



Contents lists available at ScienceDirect

## North American Spine Society Journal (NASSJ)

journal homepage: [www.elsevier.com/locate/xnsj](http://www.elsevier.com/locate/xnsj)

## Clinical Studies

Spinal fractures and/or spinal cord injuries are associated with orthopedic and internal organ injuries in proximity to the spinal injury<sup>☆</sup>Nidharshan S. Anandasivam<sup>a</sup>, Nathaniel T. Ondeck<sup>b</sup>, Paul S. Bagi<sup>a</sup>, Anoop R. Galivanche<sup>a</sup>, Andre M. Samuel<sup>b</sup>, Daniel D. Bohl<sup>c</sup>, Jonathan N. Grauer<sup>a,\*</sup><sup>a</sup> Department of Orthopaedics and Rehabilitation, Yale School of Medicine, 800 Howard Avenue, New Haven, CT 06510, United States<sup>b</sup> Department of Orthopaedic Surgery, Hospital for Special Surgery, 535 E 70th St., New York, NY 10021, United States<sup>c</sup> Department of Orthopaedic Surgery, Rush University Medical Center, 1611W. Harrison St, Suite 400, Chicago, IL 60612, United States

## ARTICLE INFO

## Keywords:

Spine trauma  
Spine fracture  
Spinal cord injury  
Associated injuries  
Injury severity  
Mechanism of injury  
Mortality

## ABSTRACT

**Background:** the demographics, mechanisms of injury, and concurrent injuries associated with cervical, thoracic and lumbar spinal fracture and/or spinal cord injury remain poorly characterized.**Methods:** Patients aged 18 and older with spinal injury between 2011 and 2015 in the National Trauma Data Bank (NTDB) were identified. Patient demographics, comorbidity burden, mechanism of injury, and associated injuries were analyzed.**Results:** in total, 520,183 patients with acute spinal injury were identified including 216,522 cervical, 191,218 thoracic, and 220,294 lumbar. The age distributions were trimodal with peaks in incidence at around 2155 and a lesser peak around 85 years of age. The number of comorbidities increased while injury severity decreased with advancing patient age. Motor vehicle accidents (MVAs) were the most common mechanism of injury. Associated bony and internal organ injuries were common and occurred in 63% of cervical spine injury patients, 79% of thoracic spine injury patients, and 71% of lumbar spine injury patients. In all three sub-populations, there was a predominance of injuries in the local area of the primary injury. For cervical, these were rib injuries (28%), thoracic spine injuries (22%), skull fractures (20%), intracranial injuries (26%) and lung injuries (21%). For thoracic, these were rib injuries (47%), lumbar spine injuries (26%), cervical spine injuries (25%), lung injuries (35%) and intracranial injuries (24%). For lumbar, these were rib injuries (38%), thoracic spine injuries (22%), pelvic fractures (20%), lung injuries (26%) and intracranial injuries (19%). Multivariate regression analysis demonstrated that increased injury severity was strongly correlated with increased mortality, with lesser contributions from increased age and comorbidity burden.**Conclusions:** the current study revealed spinal fractures and/or cord injuries had high incidences of associated injuries that had a predominance of local distribution. These findings, in combination with the mortality analysis, demonstrate the importance of local targeted evaluations for associated injuries.

## Introduction

Spinal fractures and/or spinal cord injuries (SCI) are common and associated with significant morbidity and cost. The incidence of vertebral fractures in the United States varies from about 500 to 3000 per 100,000 person-years [1]. In terms of the burden on society, patients with an unstable spinal fracture without neurological deficits have an average hospital length of stay of 29 days, and an average cost of about \$22,078 for these injuries alone [2].

Associated injury patterns are well recognized with several fracture types. For example, there are known associations with calcaneus fractures (lumbar spine injuries) [3], clavicle fractures (lung injuries) [4], and femoral shaft fractures (ipsilateral femoral neck injuries) [5]. By appreciating distributions of associated injuries, focused evaluations can be prioritized to optimize care and limit the risk of missed injuries.

For spinal injuries, non-contiguous spinal fractures have long been acknowledged to have an incidence of around 15% [6], although a few studies suggest an incidence between 4 and 10%. Keenen et al. found a 6.4% incidence of noncontiguous spinal fractures in a retrospective

<sup>☆</sup> Given his role as Editor in Chief, Jonathan Grauer, MD had no involvement in the peer-review of this article and has no access to information regarding its peer-review. Full responsibility for the editorial process for this article was delegated to Tobias Mattei, MD.

