Journal of Pediatric Surgery 56 (2021) 293–296

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Trauma

Pediatric cervical spine injury in the United States: Defining the burden of injury, need for operative intervention, and disparities in imaging across trauma centers☆

Woihwan Kim [a], Nicholas Ahn [a], Ashar Ata [a], Matthew A. Adamo [b], Pouya Entezami [b], Mary Edwards [c,*]

[a] Department of Surgery, Albany Medical Center, Albany, NY
[b] Department of Surgery, Division of Neurosurgery, Albany Medical Center, Albany, NY
[c] Department of Surgery, Division of Pediatric Surgery, Albany Medical Center, Albany, NY

ARTICLE INFO

Article history:
Received 10 March 2020
Received in revised form 17 April 2020
Accepted 3 May 2020

Key words:
Pediatric
Blunt trauma
Cervical spine injury
Spinal trauma
CT scan

ABSTRACT

Background: Pediatric cervical spine injury (PCSI) in children is rare. Incidence of PCSI requiring intervention is not known, and imaging practices for screening in United States trauma centers are not well described.
Methods: The 2016 NTDB was queried for patients younger than 15 years with PCSI. Incidence of PCSI, operative interventions, and imaging rates were analyzed by age and ACS accreditation status.
Results: Of 84,554 children, 873 (1.03%) had PCSI. Patients <4 years were less likely to have PCSI (0.68% vs. 1.1%, RR 0.59, $p < 0.001$). 165 children (0.20%) required an intervention for PCSI. 12.8% of all children were screened for PCSI with imaging, 9.3% with CT, and 3.2% with plain X-rays.
In spite of similar injury and intervention rates, stand-alone pediatric trauma centers were less likely than others to image patients without PCSI (11% vs. 13% $p < 0.001$), less likely to utilize CT scan (5.8% vs. 10.6% $p < 0.001$) and more likely to utilize plain films (5.2% vs. 2.4% $p < 0.001$).
Conclusion: Despite exceedingly low rates of PSCI requiring intervention (0.2%), imaging rates for screening are significant. Stand-alone pediatric trauma centers outperform others in limiting unnecessary imaging.
Level of evidence: IV.

Screening for blunt pediatric cervical spine injuries (CSIs) in children continues to be a vexing problem for many clinicians. It is well established that these injuries are uncommon with a reported incidence to be between 0.5% and 3% of trauma admissions to most pediatric trauma centers [1–5]. However, concern that failure to diagnose and properly motion restrict a patient with CSI on the initial trauma evaluation may worsen neurologic injury with permanent sequela often results in a propensity for liberal imaging [6–8]. While quick and diagnostically useful, excess use of computed tomography of the cervical spine (CTCS) in the pediatric population is problematic not only because of harmful radiation effects long-term [9,10], but also because of false positive findings owing to anatomic variations [11–13]. Various algorithms and risk tools have been developed [14–19], but there remains no universally accepted guideline for risk stratification and optimal imaging practice for pediatric patients deemed at risk for blunt CSI.

Furthermore, the frequency and modality of cervical spine imaging in patients with concerning mechanism are unknown. Further elucidation of these practices may help shed light on the efficacy and need for imaging. Finally, it is unclear how often pediatric trauma patients diagnosed with a CSI ultimately require an intervention other than collar support and analgesia.

Given the increased granularity of ICD10 codes specific to CSI and imaging, we analyzed the 2016 National Trauma Data Bank (NTDB) set to determine the incidence of pediatric CSI United States, and the need for operative intervention for these injuries. We investigated the frequency of various imaging modalities utilized to screen for CSI. Finally, we determined the impact of trauma center designation and preverbal age of the patient (less than 4 years) on intervention and imaging utilization.

1. Methods

Our study population consisted of trauma patients younger than 15 years in the 2016 NTDB data set who sustained a CSI from a nonpenetrating injury. We defined CSI under the 10th revision of the International Classification of Diseases (ICD-10) as codes starting with S12, S13, or S14 (fractures, dislocations, spinal cord injuries, respectively) and

☆ This paper was presented in Abstract form at the November 2019 Meeting of the Western Surgical Association in Las Vegas, NV.

* Corresponding author at: 50 New Scotland Ave, Albany, NY 122008. Tel.: +1 808 780 7412.
E-mail address: Edwardm2@amc.edu (M. Edwards).

https://doi.org/10.1016/j.jpedsurg.2020.05.009
0022-3468/

Table 1
Demographics, clinical findings and outcomes.

