-7 years	8-15 years
Age-specific model:				
Sensitivity	95% (93-97)	67% (45-84)	98% (94-100)	96% (94-98)
Specificity	32% (29-35)	91% (83-96)	30% (24-35)	24% (21-28)
Original model:				
Sensitivity	98% (96-99)	96% (81-100)	99% (95-100)	98% (96-99)
Specificity	26% (23-29)	54% (43-64)	28% (23-34)	21% (17-24)

Screening by Plain Radiograph for Cervical Spine Injury in Children

- PECARN
  - 2 views: AP and Lateral
  - Sensitivity 90% (CI 85-94%)
- Three smaller studies report sensitivities between 90-98%

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Utility of plain radiographs in detecting traumatic injuries of the cervical spine in children. Pediatr Emerg Care 2012;28.
Use of Plain Radiography to Screen for Cervical Spine Injuries; Annals of Emerg. Med 38(1): 1-7, 2001.

Pilot study to develop a Pediatric Cervical Spine Injury Risk Assessment Tool

Eunice Kennedy Shriver National Institute of Child Health & Human Development of the National Institutes of Health R21HD076108

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Objective

To determine the test accuracies of previous retrospectively-identified risk factors for CSI in children in a prospective cohort as a prerequisite to developing a pediatric risk assessment tool

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Rates of Cervical Spine Imaging During ED Evaluation and Hospital Admission

Intervention	Reported by ED Provider at Time of Initial Evaluation	Observed on Medical Record Review	PECARN Model[a]	De Novo Model[b]
Any imaging	2723 of 4091 (66.6%)	3201 of 4091 (78.2%)	2253 of 4091 (55.1%)[c]	2066 of 4091 (50.5%)[c]
CT scan	437 of 4091 (10.7%)	648 of 4091 (15.8%)	306 of 4091 (7.5%)[d]	289 of 4091 (7.1%)[d]

Open in a separate window

[a]Model including only those variables identified in the PECARN retrospective case-control study.

[b]Model created by using stepwise forward variable selection.

[c]Estimated by applying model to entire cohort, with the presence of any risk factor indicating need for imaging, and all no indicating imaging unneeded.

[d]Estimated by applying the model to those that had the CT in the cohort, with the presence of any risk factor indicating need for the CT and absence of all risk factors indicating CT unneeded.

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Leonard JC, Browne LR, Ahmad FA, Schwartz H, Wallendorf M, Leonard JR, Lerner EB, Kuppermann N. Cervical Spine Injury Risk Factors in Children With Blunt Trauma. Pediatrics. 2019 Jul;144(1):e20183221.

TABLE 3

Model Performance

	PECARN Model[a] ($N = 4091$)			De Novo Model[b] ($N = 4091$)		
	Any 1 Risk Factor	No Risk Factors[c]	Value (95% CI)	Any 1 Risk Factor	No Risk Factors[c]	Value (95% CI)
CSI present	67	7	—	68	6	—
CSI absent	2186	1831	—	1998	2019	—
Sensitivity	—	—	90.54% (83.87%–97.21%)	—	—	91.89% (85.7%–98.11%)
Specificity	—	—	45.58% (44.04%–47.12%)	—	—	50.26% (48.72%–51.81%)
Positive predictive value	—	—	2.97% (2.27%–3.68%)	—	—	3.29% (2.52%–4.06%)
Negative predictive value	—	—	99.62% (99.34%–99.90%)	—	—	99.71% (99.47%–99.94%)
Positive likelihood ratio	—	—	1.66 (1.54–1.80)	—	—	1.85 (1.71–1.99)
Negative likelihood ratio	—	—	0.21 (0.10–0.42)	—	—	0.16 (0.07–0.35)

