Original Article

The impact of body mass index on severity of cervical spine fracture: A retrospective cohort study

ABSTRACT

Background: No study has evaluated the relationship between increasing BMI and severity/type of cervical spine injuries.

Aims and Objectives: The objective of our study was to study the impact of body mass index (BMI) on severity of cervical spine fracture.

Methods: We performed a retrospective cohort study of patients with traumatic cervical spine fractures at a level I trauma center over a 74-year period. CT scans of the cervical spine were blindly graded according to the AO Spine sub-axial cervical spine classification. The association between BMI and severity of cervical spine fracture was studied by multiple-variable logistic regression.

Results: A total of 291 patients with an average BMI of 26.1 ± 5.4 kg/m^2 were studied. Higher BMI was not associated with more severe injury (OR 1.03, 95%, CI: 0.97–1.08). For rollover motor vehicle accident (MVA), the association was trending towards significance (OR 2.55, 95%, CI: 0.98-6.66, $P = 0.06$).

Conclusions: Patients with higher BMI may be predisposed to more severe cervical spine fracture in rollover MVA, but not non-rollover MVA or falls.

Keywords: Body mass index, cervical spine, fracture, motor vehicle accident, obesity, trauma

INTRODUCTION

The prevalence of obesity in the United States was estimated at 39.8% among adults and 18.5% among youth in 2015–2016.[1,2] Obesity is a known contributor to four of the top five causes of death in the adult population and has shown to negatively affect the health-related quality of life measures.[3,4] A relationship between obesity and patterns of traumatic injuries has also been shown, particularly with motor vehicle accidents (MVA). In 2015, nearly 48% of unintentional injury deaths were due to MVA and unintentional falls; likewise, 40% of MVA and unintentional falls resulted in nonfatal injuries.[5]

The Abbreviated Injury Scale (AIS) is widely used for assessment of overall severity of body injury, and triage patients efficiently in the emergency department (ED).[6] Several studies have analyzed the impact of obesity on severity and specific injury predispositions due to MVA using this scoring system.[4,7-14] Although AIS grades individual regions according to the severity from minor to maximum, it does not reflect specific description of injury in each region. In the case of cervical spine injury, the type of fracture pattern and spinal cord injury (SCI) cannot be determined from the AIS score. Therefore, the knowledge on impact of obesity on severity of cervical spine injury is limited from prior trauma studies. Previously, Rao *et al*. found higher body mass index (BMI) was associated with extension fracture patterns in the upper thoracolumbar spine.[15] Such an analysis has not been extended to the cervical spine.

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The objective of our study was to study the impact of BMI on severity of cervical spine injury after adjusting for injury and patient-related variables. This information will be useful for providers in the ED to ascertain the risk of severe cervical spine injury due to patient's BMI. In addition to risk estimation, fracture pattern, SCI, and patient-specific comorbidities are among important considerations in deciding treatment strategy.[16,17]

PATIENTS AND METHODS

A retrospective cohort study design was used to study patients with traumatic cervical spine fracture presenting to a Level I trauma center between January 1, 2010, and December 31, 2014. Patients were selected per the following inclusion criteria: (i) traumatic injury that resulted in sub-axial cervical spinal fracture, (ii) patient age 18–80 years, (iii) availability of cervical computed tomography (CT) scan, (iv) complete health record of patient clinical and injury characteristics. Patients were excluded if they had isolated atlantoaxial injury or did not have a cervical CT scan. Patients who had suspected pathological fracture were also excluded.

Approval from the Institutional Review Board was taken before identifying patients for data collection. Review of electronic medical records was done to collect patient information such as age, gender, race, BMI, smoking status, comorbidities, mechanism of injury, cervical SCI, and injury to other organ systems. Significant injury to other systems (head, thorax, abdomen, thoracolumbar spine, pelvis, and extremities) was determined if injury to internal organs or musculoskeletal tissues warranted further investigation or intervention. Details of injury that were collected included fall height for falls, location of impact (near/front or far/rear sided), ejection status, speed, vehicle type, rollover, and protective measures including helmet or seatbelt use for MVAs.