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<https://doi.org/10.1016/j.xnsj.2021.100057>

Received 24 December 2020; Received in revised form 13 March 2021; Accepted 17 March 2021

Available online 21 March 2021

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review of 817 patients [7]; Calenoff et al. found a 4.5% incidence of multiple noncontiguous injuries in a review of 710 spinal injury patients [8]; and Herbert et al. found a 9.6% noncontiguous fracture incidence in a study of 830 patients with traumatic spine injury [9].

A few studies have also looked at non-spinal associated injuries with spinal fractures. Miller et al. studied 492 patients with cervical spine fracture or dislocation and found that 57% had at least one non-spinal injury [10]. Moreover, Herbert et al. examined 830 patients with traumatic spine injury admitted to a single institution and found 69.5% had a single fracture, 17% had multiple contiguous spinal fractures, 9.6% had multiple noncontiguous spinal fractures, and 71.7% had at least one associated injury (including spinal and non-spinal) [9]. While these studies provide baseline data, they are limited by relatively small sample sizes / local sample cohorts.

Better understanding the demographics, mechanisms of injury, and injuries associated with spinal fractures and/or cord injuries may help target workups and optimize care and guide the clinical and radiographic workup of those presenting with such injuries. Furthermore, understanding the implications of such associated injuries would underscore the importance of such considerations.

To address the above questions, the current study evaluated spinal fracture and/or cord injury patients captured by the National Trauma Data Bank (NTDB). The NTDB contains detailed data from over 900 participating registered trauma centers and is maintained by the American College of Surgeons [11].

## Materials and methods

### Study population

The patients for the current study were extracted from the 2011–2015 National Trauma Data Bank (NTDB). The NTDB contains over 5 million patient records from over 700 hospitals, and is the largest United States trauma registry [12]. The dataset's reputability has led to its use in publications in a variety of orthopedic journals [13,14]. A waiver for this study was issued by our Institutional Review Board.

Adult patients (aged 18 and over) were extracted from the NTDB years 2011–2015 using International Classification of Disease, 9th Revision (ICD-9) codes for open or closed fracture of the cervical, thoracic, or lumbar spine and/or cervical, thoracic or lumbar spine injury (see Appendix A for ICD-9 codes).

### Demographics and comorbidities

Demographic information included in this study were found in the NTDB variables for age and gender. Age was listed numerically, while gender was listed in a binary format (male or female).

The disease burden in the patient population was assessed using a modified Charlson Comorbidity Index (CCI). The modified CCI is a dataset adapted classification of comorbidity that has been validated in predicting short- and long-term patient mortality [15]. This index accounts for age, hypertension, alcoholism, diabetes, respiratory disease, obesity, congestive heart failure, coronary artery disease, prior cerebrovascular accident, liver disease, functionally dependent status, cancer, renal disease, dementia and peripheral vascular disease.

### Mechanism of injury, injury severity, and associated injuries

The NTDB also provided information regarding the mechanism of injury through ICD-9 e-codes (see Appendix B for ICD-9 e-codes). Patients with a 'motor vehicle accident' mechanism of injury included trauma involving traditional automobiles, rail transport, and aircraft accidents. The fall mechanism injury included fall from standing height and fall from height. All other mechanisms of injury were categorized in the 'other' category.

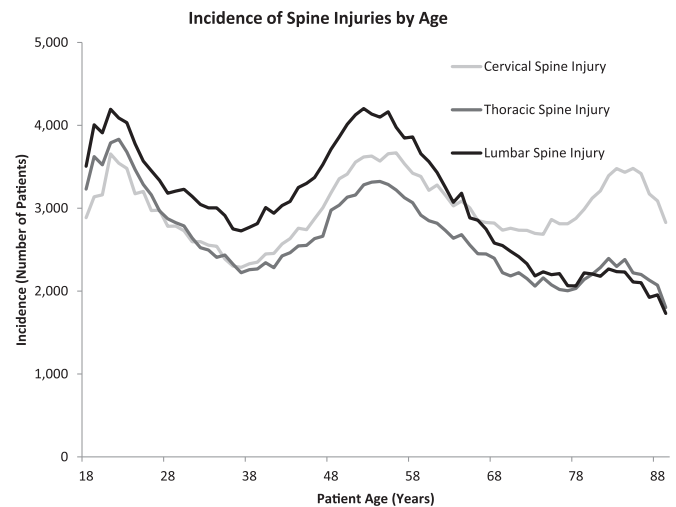


Fig. 1. Age distribution.

