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Cervical Spine Imaging in Hospitalized Children with Traumatic Brain Injury

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Abstract

Objectives—In children with TBI, to describe cervical spine imaging practice, to assess for recent changes in imaging practice, and to determine if cervical spine CT is being used in children at low risk for cervical spine injury.

Methods—The setting was children's hospitals participating in the Pediatric Health Information System database, January, 2001 to June, 2011. Participants were children (age < 18 years) with TBI who were evaluated in the Emergency Department, admitted to the hospital, and received a head CT scan on the day of admission. The primary outcome measures were cervical spine imaging studies. This study was exempted from IRB review.

Results—30,112 children met study criteria. Overall, 52% (15,687/30,112) received cervical spine imaging. Use of cervical spine radiographs alone decreased between 2001 (47%) and 2011 (23%), annual decrease 2.2% (95% confidence interval [CI] 1.1–3.3%), largely replaced by increased use of CT, with or without radiographs (8.6% in 2001, 19.5% in 2011, annual increase 0.9%, 95% CI 0.1–1.8%). 2,545 children received a cervical spine CT despite being discharged alive from the hospital in < 72 hours, and 1,655 of those had a low-risk mechanism of injury.

Conclusions—The adoption of CT clearance of the cervical spine in adults appears to have influenced the care of children with TBI, despite concerns about radiation exposure.

Keywords

Pediatrics; Craniocerebral Trauma; Spinal Cord Injuries; Neck Injuries

INTRODUCTION

Cervical spine injury (CSI) is estimated to be present in 1–2% of children(1–4) and 2–3% of adults(5) after blunt trauma and is associated with mortality, poor functional outcomes, and high costs.(6) Cervical spine precautions are the standard for pre-hospital and hospital care of children with trauma until “clearance” of the cervical spine.(7)

Clearance of the cervical spine can be achieved via a physical examination, imaging studies, or a combination.(7–10) Despite the low injury rate, imaging to assess for CSI is common in children with blunt trauma.(11) Plain radiographs were recommended in a 2002 guideline(8) as the initial imaging study for children not able to be clinically cleared. A 2013 update to that guideline recommends plain radiographs or computed tomography (CT) in such patients.(12)

A 2012 report suggests that plain radiographs identify cervical spine injuries in children with 90% sensitivity.(13) Because of excellent sensitivity for spinal column injuries (98–99%), cervical spine CT scanning has become the preferred primary imaging study in adults with trauma.(10) Cervical spine CT use in injured children is increasing.(11, 14) Unfortunately, CT scanning of the cervical spine exposes the head and neck, particularly the thyroid gland, to ionizing radiation.(15–17)

Children hospitalized for traumatic brain injury (TBI) may not qualify for immediate clinical cervical spine clearance because of altered mental status from their injury or sedatives and/or neuromuscular blockade. The most efficient time to obtain cervical spine imaging, particularly CT imaging, is during the initial trauma evaluation. However, a physical examination sufficient for clinical clearance may be possible within 48–72 hours in children whose mental status clears rapidly.

CSI and TBI share risk factors including high-energy mechanisms(1, 18) and impact to the head or face. Cervical spine imaging practice patterns in children with TBI have not been described. The purposes of this study were, in children hospitalized after TBI, 1) to describe current cervical spine imaging practice, 2) to assess for recent changes in cervical spine imaging practice, and 3) to determine if cervical spine CT is being used in children at low risk for cervical spine injury.

MATERIALS AND METHODS

Study Design

We defined a retrospective cohort of children with TBI in the PHIS database who were evaluated in the ED of a PHIS hospital and subsequently admitted.

Setting

The PHIS database was developed by the Children’s Hospital Association (www.chca.com), a business alliance of 44 children’s hospitals. The PHIS database contains administrative data including demographics, diagnoses, procedures, and charges. In addition, most PHIS hospitals submit “Level II” data including billing information for pharmacy, imaging,

laboratory, supply, nursing, and therapy services.(19) Inpatient characteristics of 36 PHIS hospitals have been published previously.(19) Conway et al described the extensive data reliability and quality monitoring processes for PHIS data.(20) PHIS contains data for more than 500,000 discharges per year.(21)

Selection of Participants

We obtained data from PHIS regarding patients who met our inclusion criteria and had supplemental billing (level II) data recorded (Figure 1). We identified children < 18 years of age discharged from a PHIS hospital between January, 2001 and June, 2011 with an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) discharge diagnosis code for TBI (Figure 1). These ICD-9-CM diagnosis codes are used by the Centers for Disease Control (CDC) to track hospitalization and Emergency Department (ED) visit rates for TBI nationally.(22)