	Pediatric blunt trauma			Cervical spine injured		
	No CSI	CSI	p	No intervention	Intervention	p
# Patients	83,681	873	-	708	165	-
Age (mean years)	7.3	8.8	< 0.0001	9.0	8.8	0.0063
Male (%)	62.3	60.5	0.481	61.2	57.6	0.397
GCS total (mean)	14.4	11.2	< 0.0001	11.1	11.4	0.6301
GCS eye (mean)	3.8	3.0	< 0.0001	3.0	3.1	0.7429
GCS verbal (mean)	4.7	3.7	< 0.0001	3.6	3.7	0.5289
GCS motor (mean)	5.8	4.5	< 0.0001	4.5	4.6	0.4810
Mortality, arrival (%)	0.41	5.7	< 0.001	17.0	3.6	< 0.001
Mortality, in-hospital (%)	0.50	8.71	< 0.001	7.1	0	< 0.001
ISS (mean)	6.08	19.6	< 0.0001	19.3	21.0	0.2518
Length of stay (mean days)	2.3	7.0	< 0.0001	4.8	16.1	< 0.0001
% Requiring ICU	12.9	48.5	< 0.001	41.4	78.8	< 0.001
% Requiring ventilation	4.2	30.5	< 0.0001	27.5	43.0	< 0.001

excluded muscle strain, and soft tissue sprains of joints and ligaments. Procedural ICD-10 codes were analyzed to tabulate operative interventions performed. Diagnostic imaging rates were obtained by analyzing procedural ICD-10 codes for plain radiography (BR00*x*, BR01*x*), CT (BR20*x*), and MRI (BR30*x*, BR31). We further stratified our study population by preverbal (less than 4 years old) age and older; trauma accreditation level; and institution type (stand-alone pediatric vs. adult/combined). If an institution was accredited in both adult and pediatric trauma, we classified it under the adult accreditation level.

Injury rates were determined based on ICD10 codes as described above, and intervention rates were future determined based on ICD10 coding. Collar placement alone was not included as an intervention. Chi-squared and Poisson regression analyses were performed for statistical significance. The analytical software used in this study was Stata (StataCorp LLC, College Station, TX). This study was reviewed by the Institutional Review Board (IRB) at Albany Medical College and determined to be exempt.

2. Results

Out of 84,554 children aged 15 years and younger in the 2016 NTDB data set, 873 (1.03%) had a CSI (Table 1). Sixty percent were male, with a mean age of 8.8 years, and mean Glasgow Coma Score (GCS) 11.2 at presentation (Table 1). Preverbal children were significantly less likely to have CSI (0.68% vs. 1.14%, RR 0.60, $p < 0.001$) than older verbal children (Table 3). Injury rates did not vary among institution accreditation level ($p = 0.5324$).

Of the 873 children with an identified CSI, 165 required an intervention related to the cervical spine (19% of the 873 with CSI, 0.20% of the entire population). Of patients requiring intervention, 57% were male, with a mean age of 8.8 and a mean GCS of 11.4 (Table 1). Commonly associated injuries included lung (contusion, pneumothorax), head/scalp laceration, and/or intracranial bleeding (Table 2). Fifty patients with an identified CSI (5.7% of CSI) were pronounced dead on arrival. Overall mortality among those with CSI was 8.7% ($p < 0.001$) (Table 1).

Table 2
Signficant associated injuries by body region.

Significant injuries[a]	% of associated diagnoses
Head	38.3%
Chest	18.9%
Extremities	16.1%
Abdomen	13.8%
Face	6.4%
Pelvis	6.4%

[a] Signficant defined as abbreviated injury score of 3 or greater.

Injury and intervention rates are listed in Table 1. Overall, preverbal and verbal children did not differ notably in incidence of CSI requiring intervention (0.18% vs 0.20% $p = 0.005$), although this did reach statistical significance. However, when comparing children with a documented CSI, preverbal patients were significantly more likely to require an intervention than their older counterparts (RR 1.5, 95% CI 1.1 to 2.1, $p = 0.02$). Injury and intervention rates did not vary significantly by trauma accreditation status ($p = 0.6226$). Procedures performed on cervical spine injuries are listed in Table 4.