In order to understand the totality of the injury burden, the Injury Severity Score (ISS) was also included in the analysis. The ISS, derived from the Abbreviated Injury Scale, is a summary measure of trauma to multiple body regions that assigns patients integer scores of 1 to 75, with higher scores corresponding with more severe trauma [16].

Associated injuries were also extracted from the dataset using ICD-9 coding. They were categorized into bony injuries and internal organ injuries. The figures displaying the associated bony and internal organ injuries were created using Adobe® Photoshop® CS3.

### Mortality

Mortality data was identified based on a variable in the NTDB that indicated whether or not the patient died in the hospital prior to discharge (inpatient mortality). A multivariate logistic regression was performed for mortality including age (categorized as 18–39, 40–64, or 65+), patient health (using divisions of the modified CCI), and totality of injury burden (relying upon groupings of ISS). The statistical analysis was conducted using Stata® version 13.0. All tests were two-tailed with a two-sided  $\alpha$  of 0.05 being indicative of statistical significance. (Table 2).

## Results

### Demographics and comorbidities

The NTDB data years 2011–2015 contained 520,183 patients with spinal injury. By region, 216,522 patients were diagnosed with cervical spine injury, 191,218 patients were found to have thoracic spine injury, and 220,294 patients were identified with lumbar spine injury. Fig. 1 demonstrates the age distribution of the injuries by spine region. The age distributions were trimodal with peaks in incidence at around 21, 55 and a lesser peak around 85 years of age.

### Mechanism of injury and injury severity

The mechanisms of injury were consistent across the spinal regions of injury as seen in Fig. 2. Overall, the most common cause involves motor vehicle accidents (MVAs), accounting for over half of all of the injuries. This was followed by falls, accounting for over a third of injuries, and ending with other causes (about one tenth of patients). Ballistic trauma accounted for 0.54% of cervical spine injuries, 1.01% of thoracic spine injuries, and 0.71% of lumbar spine injuries.

Injury severity score (ISS) distributions for each of the injury types are shown in Fig. 3. Generally, all three injury types follow the pattern

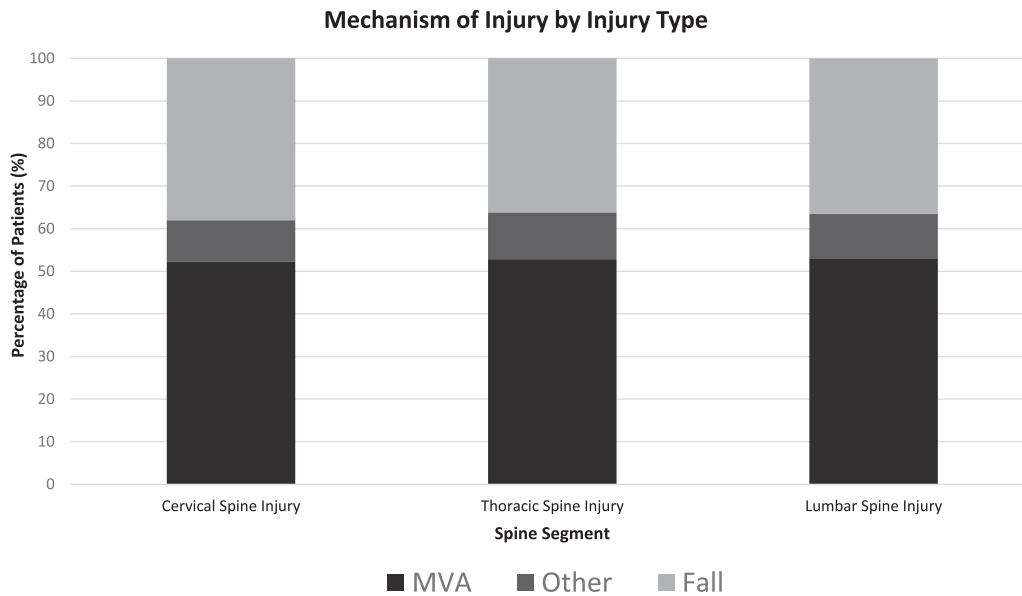


Fig. 2. Mechanism of injury.