We calculated injury severity score (ISS) and maximum abbreviated injury scale (AIS) body region scores from ICD-9-CM diagnosis codes using ICDMAP-90 software (Johns Hopkins University and Tri-Analytics, Inc., Baltimore, MD).(23) We required patients to have at least a “moderate” head injury (maximum head body region AIS score = 2). In order to minimize the likelihood that a patient had imaging at a referring ED and was transferred to the children’s hospital, we required that patients have an ED charge and a head CT on day 0 of admission (in PHIS, until midnight on the day of admission) or day 1 of admission (the 24 hours after the first midnight of admission) if admitted after 6pm on day 0. We excluded patients with missing head AIS scores or disposition (Figure 1).

To identify a subgroup of patients potentially eligible for clinical clearance without cervical spine imaging, we selected patients from the overall cohort who were discharged from the hospital alive within 72 hours of admission.

Other subsets of the same cohort have been analyzed in earlier work.(24–26)

Covariates and Outcomes

We categorized injury mechanism using the external cause-of-injury matrix created by the CDC.(27) We also analyzed patients by the admission hospital’s American College of Surgeons (ACS) Pediatric Trauma designation(28) and by hospital volume (Table 1). We defined CSI using ICD-9-CM diagnosis codes (Table 2).

The primary outcomes cervical spine imaging studies, defined using Clinical Transaction Classification™ (CTC) codes. CTC codes reflect hospital billing, and can be used to identify services received by patients.(19, 20, 24, 29) We identified CTC codes for cervical spine plain radiographs (XR) that include flexion-extension views, CT imaging, magnetic resonance (MR) imaging, and fluoroscopy.

The patient-level factors in the multivariate models were specified *a priori*: patient age at admission (years), mechanism of injury (categorical), head AIS (categorical), ISS (continuous), and discharge year (continuous). We included age because CSI distributions are known to vary with age(9), mechanism of injury because it has been associated with CSI

in children(1–3), head AIS because head injury severity is associated with CSI(14), ISS as a measure of global injury severity associated with CSI(1), and discharge year because we hypothesized that imaging patterns would change over the ten years of the study.(11)

Primary Data Analyses

We used the chi-square test for categorical variables and the Wilcoxon rank-sum test for continuous variables (length of stay, patients per hospital). We used linear regression with robust standard errors to test the slopes of the relationships between imaging modality use and CSI frequency over time and to test for change in the ratio of cervical spine injury rate to CT rate.

In order to understand how much of the observed variation in cervical spine imaging use between hospitals could be attributed to patient factors (case mix at each hospital) versus hospital factors, we first standardized hospital-level rates of cervical spine imaging overall and cervical spine CT, with or without XR, using separate population-averaged logistic models with the pre-specified covariates described above. If a patient received cervical spine CT and cervical spine MR, they were not included in the cervical spine CT group. From these models, we estimated predicted probabilities (similar to propensity scores) of any cervical spine imaging and of cervical spine CT for each patient, and then used these probabilities to calculate expected hospital imaging rates. We then calculated standardized cervical spine imaging and cervical spine CT rates for each hospital by comparing observed and expected rates in a manner similar to Weiss et al.(19)

We then used a random-intercept logistic regression model including the same pre-specified covariates(19, 20) and the intraclass correlation coefficient to estimate between-hospital variation not related to patient factors in cervical spine imaging and the use of cervical spine CT.

Statistical significance was defined as $p < 0.05$, and all analyses were performed using STATA™ (StataCorp LP, College Station, TX). This study was reviewed and informed consent was not required by the Institutional Review Board.

RESULTS

Patient Characteristics, Injury Mechanism, and Injury Severity

We identified 31,200 candidates for inclusion and 30,112 remained in the dataset after exclusions (Figure 1). In each month, a median of 240 (interquartile range [IQR] 186–294) patients were discharged from 41 PHIS hospitals. Approximately 81% of the cohort met inclusion criteria because of a head CT on day 0, and 19% because they were admitted after 6pm on day 0 and received a head CT on day 1. More than half (17,425/30,112, 58%) of the patients had a skull fracture and 46% (13,738/30,112) had an intracranial hemorrhage.