CT scans of the cervical spine were assessed by an observer blinded to clinical information. Morphology of the fracture was graded according to the AO spine subaxial cervical spine classification [Table 1].[18] Cervical spine injuries were categorized as severe (S) if they had burst fracture involving both endplates, tension band injuries, and dislocation injuries (Types A4, B0, B1, B2, B3) and/or associated SCI. Injuries with insignificant fractures or single endplate burst morphology (Types A0, A1, A2, A3) and no SCI were categorized as less severe (LS) for our analysis [Table 2 and Figures 1, 2].

Descriptive analysis of the patient cohort has been done. The association between BMI and severity of cervical spine fracture was studied by multiple-variable logistic regression analysis using a conditional step-wise backward elimination model. The dependent variable was severity of injury with LS fracture serving as reference. Independent variable of interest included BMI which was entered as a continuous variable and forced to be in the model at all steps. Other covariates included in the model included age, gender, ethnicity, smoking status, medical comorbidities, mechanism of injury, and other significant organ system injury. All variables were initially entered in the model, and backward elimination removal criteria were set at $P > 0.1$. Regression analysis was carried out in SPSS v24.0 (IBM® SPSS® Statistics, IBM Corp., Armonk, NY, USA).

RESULTS

A total of 751 patients with cervical spine fracture were identified, out of which 291 patients met our inclusion criteria and had adequate records available for analysis. The mean age of included patients was 46.1 ± 19.3 years and 212 patients (75.8%) were male [Table 3]. The average BMI of the cohort was 26.1 ± 5.4 kg/m^2 (range: 18.0–36.4 kg/m^2). The most common fracture sustained was an isolated

Table 1: AO Spine subaxial cervical spine fracture morphological classification

Type	Subtype	Description
A (compression injuries with intact tension band)	A0	No bony or minor injury such as an isolated lamina or spinous process fracture
	A1	Compression fractures involving a single endplate without involvement of the posterior wall of the vertebral body
	A2	Coronal split or pincer fractures involving both endplates without involvement of the posterior aspect of the vertebral wall
	A3	Burst fractures involving a single endplate
	A4	Burst fracture or sagittal-split injury involving both endplates
B (tension band injuries)	B0	Posterior tension band injury (bony): Primary physical separation through fractured bony structures only
	B1	Posterior tension band injury (bony, capsuloligamentous, ligamentous): Complete disruption or separation of the posterior capsuloligamentous or bony capsuloligamentous structures
	B3	Anterior tension band injury: Physical disruption or separation of the anterior structures (bone/disk) with tethering of the posterior elements
C (translational injury)		Injuries with displacement or translation of one vertebral body relative to another in any direction

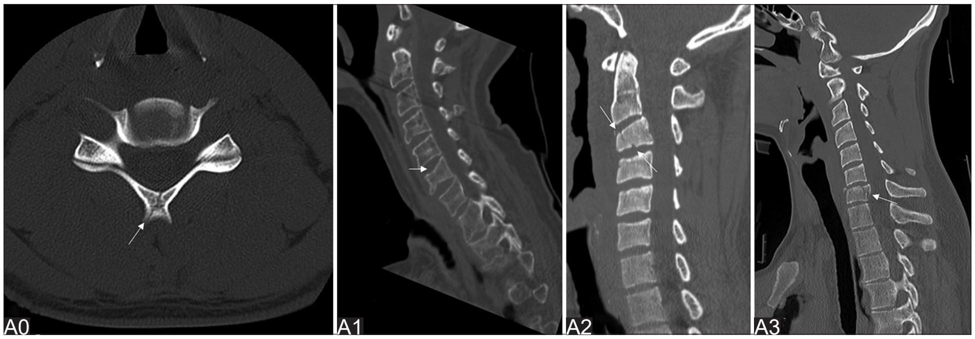

Figure 1: Representative images in patient cohort showing the classification of less severe fracture Types (A0, A1, A2, A3)

Figure 2: Representative images in patient cohort showing the classification of severe (S) fracture Types (A4, B2, B3, C)

Table 2: Classification of severity of cervical spine injury based on the fracture morphology and spinal cord injury

	LS	S
Fracture morphology	A0, A1, A2, A3	A4, B1, B2, B3, C
SCI	Absent	Present

LS - Less severe; S - Severe, SCI: Spinal cord injury

fracture of the spinous process or lamina (Type A0) in 184 patients (63.2%). A fracture resulting in translational injury (Type C) was seen in 52 patients (17.9%). The distribution of fracture types according to morphology has been given in Figure 3. Out of all patients, 34 (11.7%) had associated SCI. All patients with SCI had an associated severe fracture type. Based on the morphology of fracture and SCI, 106 (36.4%) were categorized as severe (S) injury. The remaining 185 (63.6%) patients were classified as LS injury.