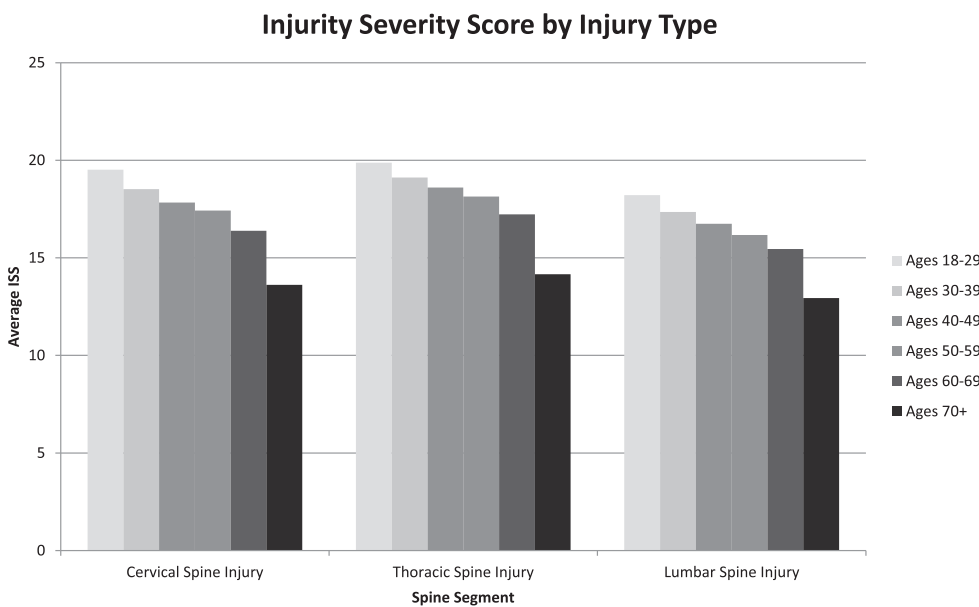


Fig. 3. Injury severity score.

of decreasing ISS with increasing age. Notably, lumbar spine injury patients had the highest fraction of patients with ISS<10 and generally had lower injury severity scores than the two other injury groups.

**Associated injuries**

Overall, associated injuries occurred in 63% of cervical spine injury patients, 79% of thoracic spine injury patients and 71% of lumbar spine injury patients. With respect to orthopedic trauma, adjacent spine regions and ribs are the most common bony injury sites for cervical, thoracic, and lumbar spine injury as demonstrated in Fig. 4.

Many of the associated injuries occurred near the primary injury. For cervical spine injuries, these were rib injuries (28%), thoracic spine injuries (22%), skull fractures (20%), intracranial injuries (26%) and lung injuries (21%). For thoracic spine injuries, these were rib injuries (47%), lumbar spine injuries (26%), cervical spine injuries (25%), lung injuries (35%) and intracranial injuries (24%). For lumbar spine injuries, these

were rib injuries (38%), thoracic spine injuries (22%), pelvic fractures (20%), lung injuries (26%) and intracranial injuries (19%).

Associated internal organ injuries, as shown in Fig. 5, demonstrated a similar proximity pattern as skeletal fractures for both cervical and thoracic injury. Cervical spine injury was notable for over 1 in 4 patients having intracranial injury and over 1 in 5 patients having lung injury. While lumbar spine injury was significant for increases in abdominal organ injuries in comparison with cervical and thoracic spine injury, the highest incidence of internal organ injury was more distant to the index fracture with over 1 in 4 patients having a lung injury.