Approximately 23% of the patients were < 1 year old, and 64% were male (Table 1). Most inflicted injury (64%) was in children < 1 year old. The median ISS score was 9 (IQR 9–16, range 4–75), and 29% (8,628/30,112) had an ISS score > 15. All 9 patients with the

maximum ISS score of 75 (“unsurvivable”) had the maximum Spine AIS score of 6, and 7 of 9 died.

Hospital Care and Outcomes

In-hospital mortality was 3.5% (1,055/30,112), and the median length of stay was 3 days (IQR 2–5, range 1 to 308).

Cervical Spine Imaging

Overall, 52% of the patients were billed for cervical spine imaging (XR, CT, or MR) (Table 1). None were billed for cervical spine fluoroscopy. The proportion of patients receiving any cervical spine imaging declined from 57% in 2001 to 51% in 2011 (0.7% decrease per year, 95% CI 0.4% to 0.9%). Most (84%) patients with imaging had their first cervical spine imaging study on day 0 of the hospitalization, with another 12% on day 1 and 2% on day 2.

After no cervical spine imaging (48%), cervical spine XR alone was the most common imaging regimen (28%) (Table 1). Of the patients who received a MR scan of the cervical spine, most (80%) also received another type of cervical spine imaging (XR, CT, or both). Cervical spine MR imaging was associated with CSI (44% of children with an injury received MR imaging, compared to 4% of children without an injury, $p < 0.001$) and with brain MR imaging (7% of those who received a brain MR versus 0.3% of those who did not, $p < 0.001$).

The proportion of children with no cervical spine imaging (and presumed clinical clearance) increased modestly from 43% in 2001 to 49% in 2011 with an annual increase of 0.7% (95% CI 0.4% to 0.9%) (Figure 2). Use of cervical spine XR alone decreased substantially between 2001 (47%) and 2011 (23%), annual decrease 2.2% (95% CI 1.1% to 3.3%), largely replaced by an increased use of CT, with or without XR (8.6% in 2001, 19.5% in 2011, annual increase 0.9%, 95% CI 0.1% to 1.8%). The use of MR imaging, alone or in combination with other imaging modalities, increased substantially over the last decade from 1.5% in 2001 to 8.2% in 2011 with an annual increase of 0.6% (95% CI 0.5% to 0.7%).

Among the 17,748 (59%) patients discharged from the hospital alive within 72 hours of admission, the proportion of children with no cervical spine imaging increased from 50% in 2001 to 57% in 2011 (annual increase 1.0%, 95% CI 0.8% to 1.9%). Isolated cervical spine XR use decreased from 44% to 25% over the ten year period (annual decrease 1.9%, 95% CI 1.0% to 2.7%) and CT imaging increased from 5.4% to 16.4% (annual increase 1.3%, 95% CI 0.1% to 2.5%). Among these patients with short stays, 2,545 (14%) received cervical spine CT. Most of those (1,655/2,545, 65%) were not injured in motor vehicle collisions.

Hospitals and Between-hospital variation

Most hospitals did not have an ACS Pediatric Trauma designation (Table 1), and the median number of patients per hospital was 611 (range 69–2,213, IQR 367–950). Expected rates of cervical spine imaging by hospital after adjustment for age, mechanism of injury, head AIS, ISS, and discharge year were 36 to 63%, while observed rates varied from 9 to 81% (Figure

3). Although several hospitals with no ACS certification had below-expected cervical spine imaging rates (Figure 3), children treated at hospitals with level I certification received less cervical spine imaging than those treated at hospitals without ACS certification (50% versus 54%, $p < 0.001$).

Expected rates of CT use (with or without XR) ranged from 12.0% to 27.6%, while observed rates ranged from 0.9% to 59.4% (Figure 4). Several hospitals had CT rates that were much higher than predicted.

Using random-intercept logistic models adjusted for the same pre-specified covariates, we estimated from the intraclass correlation coefficient that 14.0% (95% CI 9.4% to 20.4%) of the total variance in any cervical spine imaging and 18.6% (95% CI 12.5% to 26.6%) of the total variance in CT use is between-hospital variance not explained by identified patient factors.

Cervical Spine Injuries

Overall, 1.4% of patients (428/30,112) had a CSI including dislocations, bony fractures, and cord injuries (Table 2). The median number of CSI per hospital was 17 (range 0 to 52), which represents 1.6 injuries per hospital per year in children with TBI. The CSI rate increased over time from 0.9% in 2001 to 1.6% in 2011 (peak 2.1% in 2005), annual increase 0.08% (95% CI 0.03% to 0.13%). The ratio of the proportion of patients with CSI/proportion of patients receiving CT imaging decreased significantly over time (monthly decrease 0.005, 95% CI 0.003 to 0.007).