Of the 83,681 children without a documented cervical spine injury, 12.8% underwent imaging of the cervical spine. Modalities utilized were primarily CT scan (9.3% of all patients), followed by plain X-rays (3.2% of all patients) and MRI (1.4% of all patients) (Figs. 1 and 2). Designated stand-alone pediatric trauma centers were significantly less likely than other trauma centers to image patients without CSI (11% vs. 13% $p < 0.001$). When imaging uninjured patients, stand-alone pediatric trauma centers were significantly less likely than others to utilize CTCS (5.8% vs. 10.6% $p < 0.001$) and significantly more likely to utilize plain films (5.2% vs. 2.4% $p < 0.001$). Level 1 adult and pediatric trauma centers were also more likely to utilize MRI ($p < 0.001$).

3. Discussion

This comprehensive study of injured children in the United States during the year of 2016 reaffirms the very low rate of blunt injury to the cervical spine, with an overall rate of injury of 1%. Injury rates were significantly lower for children less the age of 4 years at 0.68%. The overall rates of injury significant enough to require an intervention were exceedingly low at 0.20% of the overall cohort (19% of those patients with a documented injury). Of note, although patients in the preverbal age group were less likely to be injured, they were much more likely to undergo an intervention if injured. Overall rates of CSI requiring intervention were similar between the two age groups. Although intervention and injury rates were the similar across all trauma centers, there was a significant disparity in imaging practices when evaluating for CSI. Designated pediatric trauma centers were significantly less likely to image patients that ultimately were not diagnosed with a CSI compared to adult and combined centers. In addition, stand-alone

Table 3
CSI and intevention rates as a function of age.

	Preverbal (<4 years)	Verbal	p
Patients with blunt trauma	19,702	64, 852	-
Cervical spine injury	134 (0.680%)	739 (1.14%)	< 0.001
Intervention rate for CSI	35 (26%)	130 (18%)	0.02
Intervention rate for all patients	35 (0.18%)	130 (0.20%)	0.005

Table 4
Operative interventions performed for CSI.

Procedure	# Performed	Average time to procedure (h)
Fusion of cervical structures	97	107
Reposition of cervical structures	44	141
Immobilization of cervical structures	42	69
Traction of head/neck	37	56
Excision of cervical vertebra	20	119
Supplement with tissue substitute	4	66
Replacement of cervical vertebra	4	84
Drainage of spinal structures	4	72
Release of cervical structures	3	46
Insertion of infusion device	1	301

pediatric centers were much more likely to utilize plain films as opposed to CT scans for patients without injuries.

If a CSI is identified on imaging for the very young, it can be deduced that there was an enormous amount of force involved in the trauma and implies a critical level of acuity on presentation [2,20,21]. Poorman et al. reported similar intervention rates of 20% among children with a CSI based on their retrospective review of the Kids' Inpatient Database (KID) [2]. The higher operative intervention rate for the younger preverbal children with CSI was an expected finding. It is well described that infants and young children have increased spine malleability from ossifying cartilage and elastic ligaments that prevents fracture, but at the same time leaves the spinal cord relatively unprotected to trauma. This is especially true in the atlantoaxial articulation region in younger children where their biomechanics have a more unstable nature compared to adults [21].

Despite an exceedingly low injury rate, almost 13% of all children underwent imaging of the cervical spine to screen for an injury, most commonly with CT scanning. This is despite multiple studies stating that plain films are a reasonable alternative in stable patients [14,20–21], and compelling evidence linking ionizing radiation exposure from CT to malignancy risk in children [9,10]. It is clear from these data that stand-alone pediatric trauma centers were significantly more successful in utilizing screening modalities which are not only less expensive but associated with significantly less exposure to ionizing radiation than adult and combined adult/pediatric centers. This discrepancy may be because of a relative lack of providers' confidence in the clinical evaluation of young children, and the inevitable effect of employing adult trauma practices to children in centers primarily taking care of injured adults, as utilization of CT scanning to screen for CSI is currently considered standard of care in adults suffering from blunt injury [22].