**Mortality**

Finally, the impact of demographics and associated injuries on mortality for cervical, thoracic and lumbar spine injury was assessed through a multivariate regression shown in Tables 1–3. For all spine regions, the

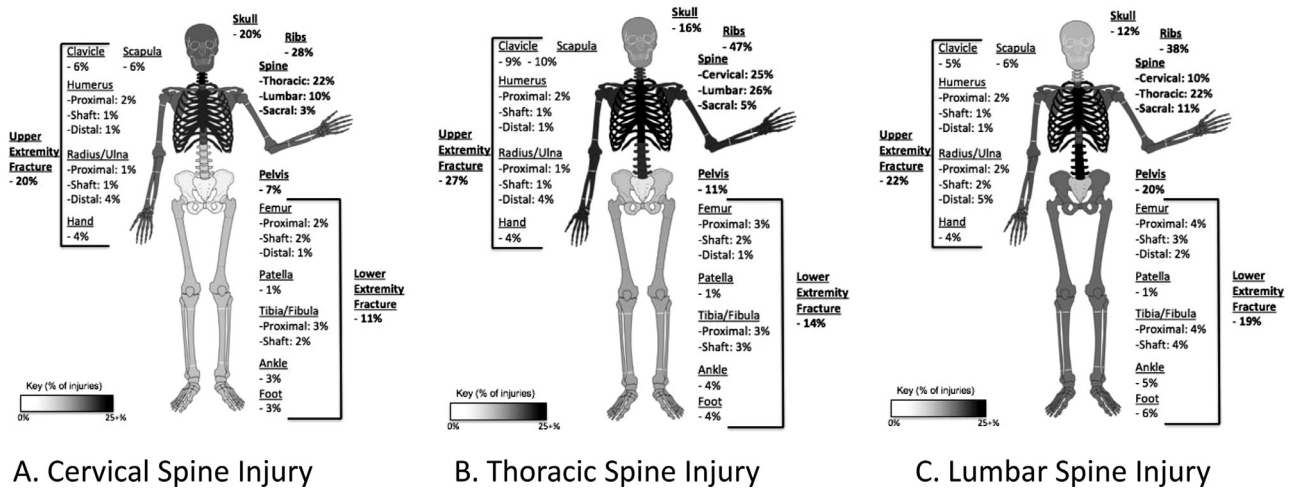


Fig. 4. Percentage of cervical, thoracic and lumbar spine injury patients with associated bone injuries.

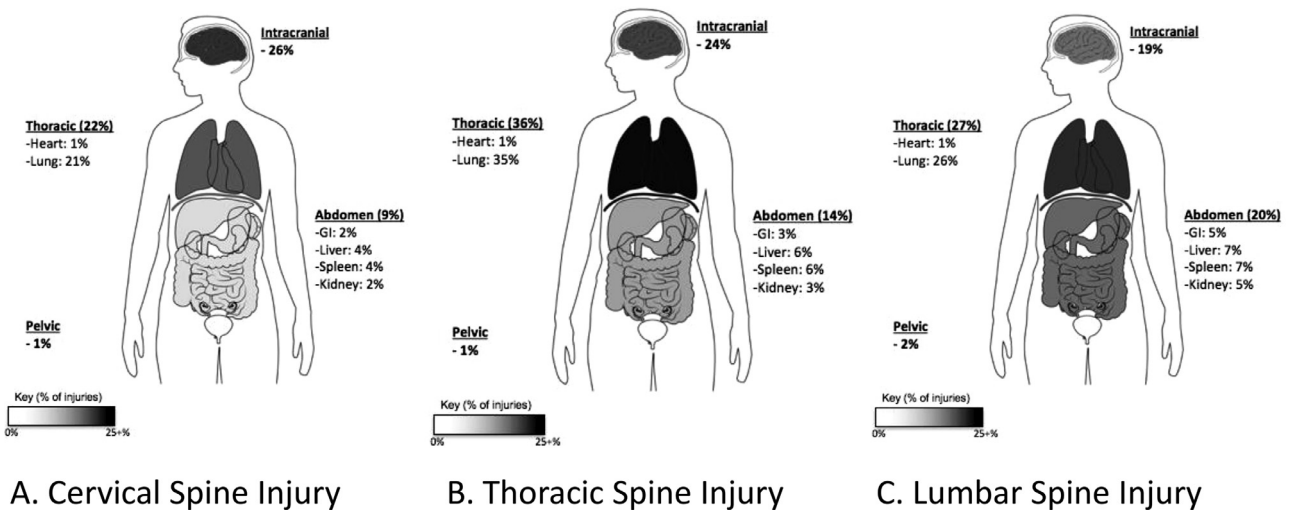


Fig. 5. Percentage of cervical, thoracic and lumbar spine injury patients with associated internal organ injuries.

Table 1  
Cervical spine regression for mortality.