CSI was associated with increased patient age (2.8% of teenagers versus 0.3% of infants), injury mechanism (3.7% of motor vehicle traffic events versus 0.5% of falls and 0.4% of inflicted injuries), head injury severity (7.0% with head AIS of 5 versus 1.0–1.3% in lower head AIS categories), and overall injury severity.

The most common injury was a spinal column fracture without cord injury (55%). Overall, 29% of children with CSI had a spinal cord injury. Mortality was much higher in children with CSI (17% versus 3%). More than two-thirds of all CSI was located at C1-C4. The upper cervical spine (C1-C4) was the most common injury location for younger children. At approximately 16 years of age, patients suffered upper and lower (C5-C7) cervical spine injuries at similar rates (Figure 4).

Cervical spine fusions (0.2%) were rare overall, and only 10% of those with CSI received a fusion. Hospital rates of cervical spine fusion ranged from 0 to 33% of those with CSI.

DISCUSSION

The adoption of CT clearance of the cervical spine as the standard of care in adults(10) appears to have been applied to the care of injured children overall(11, 14) and children with TBI (this study), in spite of concerns about radiation exposure.(15) Children are thought to be at higher radiation risk than adults because of higher tissue radiosensitivity and longer life expectancy.(15–17, 30) Cervical spine imaging practices in children with TBI changed over the ten years of our study; presumed clinical clearance (no imaging) increased

modestly, plain radiograph use decreased significantly, and CT and MR use increased significantly.

Approximately 2,500 children in our study received a cervical spine CT despite being discharged alive from the hospital in < 72 hours, and approximately 1,650 of those had a low-risk mechanism of injury. Although the clinical circumstances for each child are not available, it seems likely that some could have been cleared without the risks of CT radiation. The relative balance of risks (delayed diagnosis of an unlikely injury and prolonged exposure to a cervical collar) and benefits (less radiation exposure if clinical clearance becomes possible) of delaying cervical spine imaging in hospitalized children with TBI is not completely understood.

The proportion of children with TBI receiving no cervical spine imaging increased slowly over the last ten years. This may reflect the influence of recent studies advocating clinical clearance. The National Emergency X-Radiography Utilization Study (NEXUS)(5) and Canadian Cervical Spine(31) studies established and validated criteria by which selected adults could be clinically cleared. The NEXUS criteria were validated in a pediatric cohort, but few of those children were < 9 years old, and the NEXUS investigators suggested caution in the application of the criteria to young children.(4) Using trauma registry data from many centers, Pieretti-Vanmarcke et al recently supported clinical clearance in any child not injured in a motor vehicle collision who has a Glasgow Coma Scale (GCS) 14 and a $GCS_{EYE} > 1$.(14)

We found increasing use of MR imaging overall and as the only cervical spine imaging study, likely representing MR clearance. MR imaging for clearance of the cervical spine has been proposed, particularly for intubated patients with altered mental status, because it has excellent sensitivity for abnormalities of the spinal cord, nerve roots, intervertebral discs, and interosseous ligaments.(8, 10, 32) MR does not expose the patient to ionizing radiation, but it is costly and time-consuming, and young children are likely to require deep sedation or anesthesia to tolerate it.

Significant between-hospital variation in cervical spine imaging practice not explainable by patient factors exists. Our data show substantial hospital-level variation in imaging practice, particularly in the use of cervical spine CT, and several hospitals had much higher CT use than expected based on patient characteristics. These findings are consistent with those reported by Pieretti-Vanmarcke et al, in which several centers predominantly used clinical clearance, several primarily used plain radiographs with CT as necessary, and several used CT extensively.(14) In our study, children treated at hospitals with ACS level 1 certification were less likely to receive cervical spine imaging. Mannix et al reported similar findings in injured children discharged from an emergency department.(11)

In this cohort of hospitalized children with TBI, CSI was diagnosed at a rate (1.4%) similar to that in large pediatric blunt trauma cohorts.(1–4) Although it remains a rare injury(33), the rate of CSI in hospitalized children with TBI increased during our study. This may be due to improved imaging technology (MR in particular) that allows detection of more subtle injuries. The increase in CSI diagnosis rate was not strictly due to the increase in CT rate, as

the ratio of CSI diagnosis rate/CT rate decreased over time. It is also possible that improved pre-hospital care of children with both TBI and CSI has increased the likelihood of survival to the hospital. We found an injury distribution across ages similar to that reported by Kokoska et al(2), with C1-C4 the most common location of injury children < 16 years old.