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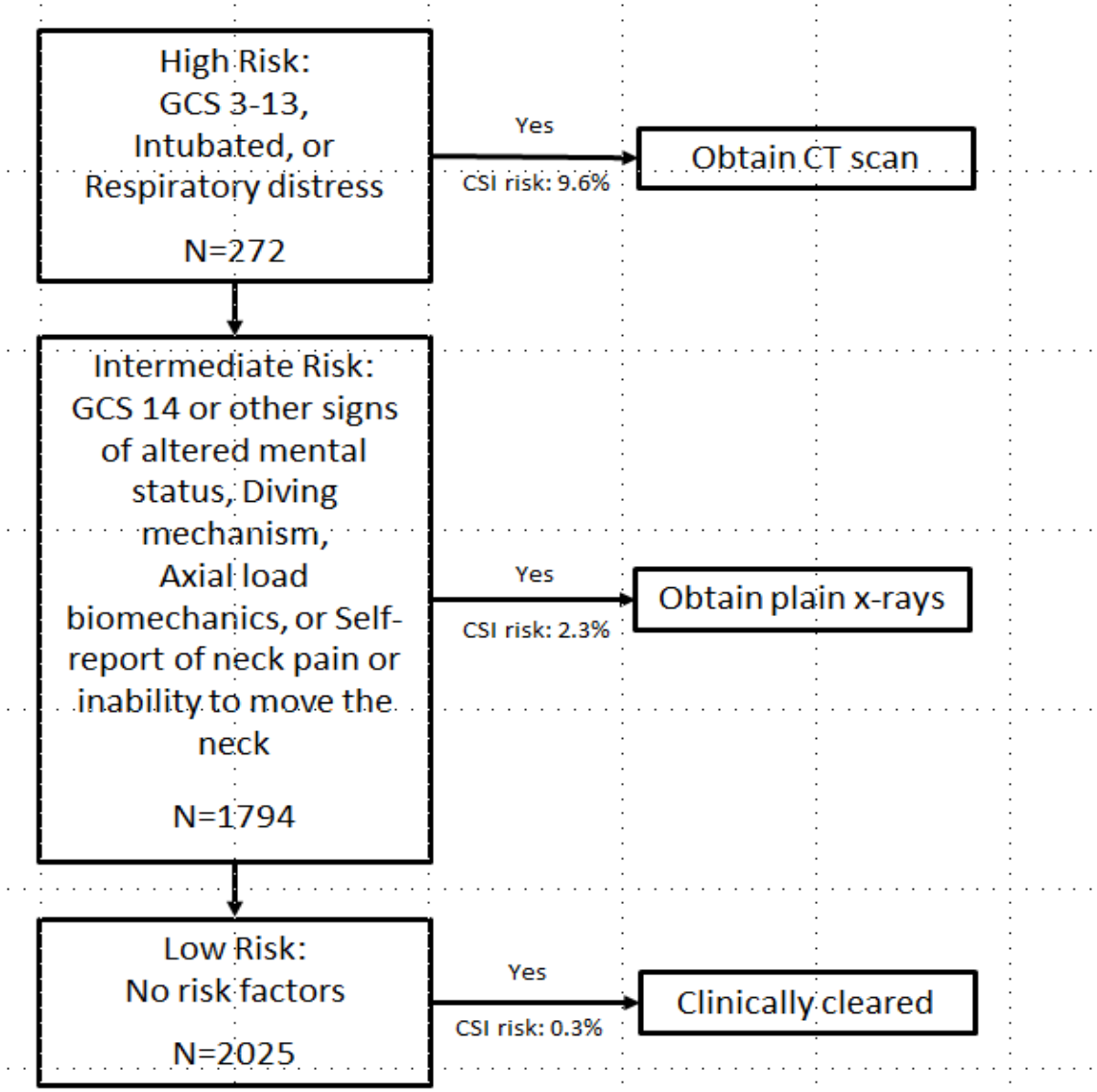

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Position Statement

EMS Spinal Precautions and the Use of the Long Backboard

National Association of EMS Physicians and American College
of Surgeons Committee on Trauma

PREHOSPITAL EMERGENCY CARE 2013;17:392–393

ACEP Position Statement

Clinical & Practice Management

Clinical Policies

Policy Statements

EMS Management of Patients with Potential Spinal Injury

Approved by the ACEP Board of Directors January 2015

Related Links

Policy Statements

» Pedestrian Injury Prevention

» Emergency Medicine

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Joint Position Statement

Spinal Motion Restriction in the Trauma Patient

Originally approved February 2018, replacing the following rescinded policy statement:

- **EMS Management of Patients with Potential Spinal Injury (2015-2018)**

A joint policy statement of the American College of Emergency Physicians, the American College of Surgeons Committee on Trauma, and the National Association of EMS Physicians