Injury to other organ systems was present as follows: head ($n = 75$, 25.8%), thorax ($n = 69$, 23.7%), abdominal ($n = 6$, 2.1%), thoracic or lumbar spine fracture ($n = 64$, 22.0%), pelvis ($n = 16$, 5.5%), and extremities ($n = 44$, 15.1%). MVA was the most common injury mechanism ($n = 177$, 60.8%) followed by fall from height ($n = 85$, 29.2%) and random traumatic events ($n = 29$, 10.0%). Injury-related characteristics have been given in Table 4.

Our multiple-variable logistic regression model found that increasing BMI was not associated with a likelihood of severe cervical spine injury after adjusting for other clinical and injury parameters (odds ratio [OR] 1.03, 95% confidence interval [CI]: 0.97–1.08, $P = 0.34$). A subanalysis of MVA cases was done to include side of impact, rollover, protection, and ejection of the occupant as covariates in addition to other patient variables. Although trending toward significance, the OR of severe cervical spine injury due to increasing patient BMI was 1.08 (95% CI: 0.99–1.18, $P = 0.06$). In this analysis, the presence of rollover was also represented in the final model with OR 2.55 (95% CI: 0.98–6.66, $P = 0.06$).

DISCUSSION

Higher BMI has been shown to be a positive predictor of systemic injury and mortality, especially in MVA.[4,7-14] Some studies have reported the impact of weight on the odds of sustaining neck injury,[9,10] but none have incorporated specific fracture pattern and SCI in their analysis. Our primary objective was to study the impact of BMI on the severity of cervical spine injury as determined by fracture pattern and SCI. Knowledge of this relationship will help providers estimate significance of patient's BMI on the risk of sustaining severe cervical spine injury.

In our analysis, the overall incidence of severe cervical spine injury was approximately 36%. When considering all injury mechanisms, BMI was not significantly associated with severe cervical spine injury after adjusting for patient

Table 3: Demographic and clinical profile of patients with traumatic cervical spine fracture

	n (%)
Total patients	291 (100)
Age (years), mean±SD	46.1±19.3
Sex	
Female	79 (21.2)
Male	212 (75.8)
Race	
White	248 (85.2)
African American	24 (8.3)
Other (Hispanic, Asian)	19 (6.5)
BMI (kg/m^2), mean±SD	26.1±5.4
Tobacco/smoking	
Current	92 (31.6)
Former (quit>6 months)	68 (23.3)
Never	132 (45.1)
Comorbidities	
Diabetes	30 (10.3)
Chronic heart disease	57 (19.6)
Hypertension	48 (16.5)
Chronic lung disease	26 (8.9)
Mental health disorders (anxiety, depression, bipolar)	33 (11.3)
History of malignancy	22 (7.6)
Endocrine disorders	8 (2.7)
Gastrointestinal disorder	12 (4.1)
Kidney/renal disease	12 (4.1)
Chronic liver disease	4 (1.4)
Neurological disorders	5 (1.7)

BMI - Body mass index; SD - Standard deviation

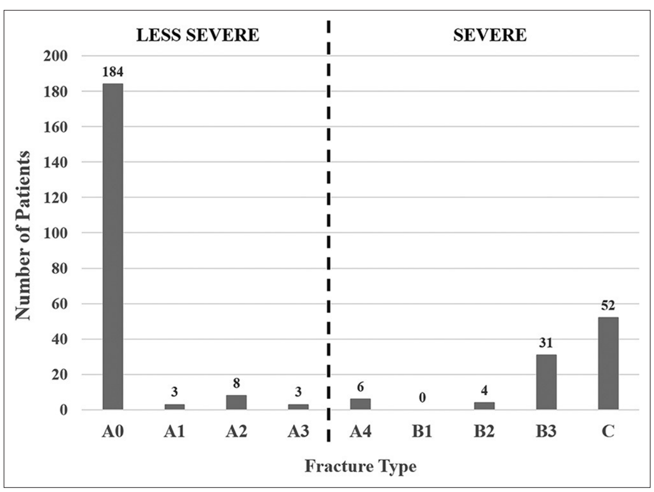

Figure 3: Distribution of patients according to the morphology of fracture

Table 4: Injury characteristics of patients with traumatic cervical spine fracture