Our study has several limitations. Detailed injury data such as the height of a fall or suspected child abuse, physical exam findings including GCS or the degree of pain from a distracting injury, imaging results, and operative reports are not present in the PHIS database. We designed our inclusion criteria to minimize the likelihood that a patient received cervical spine imaging at another institution and was transferred to the PHIS hospital, but no reliable transfer-in variable is in the dataset. Some patients may have received cervical spine imaging prior to transfer to the PHIS center, and those studies would not be captured in the PHIS database. Similarly, some head imaging may have been secondary to an identified primary cervical spine injury. Some trauma centers are certified by state organizations and not by the ACS, and as such some hospitals in the “No ACS certification” group are busy and prominent centers. We have data regarding the cervical spine imaging study chosen by care providers, but not about the potentially nuanced decision-making process that led to that study. We assumed that children in our study were clinically cleared if they did not receive cervical spine imaging, but no data are available to test that assumption. Residual confounding is possible, as ISS and regional AIS scores may not capture all aspects of each patient’s injury severity.

In conclusion, the adoption of CT clearance of the cervical spine as the standard of care in adults appears to have influenced the care of children with TBI, despite concerns about radiation exposure. Cervical spine imaging practices in children with TBI have changed over the last ten years; clinical clearance increased modestly, plain radiograph use decreased significantly, and CT and MR use increased significantly.

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- Discharge date from a PHIS hospital, January, 2001 to June, 2011
- ICD-9-CM^a diagnosis code for TBI: 800.0-801.9, 803.0-804.9, 850-854.1, or 959.01
- Head Abbreviated Injury Scale^b score ≥ 2
- Emergency Department evaluation prior to admission
- Head CT^c scan on day 0 of admission (or day 1 if admitted after 6pm on day 0)

N = 31,200

1,088 Excluded from the analysis (3.5%)
166 Head AIS missing (0.5%)
766 Disposition missing (2.5%)
156 Subsequent admission (0.5%)

N = 30,112 (96.5%)
Included in the analysis

^a International Classification of Diseases, 9th revision, Clinical Modification

^b Maximum Abbreviated Injury Scale for Head body region, derived using ICDMAP-90

^c Computed Tomography

Figure 1.

Patient selection method for hospitalized children < 18 years old with traumatic brain injury

Legend. XR = plain radiograph. CT = Computed tomography. Lowess = Locally weighted regression and scatterplot smoothing.³³ MR* = Magnetic resonance imaging, alone or in combination with other modalities.

Figure 2.
Cervical spine imaging regimens over time
y-axis label: "Proportion of Patients"

Legend. C-spine = Cervical spine. CT = Computed Tomography. Obs-Exp = Observed minus Expected. ACS = American College of Surgeons.

Figure 3.
Between-hospital variation in cervical spine imaging
y-axis label: "Proportion of Patients, by Hospital"

Figure 4.
Location of cervical spine injuries, by patient age

Table 1

Select demographic and clinical features of children with TBI, by cervical spine imaging type

	None, n(%)	XR only, n(%)	CT only, n(%)	XR+CT, n(%)	MR*, n(%)
	N = 14,425(48)	N = 8,456(28)	N = 3,328(11)	N = 2,420(8)	N = 1,483(5)
Age					
0 to 364 days	5,239(36)	900(11)	316(10)	133(6)	260(18)
1 to <5 years	3,133(22)	2,120(25)	875(13)	531(22)	337(23)
5 to <13 years	4,066(28)	3,513(42)	1,140(34)	1,028(42)	513(35)
13 to <18 years	1,987(14)	1,923(23)	997(30)	728(30)	373(25)
Gender					
Male	9,079(63)	5,517(65)	2,130(64)	1,585(66)	943(64)
Missing	2(0)	11(0)	2(0)	1(0)	3(0)
Mechanism					
Fall	5,857(41)	2,356(28)	703(21)	520(21)	233(16)
Motor vehicle traffic	1,358(9)	2,614(31)	1,382(42)	1,042(43)	611(41)
Inflicted Injury	1,802(12)	477(6)	237(7)	76(3)	181(12)
Other/Missing	5,408(37)	3,009(36)	1,006(30)	782(32)	458(31)
Head AIS					
2 ("Moderate")	3,751(26)	3,173(38)	785(24)	764(32)	277(19)
3 ("Serious")	7,186(50)	3,838(45)	1,652(50)	1,164(48)	732(49)
4 ("Severe")	3,180(22)	1,240(15)	559(17)	368(15)	379(26)
5 ("Critical")	308(2)	205(2)	332(10)	124(5)	95(6)
ICDISS					
< 15	10,598(73)	6,496(77)	2,008(60)	1,647(68)	735(50)
15	3,827(27)	1,960(23)	1,320(40)	773(32)	748(50)
Mech. Vent. 96 hours	201(1)	205(2)	194(6)	142(6)	371(25)
ICP monitor	354(2)	363(4)	343(10)	222(9)	331(22)
Cervical spine fusion	0(0)	1(0)	0(0)	8(0)	39(3)
LOS, days, med(IQR)	3(2-4)	3(2-4)	4(2-6)	4(2-6)	9(5-18)
Mortality	378(3)	197(2)	347(10)	104(4)	29(2)