Used by permission from *Prehospital Emergency Care*

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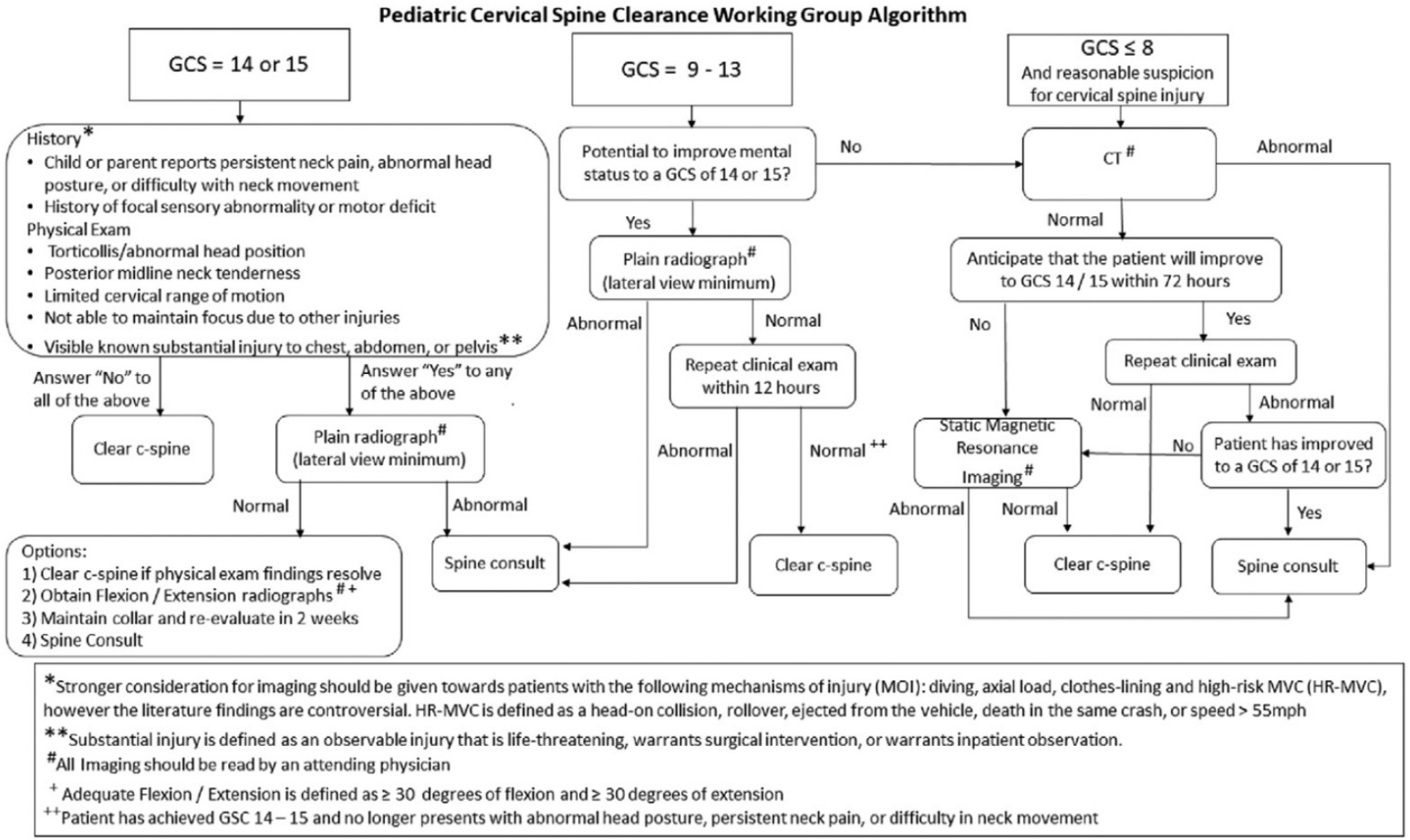

Fig. 1

The PCSCWG algorithm. C-spine = cervical spine.

Disclaimer

- Preliminary results
- Presented in Abstract form at the AAP & PTS

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Purpose

- Derive and validate a clinical decision rule for cervical spine imaging after blunt trauma in children

Methods

Study design: Prospective observational study

Setting: 18 pediatric EDs within PECARN

Study period: 12/12/2018 through 12/31/2021

Population: Children ages 0-17 years who experienced blunt trauma

- Inclusion criteria: Underwent trauma team evaluation, EMS scene response and/or cervical spine imaging
- Exclusion criteria: Exposed to solely penetrating trauma

Methods

Data collection:

- REDCap® survey of ED providers after completion of their trauma evaluation
- Medical record review for cervical spine imaging
- Parental phone call if no imaging obtained

Methods

Data elements:

- Mechanism of injury
- Injury biomechanics- axial load or clothes-lining
- History of loss of consciousness
- Self-reported neck pain
- Self-reported difficulty moving neck
- Self-reported paresthesia, numbness or weakness
- Conditions predisposing to CSI

Methods

- Abnormal airway, breathing and/or circulation
- Altered mental status (GCS and AVPU)
- Substantial regional injuries*
  - Head
  - Torso (thorax, abdomen, spine, and pelvis)
- Neurological deficits (paresthesia, numbness or weakness)

**Injuries that warrant inpatient observation or surgical intervention*

Methods

Comparison groups:

- CSIs vs. no CSIs
- Determined by review of the cervical spine imaging with spine surgeon confirmation
- For those without imaging, structured interview of parents used to determine injury status

Methods

Data Analysis:

A classification rule was constructed using the derivation cohort by

1. Evaluating the association of individual variables with CSI and retaining those with Chi- square p-values <0.15 for subsequent modeling
2. Selecting a clinically sensible subset of variables that identified patients whose risk of CSI exceeded 10% as verified with logistic regression odds ratios
3. Completing a classification and regression tree (CART) analysis on low-risk participants using the remaining variables

Methods

Data Analysis:

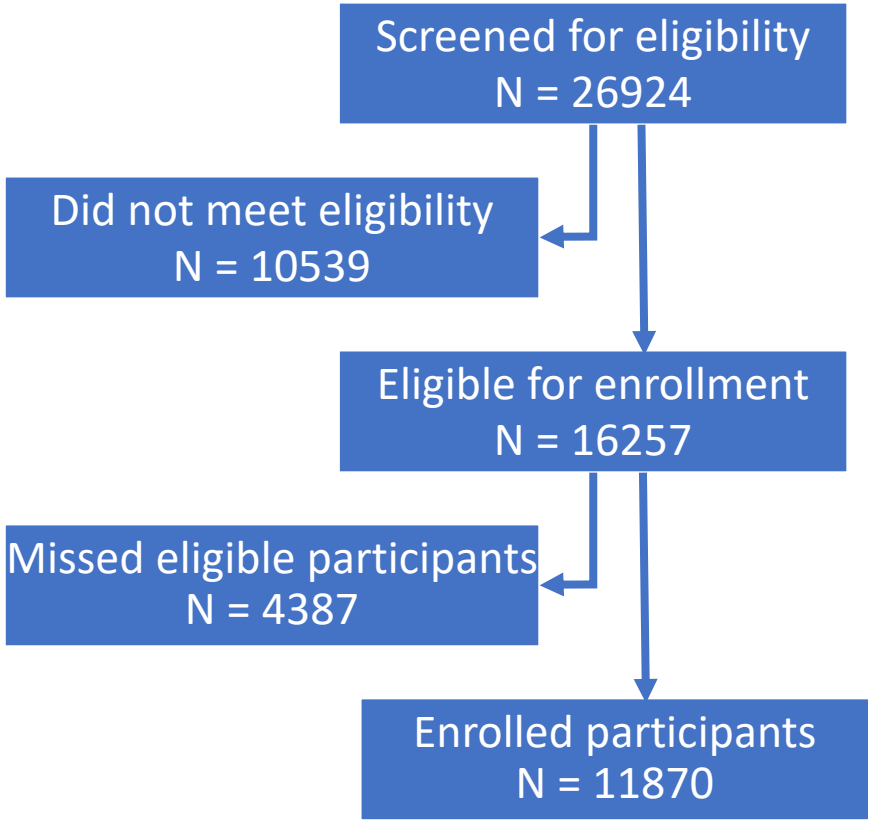
- Measures of test performance (sensitivity, specificity, positive predictive value, and negative predictive value)
- Descriptive statistics
  - Cohort characteristics
  - Children with CSI missed by the rule
  - Projected imaging rates if rule applied to the cohort

Methods

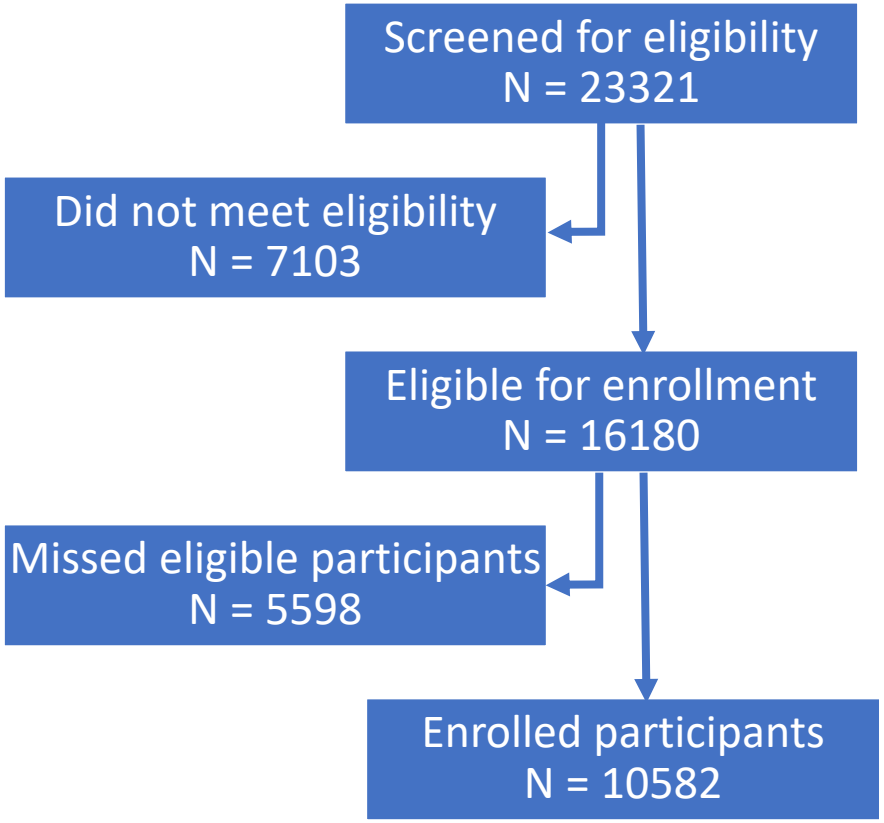
Human subjects:

- Central IRB
- Waiver of informed consent for prospective observational data collection and medical record review
- Verbal consent after mail notification for phone follow-up