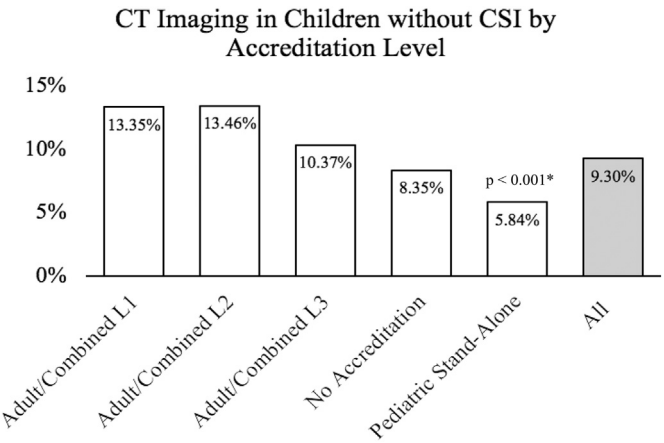

Fig. 1. Rates of CT Imaging of the cervical spine in Children without CSI by trauma accreditation level.

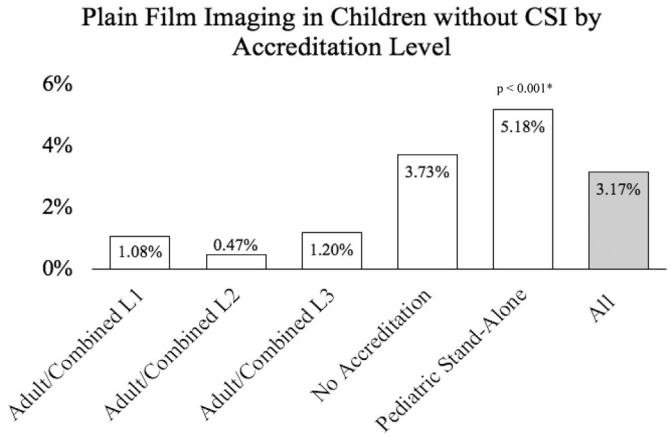

Fig. 2. Rates of plain film imaging of the cervical spine in children without CSI by trauma center accreditation level.

These findings reflect overall disparities in clinical management across U.S. trauma centers. A study surveying pediatric cervical spine clearance among 25 trauma centers showed that 46% had an established written protocol and other differences in management underscoring the variance of practice [23]. The PECARN group developed a decision support tool with high sensitivity and specificity rates to identify clinical factors highly associated with pediatric CSI in blunt trauma that was later validated prospectively [14,24]. Research data are available for the development of evidence-based practice management guidelines; however, standardization across trauma centers and adherence are formidable but necessary tasks to optimize care of injured children.

The strength of this study is in the number of injured children and in the granularity and fidelity of the NTDB data set. Unlike prior years, the 2016 set exclusively utilized the ICD10 procedure codes, which clearly document injury, interventions, and imaging specific to the cervical spine. However, given this limitation, it is impossible to stratify practices beyond the year of 2016. The purpose of this study was to document imaging practices across trauma centers and to determine contemporary injury and intervention rates for blunt CSI in children. However, as the coding in this data set was done retrospectively, these data are not useful in determining clinical factors that would predict injury, other than age, associated injuries and GCS (as described). This study does not account for imaging done at facilities prior to transfer. Therefore, it is very possible that some of the improved performance seen in imaging practices at pediatric centers may have been because of review of imaging done at other centers prior to transfer. Finally, this data set will not account for injuries that were missed prior to discharge and seen at another facility. While NTDB codes will assign injury codes retrospectively based on information obtained from all imaging, clinical and autopsy data from the contributing institution and/or injury data obtained following discharge for patients obtaining follow up at another institution will likely be lost.

4. Conclusion

Children suffering from blunt injury have an exceedingly low rate of CSI requiring intervention at 0.20%. Trauma centers liberally employ CT scan to screen for these very rare injuries. Despite similar injury and intervention rates, patients presenting to designated pediatric trauma centers are less likely to undergo unnecessary imaging of the cervical spine, and if imaged, less likely to be exposed to CT. Improved dissemination and education regarding clinical decision rules to identify children at risk for blunt CSI are necessary to alleviate this disparity in care.

Disclosures

The authors have no sources of funding or conflicts of interest to disclose.