	None, n(%)	XR only, n(%)	CT only, n(%)	XR+CT, n(%)	MR*, n(%)
	N = 14,425(48)	N = 8,456(28)	N = 3,328(11)	N = 2,420(8)	N = 1,483(5)
Hospital ACS Level					
I (17 hospitals)	6,362(44)	3,932(47)	1,640(49)	1,242(51)	673(45)
II (2 hospitals)	818(6)	663(8)	61(2)	176(7)	99(7)
None (22 hospitals)	7,245(50)	3,861(46)	1,627(49)	1,002(41)	711(48)
Patients per hospital					
<500 (16 hospitals)	2,656(18)	723(9)	485(15)	245(10)	130(9)
500–1000 (16 hospitals)	6,406(44)	3,321(39)	1,209(36)	807(33)	752(51)
>1000 (9 hospitals)	5,363(37)	4,412(52)	1,634(49)	1,368(56)	601(41)

Column percentages may not add to 100% because of rounding

Legend. XR = plain radiograph. CT = Computed Tomography. MR* = Magnetic Resonance imaging, alone or in combination with XR and/or CT. AIS = Maximum Abbreviated Injury Scale score, Head body region, derived using ICDMAP-90. ICDISS = Injury Severity Score, calculated using ICDMAP-90. Mech. Vent. = Mechanical Ventilation. ICP = intracranial pressure. LOS = Length of Stay. Med(IQR) = Median(interquartile range). ACS = American College of Surgeons Pediatric Trauma Designation: Level I, Level II, or None

Table 2

Select demographic and clinical features of children with TBI with and without cervical spine injury

		Cervical spine injury, n(%)	No cervical spine injury, n(%)	$\chi^2 p$
		N = 428(1.4)	N = 29,684(98.6)	
	Age			< 0.001
	0 to 364 days	19(4)	6,829(23)	
	1 to <5 years	92(22)	6,904(23)	
	5 to <13 years	150(35)	10,110(34)	
	13 to <18 years	167(39)	5,841(20)	
	Gender			
	Male	268(63)	18,986(64)	0.597
	Missing	1(0)	18(0)	
	Mechanism			< 0.001
	Fall	45(11)	9,624(32)	
	Motor vehicle traffic	256(60)	6,751(23)	
	Inflicted Injury	10(2)	2,763(9)	
	Other/Missing	117(27)	10,546(36)	
	Head AIS			< 0.001
	2 ("Moderate")	90(21)	8,660(29)	
	3 ("Serious")	187(44)	14,385(48)	
	4 ("Severe")	77(18)	5,649(19)	
	5 ("Critical")	74(17)	990(3)	
	ICDISS			< 0.001
	< 15	168(39)	21,316(72)	
	15	260(61)	8,368(28)	
	Injury Type			
	Fracture with cord injury	38(9)		
	Fracture without cord injury	236(55)		
	Cord injury only	77(18)		
	Dislocation only	66(15)		
	Other combinations	11(3)		
	Injury Location			
	C1-C4	277(65)		
	C5-C7	108(25)		
	Multiple locations	38(9)		
	Unspecified	5(1)		
	Cervical spine fusion	44(10)	4(0)	< 0.001
	Length of stay, median(IQR)	6(3–12)	3(2–5)	< 0.001 *
	Mortality	72(17)	983(3)	< 0.001

Legend. AIS = Maximum Abbreviated Injury Scale score, Head body region, derived using ICDMAP-90. ICDISS = Injury Severity Score, calculated using ICDMAP-90. IQR = interquartile range.

* Wilcoxon p-value

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