	Multivariate Odds Ratio	95% Confidence Interval	P-Value
Age			
18–39	Reference		
40–64	1.51	1.29 – 1.77	<0.001
65+	2.35	1.96 – 2.81	<0.001
ModifiedCCI			
0	Reference		
1	0.77	0.66 – 0.91	0.002
2	0.87	0.74 – 1.03	0.12
3	0.85	0.72 – 1.02	0.08
4	1.44	1.20 – 1.73	<0.001
>4	2.08	1.73 – 2.49	<0.001
ISS			
0–10	Reference		
11–20	1.55	1.43 – 1.69	<0.001
21–30	5.53	5.12 – 5.99	<0.001
>30	25.33	23.47 – 27.34	<0.001

totality of patient trauma was the most significant driver for mortality (odds ratios of 25 to 60 for ISS scores greater than 30) with lesser contributions from age and increased comorbidity burden.

### Discussion

Spinal fractures are a common and serious injuries that have received significant attention in the literature regarding their management and prognosis. However, much less has been explored regarding the affected patient population, common causes, as well as the rate and role of associated injuries. In this context, the purpose of the present study was to evaluate the demographics, mechanisms of injury, and the profile of associated bony and internal organ injuries. Understanding the aforementioned information is helpful as it allows clinicians to identify patient populations for which they need to maintain a higher index of suspicion for spinal trauma and then, in those individuals with spinal injury, to more easily identify and manage associated injuries.

The use of knowledge of common injury patterns in order to quickly diagnose and manage associated injuries is of utmost value as this study demonstrates that the severity of injury, as measured through the ISS, drives mortality far more than age and patient comorbidities (Tables 1–3). Furthermore, as we enter the age of bundled payments, judicious imaging ordering based upon situational and clinical suspicion has become more important than ever.

**Table 2**  
Thoracic spine regression for mortality.

Outcome: Mortality	Multivariate Odds Ratio	95% Confidence Interval	P-Value
Age			
18–39	Reference		
40–64	1.63	1.37 – 1.94	<0.001
65+	2.25	1.84 – 2.75	<0.001
Modified CCI			
0	Reference		
1	0.70	0.59 – 0.84	<0.001
2	0.90	0.75 – 1.09	0.28
3	0.89	0.74 – 1.09	0.26
4	1.47	1.20 – 1.80	<0.001
>4	1.97	1.60 – 2.41	<0.001
ISS			
0–10	Reference		
11–20	2.17	1.92 – 2.45	<0.001
21–30	7.47	6.68 – 8.37	<0.001
>30	38.45	34.50 – 42.86	<0.001

**Table 3**  
Lumbar spine regression for mortality.

Outcome: Mortality	Multivariate Odds Ratio	95% Confidence Interval	P-Value
Age			
18–39	Reference		
40–64	1.52	1.26 – 1.83	0.001
65+	1.95	1.57 – 2.41	<0.001
Modified CCI			
0	Reference		
1	0.73	0.60 – 0.88	0.001
2	0.94	0.77 – 1.15	0.548
3	1.03	0.83 – 1.26	0.803
4	1.73	1.39 – 2.14	<0.001
>4	2.43	1.95 – 3.02	<0.001
ISS			
0–10	Reference		
11–20	2.93	2.54 – 3.36	<0.001
21–30	10.79	9.50 – 12.27	<0.001
>30	59.78	52.84 – 67.64	<0.001

The demographic investigation revealed a peak in incidence at age 21 years, which coincides with a common motor vehicle mechanism of injury across all three spinal distributions. This is intuitive given that individuals of this age are less experienced drivers and have more severe crashes than older individuals as measured by cost per victim [17]. The peak in incidence at age 85 years coincides with a fall mechanism, which is also expected given the bone weakening that accompanies aging. Patients presenting to the emergency room with either of these mechanisms should be carefully evaluated for clinical and radiographic signs of spine trauma.

The association between patient comorbidities and mortality following surgical intervention of the spine has been demonstrated, as patients who have achieved one year survival following invasive management for odontoid fractures, have a significantly lower CCI score (1.5) than those who did not (3.2) [18]. Thus, CCI scores are important when making the decision to proceed with operative management versus continuing with a more conservative approach.