	n (%)
MVA (60.8%)	
Protection	
Restrained/helmeted	67 (23.0)
Unrestrained/not helmeted	88 (49.7)
Unknown/not documented	24 (13.6)
Side of impact	
Near/front side	160 (90.4)
Far/rear side	9 (5.1)
Unknown/not stated	8 (4.5)
Rollover	
Yes	61 (34.5)
No	111 (62.7)
Not stated	5 (2.8)
Ejection from vehicle	
Yes	14 (7.9)
No	163 (92.1)
Ejection distance, mean±SD (m)	16.5±34.8
Fall from height (29.21%)	
Height, mean±SD (m)	2.5±2.2
Random traumatic events (9.97%)	
Struck by fast-moving objects	11 (37.9)
Diving injury	4 (13.8)
Physical assault	11 (37.9)
Sports-related injuries	3 (10.3)

SD - Standard deviation; MVA - Motor vehicle accident

and injury variables. A previous analysis by Funk *et al*.[9] found that higher BMI was associated with significant risk for moderate-to-severe neck injury after rollover MVA. They found the presence of AIS 2+ (moderate to severe) neck injury in 1.3% of their MVA cohort, although the determination of fracture type and SCI is not possible from their analysis. In another study of MVA rollover crashes, Hu *et al*.[10] found that age, weight, and number of quarter turns were significant predictors of serious neck injury (AIS 3–6). In our subanalysis of patients involved in MVA, the association between BMI and severity of cervical injury was trending toward significance.

There are some key differences between studies using MVA databases and our retrospective cohort analysis. First, MVA crash data studying neck injury is limited to only rollover MVAs.[9,10] Therefore, their findings may not be extrapolated to nonrollover MVAs. An advantage of our study is that we included all possible injury types. Of all MVAs, rollover was documented in approximately 35%. We also found an association between rollover and severe cervical spine injury, which was trending toward significance. Our findings may not have achieved significance due to sample size despite incorporating 5 years of data. Biomechanically, neck injuries during rollover MVA occur due to vertical deformation rather than lateral deformation. As a result, patients with higher BMI apply more torso loading to the neck resulting in greater risk of cervical spine injury.[9,10] Taken together, all these results may indicate that the impact of BMI may be more significant in rollover MVA than nonrollover or other injury mechanisms. We have used a widely accepted classification system of cervical spine fractures and the presence of SCI to determine severity. As these factors are important in deciding treatment strategy, incorporating the impact of BMI on these parameters will be useful in clinical decision-making. While AIS is a widely accepted system to triage patients in the ED, it has limited ability to convey specific injuries, especially fracture patterns in spine injuries.

There are several limitations to our study. First, it is a retrospective analysis with small sample size from a single institution with the BMI average for this study cohort being lower than the general population in the United States (29.6 kg/m^2 females, 29.1 kg/m^2 males).[19] A significant number of patients were excluded due to inadequate data. It may be difficult to extrapolate our findings to other geographic regions and/or nationally. As an example, our study population had a large representation of White ethnicity (85.2%) as compared to the African-American, Hispanic, Asian, and other races, which may not be consistent with other geographical areas and overall US population. The documentation of injury-related parameters was not uniform, and all variables may not be powered to achieve significance. Although we have included some details on MVA, we were unable to run a robust adjustment of variables as has been done from crash database studies.[9,10] Assessment of treatment strategy and its outcome was beyond the scope of this study. Despite these limitations, we believe our results add meaningful data to the limited evidence available.

CONCLUSION

Our findings indicate that patients with higher BMI may be predisposed to more severe cervical spine fracture and/or SCI after MVA, especially when rollover is present. The same risk may not be present in other common modes of injury such as nonrollover MVA and falls. Further prospective studies with larger sample size, use of clinically relevant outcome parameters (fracture classification, neural deficit), and comprehensive measurement of injury-related variables may be helpful to corroborate our findings.

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Conflicts of interest

There are no conflicts of interest.

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