References

[1] Shin JI, Lee NJ, Cho SK. Pediatric cervical spine and spinal cord injury: a national database study. Spine. 2016;41(4):283–92.
[2] Poorman GW, Segreto FA, Beaubrun BM, et al. Traumatic fracture of the pediatric cervical spine: etiology, epidemiology, concurrent injuries, and an analysis of perioperative outcomes using the Kids' Inpatient Database. Int J Spine Surg. 2019;13(1):68–78.
[3] Viccellio P, Simon H, Pressman BD, et al. A prospective multicenter study of cervical spine injury in children. Pediatrics. 2001;108(2):E20.
[4] Polk-Williams A, Carr BG, Blinman TA, et al. Cervical spine injury in young children: a National Trauma Data Bank review. J Pediatr Surg. 2008;43(9):1718–21.
[5] McAllister AS, Nagaraj U, Radhakrishnan R. Emergent imaging of pediatric cervical spine trauma. Radiographics. 2019;39(4):1126–42.
[6] Ohana O, Soffer S, Zimlichman E, et al. Overuse of CT and MRI in paediatric emergency departments. Br J Radiol. 2018;91:1085.
[7] Broder J, Fordham LA, Warshauer DM. Increasing utilization of computed tomography in the pediatric emergency department: 2000–2006. Emerg Radiol. 2007;14:227–32.
[8] Adelgais KM, Browne L, Holsti M, et al. Cervical spine computed tomography utilization in pediatric trauma patients. J Pediatr Surg. 2014;49:333–7.
[9] Chen JX, Kachniarz B, Gilani S, et al. Risk of malignancy associated with head and neck CT in children: a systematic review. Otolaryngol Head Neck Surg. 2014;151:554–66.
[10] Brenner DJ, Elliston CD, Hall EJ, et al. Estimated risks of radiation-induced fatal cancer from pediatric CT. Am J Roentgenol. 2001;176:289–96.
[11] Adib O, Berthier E, Loisel D, et al. Pediatric cervical spine in emergency: radiographic features of normal anatomy, variants and pitfalls. Skelet Radiol. 2016;45l:1607–17.
[12] O'Brien W, Shen P, Lee P. The dens: normal development, developmental variants and anomalies, and traumatic injuries. J Clin Imaging Sci. 2015;5. https://doi.org/10.4103/2156-7514.159565 [eCollection 2015].
[13] Lustrin ES, Karakas SP, Ortiz AO, et al. Pediatric cervical spine: normal anatomy, variants, and trauma. Radiographics. 2003;23:539–60.
[14] Leonard JC, et al. Factors associated with cervical spine injury in children after blunt trauma. Ann Emerg Med. 2011;58(2):145–55.
[15] Chung S, Mikrogianakis A, Wales PW, et al. Trauma Association of Canada pediatric subcommittee national pediatric cervical spine evaluation pathway: consensus guidelines. J Trauma. 2011;70:873–84.
[16] Arbuthnot MK, Mooney DP, Glenn IC. Head and cervical spine evaluation for the pediatric surgeon. Surg Clin N Am. 2017;97:35–58.
[17] Pieretti-Vanmarcke R, Velmahos GC, Nance ML, et al. Clinical clearance of the cervical spine in blunt trauma patients younger than 3 years: a multi-center study of the American Association for the Surgery of Trauma. J Trauma. 2009;67:543–9.
[18] Hale AT, Alvarado A, Bey AK, et al. X-ray vs. CT in identifying significant C-spine injuries in the pediatric population. Childs Nerv Syst. 2017;33:1977–83.
[19] Arbuthnot M, Mooney DP. The sensitivity and negative predictive value of a pediatric cervical spine clearance algorithm that minimizes computerized tomography. J Pediatr Surg. 2017;52:130–5.
[20] Nightingale RW, Winkelstein BA, Van Ee CA, et al. Injury mechanisms in the pediatric cervical spine during out-of-position airbag deployments. Annu Proc Assoc Adv Automot Med. 1998;42:153.
[21] Adelson AL, Pollack DP, Albright IF. Principles and practice of pediatric neurosurgery. 3d ed.. New York: Thieme; 2014; 791.
[22] Como JJ, Diaz JJ, Dunham CM, et al. Practice management guidelines for identification of cervical spine injuries following trauma: update from the Eastern Association for the Surgery of Trauma practice management guidelines committee. J Trauma. 2009;67:651–9.
[23] Pannu GS, Shah MP, Herman MJ. Cervical spine clearance in pediatric trauma centers: the need for standardization and an evidence-based protocol. J Pediatr Orthop. 2017;37:e145–9.
[24] Leonard JC, Browne LR, Ahmad FA, et al. Cervical spine injury risk factors in children with blunt trauma. Pediatrics. 2019;144. https://doi.org/10.1542/peds.2018-3221 pii: e20183221.