Results



Derivation Cohort



Validation Cohort

Results

Characteristics for study population	Enrolled (N = 22452)	Missed (N = 9985)
Age, median (IQR)	8.0 [2.0, 13.0]	7.0 [2.0, 13.0]
Female, n (%)	9373 (41.7%)	4190 (42.0%)
Race: White, n (%)	10919 (48.6%)	4846 (48.5%)
Race: Black, n (%)	6800 (30.3%)	2889 (28.9%)
Race: Other, n (%)	3541 (15.8%)	1648 (16.5%)
Ethnicity: Hispanic, n (%)	4335 (19.3%)	2194 (22.0%)
MOI: MVC, n (%)	6363 (28.3%)	2718 (27.2%)
MOI: Fall, n (%)	7451 (33.2%)	3431 (34.4%)
MOI: Sports, n (%)	2189 (9.7%)	1066 (10.7%)
ED Disposition: ICU, n (%)	1614 (7.2%)	716 (7.2%)
ED Disposition: OR, n (%)	618 (2.8%)	279 (2.8%)
CSI, n (%)	434 (1.9%)	148 (1.5%)

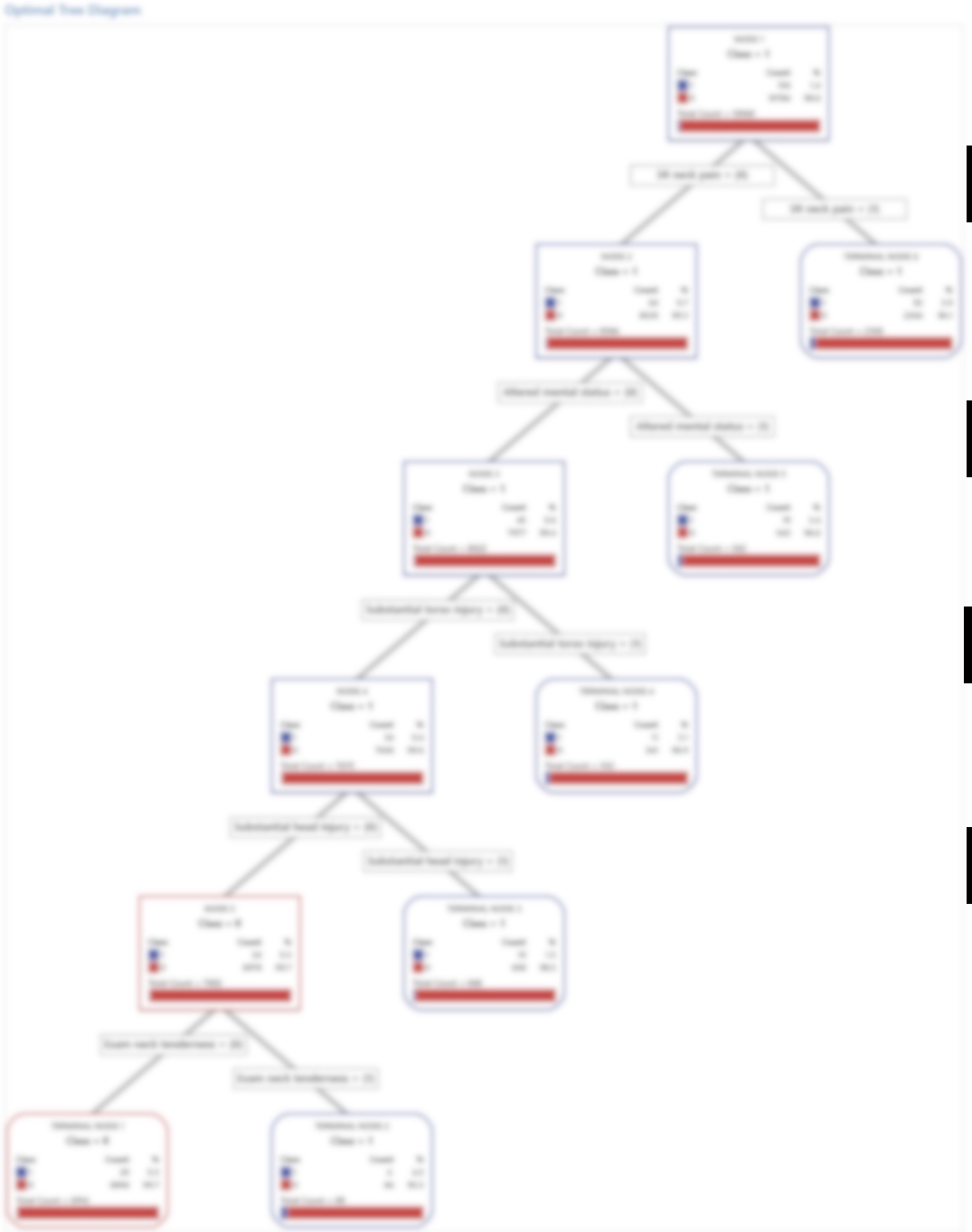
Results

Characteristic	Derivation N=11870	Validation N=10058
Age, median (IQR)	8.0 [2.0, 13.0]	8.0 [3.0, 13.0]
Female, n (%)	5010 (42.2%)	4363 (41.2%)
Race: White, n (%)	6480 (54.6%)	4439 (41.9%)
Race: Black, n (%)	2695 (22.7%)	4105 (38.8%)
Race: Other, n (%)	1889 (15.9%)	1652 (15.6%)
Ethnicity: Hispanic, n (%)	1714 (14.4%)	2621 (24.8%)
MOI: MVC, n (%)	3131 (26.4%)	3232 (30.5%)
MOI: Fall, n (%)	3902 (32.9%)	3549 (33.5%)
MOI: Sports, n (%)	1332 (11.2%)	857 (8.1%)
Mode of Arrival: EMS, n (%)	6881 (58.0%)	6748 (63.8%)
ED Disposition: ICU, n (%)	1078 (9.1%)	536 (5.1%)
ED Disposition: OR, n (%)	384 (3.2%)	234 (2.2%)
CSI, n (%)	274 (2.3%)	160 (1.5%)

Results

High Risk Variables	CSI Yes; n (%)	CSI No; n (%)	Univariable ORs with 95% confidence intervals
[redacted]	123 (28.3%)	399 (1.8%)	21.43 (16.97, 26.94)
[redacted]	81 (18.7%)	259 (1.2%)	19.28 (14.64, 25.17)
[redacted]	148 (34.1%)	835 (3.8%)	13.13 (10.62, 16.17)
[redacted]	53 (12.2%)	554 (2.5%)	5.39 (3.95, 7.21)
Any of the above	187 (43.1%)	1365 (6.2%)	11.46 (9.39, 13.95)

Results



[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

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Results

Statistics for combined variable set	Derivation Cohort % (95% Confidence Interval)	Validation Cohort % (95% Confidence Interval)
Sensitivity	92.7 (89.6-95.8)	93.8 (90.0-97.5)
Specificity	59.5 (58.6-60.4)	60.4 (59.4-61.3)
Positive Predictive Value	0.05 (0.04-0.06)	0.04 (0.03-0.04)
Negative Predictive Value	99.7 (99.6-99.8)	99.8 (99.7-99.9)

Results

- **30** children with CSI missed by ED provider observations
  - On medical record review, **18** had one or more of the rule's risk factors
  - An additional **3** had risk factors observed by an EMS or surgical provider
- None of the children missed by ED provider observations required surgical intervention