The characterization of associated bony injuries for index cervical, thoracic and lumbar spine trauma revealed a high prevalence of concurrent spine injury. For all three regions, over 1 in 5 patients had an associated injury in the adjacent spine segment. Additionally, other local injuries were found to be frequent including skull injuries for cervical trauma, rib injuries for thoracic trauma, and pelvis injuries for lumbar spine trauma. These findings underscore the attention that must be paid to the local region of the index injury when evaluating patients with spine injury.

Associated internal organ injuries were also evaluated for all three spinal regions. As expected, local injuries were widespread with the most common concurrent injury with cervical spine insult being intracranial (over 1 in 4 patients) and with thoracic spine insult being lung injury (over 1 in 3 patients). However, this local pattern was not as strong for lumbar spine injury. While certainly the percentage of patients with gastrointestinal, liver, spleen and kidney injuries increased as the index spine injury became more proximal to the abdomen, there was a much less anticipated high incidence of intracranial (under 1 in 5) injury.

The above-noted associated injury results emphasize the importance of thorough trauma evaluation, especially for patients with a known lumbar injury. Additionally, this analysis demonstrates that the percentage of patients with intracranial injuries was higher than those with cranial fractures highlighting the fact that patients may lack more easily identified bony signs of head trauma yet may still have internal injury that may be only discovered through mental status examination and appropriate imaging.

Strengths of the current study include that this is the first analysis focused on all causes of traumatic spinal injury grouped by insults to the cervical, thoracic and lumbar spine. This novel all-encompassing approach allows physicians to more thoroughly understand the intricacies of the demographics, mechanisms of injury and concurrent injuries in spinal trauma patients. Additionally, the sample size of over a half-million is the largest cohort of traumatic spine injury patients in the literature, to the authors' knowledge.

Limitations of this study involve dataset quality, particularly administratively coded data [19]. However, the NTDB is partially chart abstracted (including age, comorbidity, and injury severity score variables) and all submitted data is screened with the Validator, an edit check program [20]. Additionally, the present study does not utilize NTDB data coded in the ICD-10 format, to avoid ICD-9/10 code crossover. Finally, the NTDB lacks some important demographic variables including race, geographic region, and urban/rural classification.

## Conclusions

In conclusion, there are peaks in cervical, thoracic and lumbar spinal trauma at around 21, 55 and a lesser peak around 85 years of age, with motor vehicle accidents and falls being the most common mechanisms. There is high prevalence of both local bony and internal organ injury with spinal trauma. Clinicians should be aware of the epidemiology and injury pattern of spinal trauma as injury severity and concurrent injuries have been shown to have strong associations with mortality.

## Declarations of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A

-Cervical spine injuries defined by ICD-9 codes:

- 805.0: Closed fracture of cervical vertebra without mention of spinal cord injury
- 805.1: Open fracture of cervical vertebra without mention of spinal cord injury
- 806.0: Closed fracture of cervical vertebra with spinal cord injury
- 806.1: Open fracture of cervical vertebra with spinal cord injury
- 952.0: Cervical spine cord injury without evidence of spinal bone injury

-Thoracic spine injuries defined by ICD-9 codes:

- 805.2: Closed fracture of thoracic vertebra without mention of spinal cord injury



805.3: Open fracture of dorsal vertebra without mention of spinal cord injury  
 806.2: Closed fracture of thoracic vertebra with spinal cord injury  
 806.3: Open fracture of thoracic vertebra with spinal cord injury  
 952.1: Thoracic spinal cord injury without evidence of spinal cord injury

-Lumbar spine injuries defined by ICD-9 codes:

805.4: Closed fracture of lumbar vertebra without mention of spinal cord injury  
 805.5: Open fracture of lumbar vertebra without mention of spinal cord injury.  
 806.4: Closed fracture of lumbar spine with spinal cord injury  
 806.5: Open fracture of lumbar spine with spinal cord injury  
 952.2: Lumbar spinal cord injury without evidence of spinal bone injury

## Appendix B

- Motor Vehicle Accident Mechanisms defined by ICD-9 e-codes: 800 – 825.99, 829–829.99, 840 – 844.99, 958.5, 988.5
- Fall Mechanisms defined by ICD-9 e-codes: 833 – 835.99, 844.7, 880 – 889.99, 957 – 957.99, 968.1, 987 – 987.99, 988
- Other Mechanisms included all other ICD-9 e-codes

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