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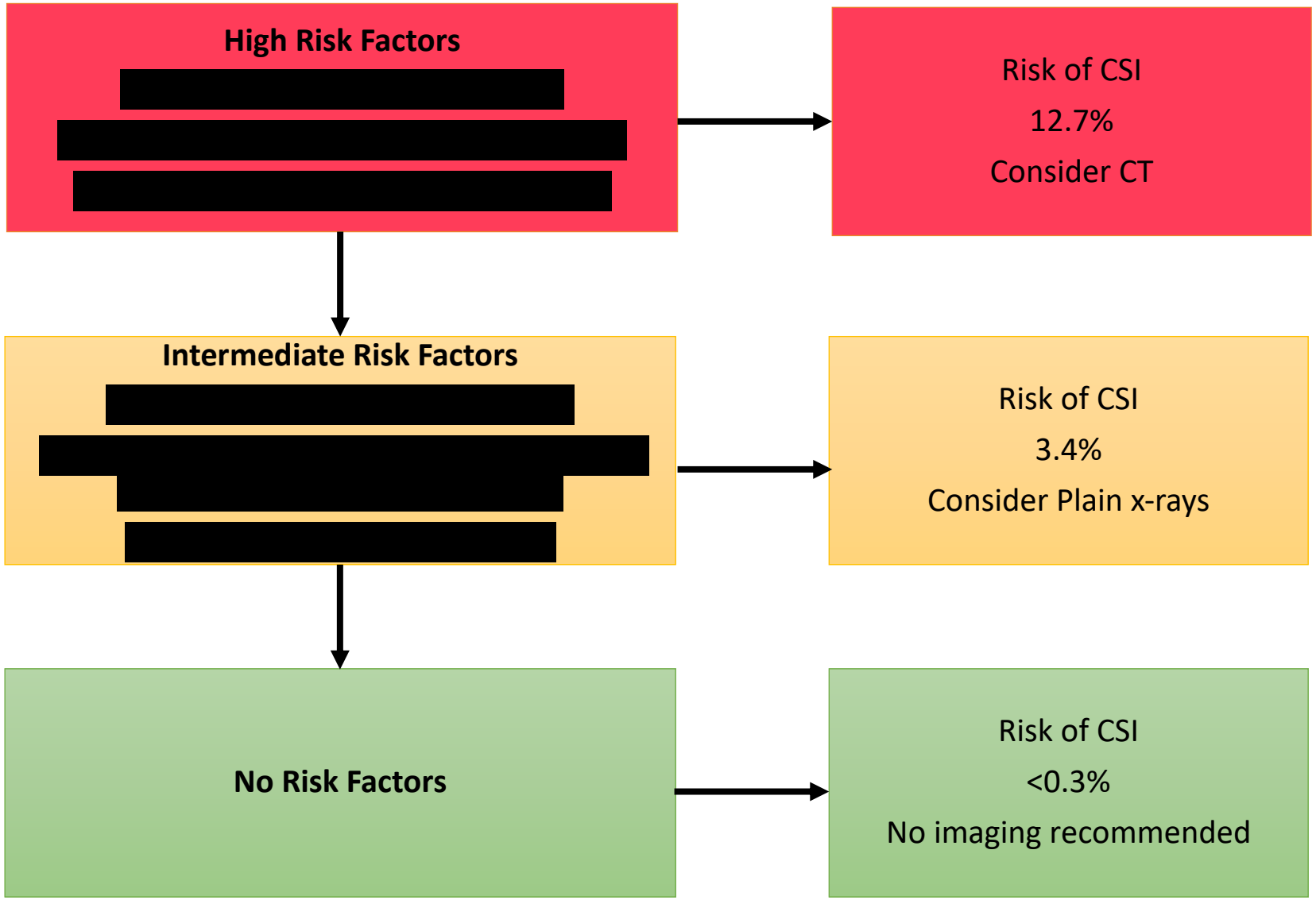
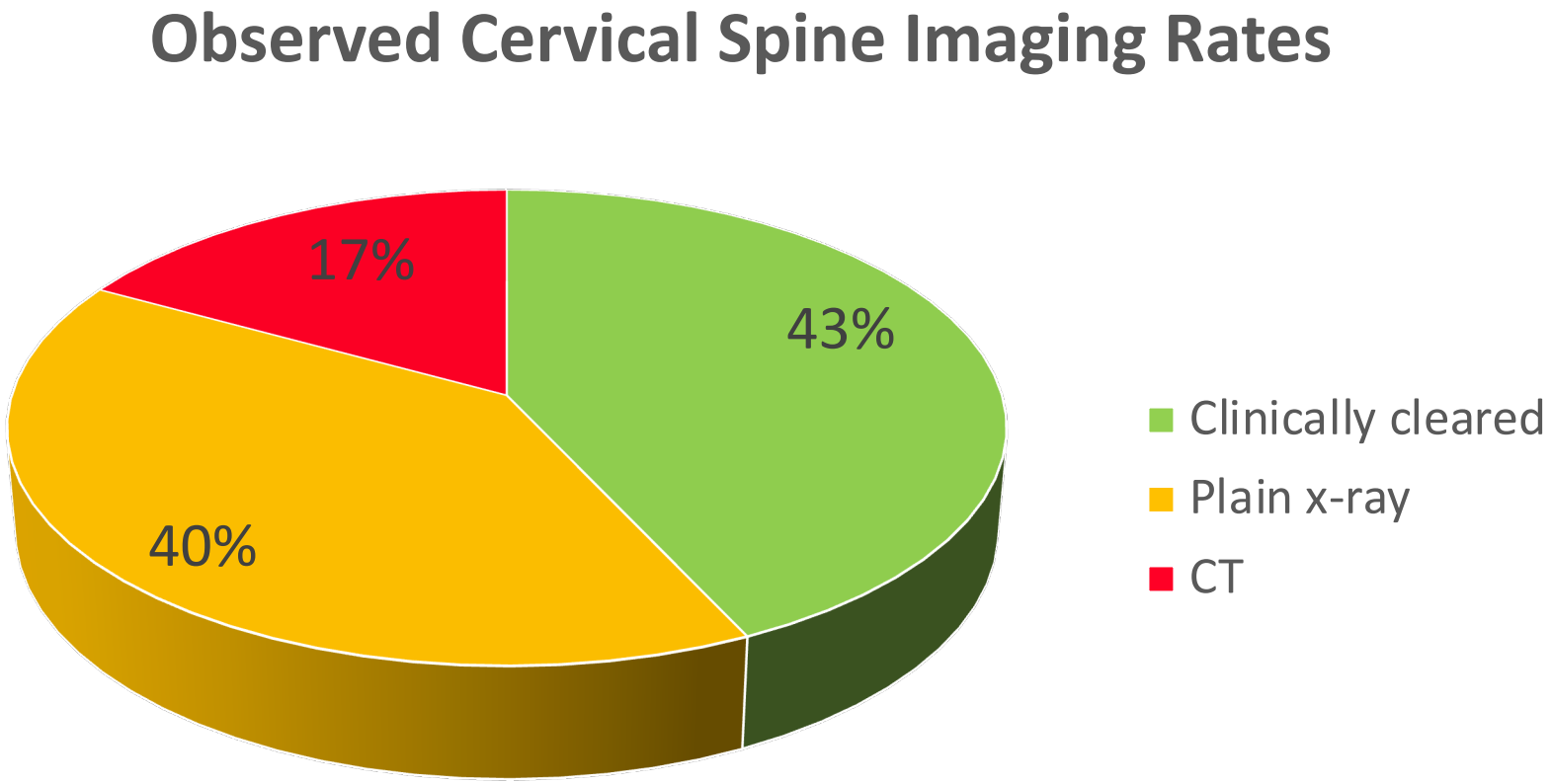
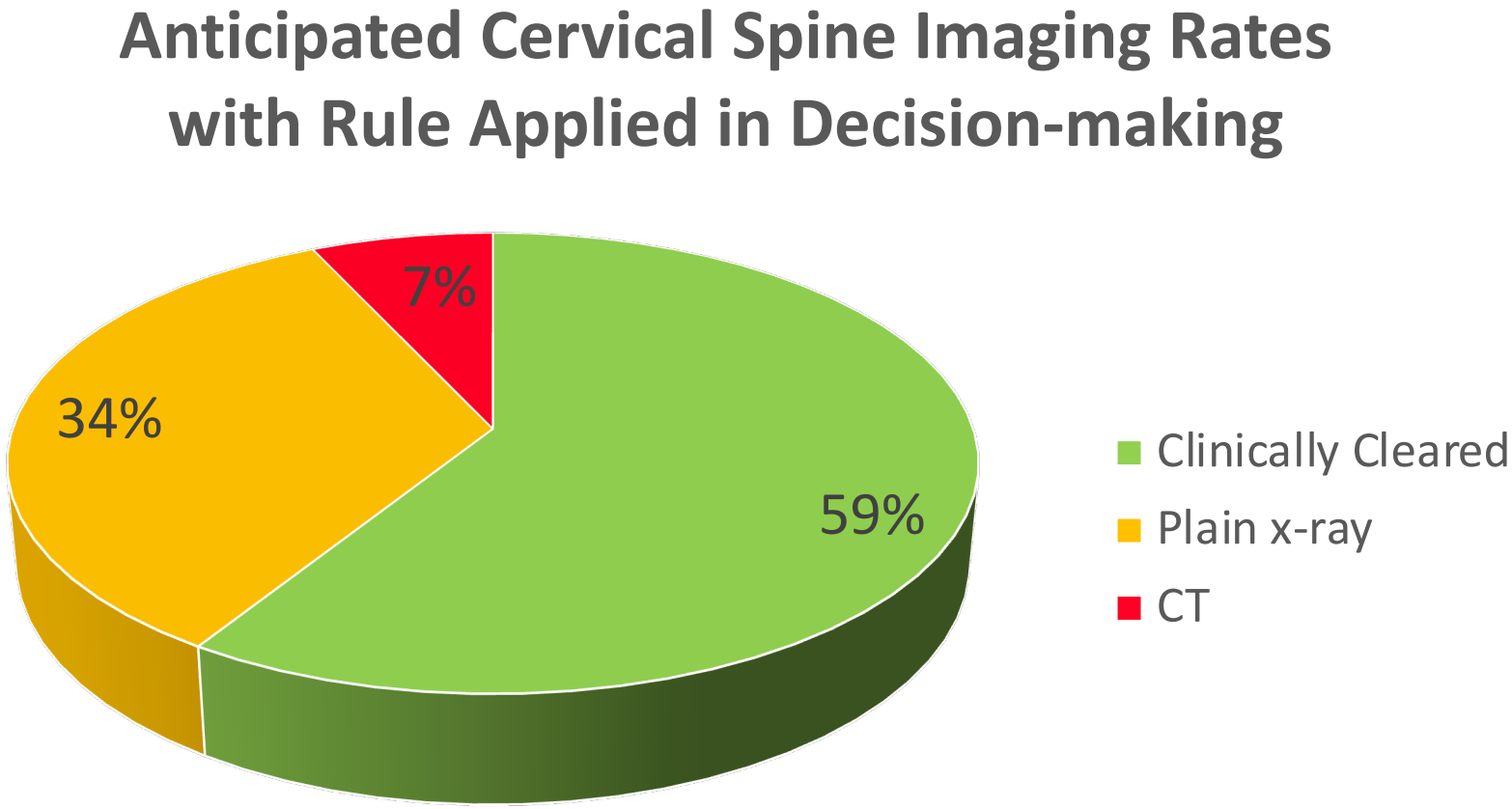
Results


High Risk Factors
[redacted]
Risk of CSI
12.7%
Consider CT
Intermediate Risk Factors
[redacted]
Risk of CSI
3.4%
Consider Plain x-rays
No Risk Factors
Risk of CSI
<0.3%
No imaging recommended

Results


Observed Cervical Spine Imaging Rates
17%
43%
40%
Clinically cleared
Plain x-ray
CT

Results


Anticipated Cervical Spine Imaging Rates with Rule Applied in Decision-making
7%
34%
59%
Clinically Cleared
Plain x-ray
CT

Conclusions

- The PECARN CSI prediction rule has sufficient discriminatory power to be used to guide imaging decision-making
- When used appropriately, the PECARN CSI rule has the potential to reduce overall imaging by 25%
- Importantly, cervical spine CT rates could be cut in half
- Future directions include…
  - ED-based implementation trial that included community sites
  - Validation of the prediction rule using EMS observations

Co-investigators

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- CS Mott Children's Hospital
- Texas Children's Hospital
- Primary Children's Hospital
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- Children's Medical Center of Dallas
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