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A Review of Cervical Spine Injury Associated with Traumatic Brain Injury: Prevalence, Etiology, and Injury Characteristics

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Abstract: Traumatic Brain Injury (TBI) is commonly associated with other injuries such as cervical spine injury (CSI) which critically affects TBI patients, interfering with airway management techniques, selection of proper radiological studies, and the management approach of both the TBI and the CSI. This study aims to assess the prevalence, etiology, and characteristics of CSI in patients who sustained TBI. Also, we will investigate other associated injuries in patients experienced combined TBI and CSI, and their effects on patients' mortality and course of hospitalization. The study was conducted in the health information management (HIM) department. The charts of all adult (>14 years old) patients with TBI presenting to the emergency department (ED) at King Abdulaziz Medical City in Jeddah or referred from other hospital over a four years period (January 2013 to December 2016) were reviewed. 220 patients with traumatic brain injury were included in the study. Most of the patients were young adult (median age 29 years). In 185 of the 220 patients (84.1%), a diagnosis of cervical spine injury was ruled out on the basis of the clinical presentation and computed tomography scans reports. in the remaining 35 patients, cervical spine injury was confirmed with the prevalence of 15.9%. The rate of cervical spine injury was highest among young adult (men greater than women) who sustained motor vehicle related injury, and usually associated with thoracic, thoracolumbar trauma and abdominal injury that only explained by mechanism of injury.

Keywords: Cervical spine injury, Traumatic brain injury, cervical spine fracture, head injury.

INTRODUCTION

Traumatic brain injury (TBI) is a major public health problem, and has been documented to be linked with significant morbidity and mortality in all age groups. TBI defined as an insult to the brain caused by an external force, leading to temporary or permanent impairment of cognitive, physical, and psychosocial functions, with an associated altered level of consciousness [1]. This type of trauma is commonly associated with other injuries such as cervical spine injury (CSI) which critically affects TBI patients, interfering with airway management techniques, selection of proper radiological studies, and the management approach of both the TBI and the CSI [2]. The reported incidence of CSI in patients with head trauma, regardless of the age ranges from 5 to 10% that rises with the severity of head injury measured by Glasgow Coma Scale (GCS) [2,3]. Moreover, few risk factors have been addressed in patients sustained both TBI and CSI including etiology, characteristics and locations of CSI, and other associated injuries [4,5]. Identifying such risk factors will be particularly useful in early diagnosis and management of such trauma, which may be difficult to recognize due to an altered state of consciousness, and the overall critical nature of the trauma. Failure to detect unstable CSI during initial evaluation may worsen the neurological consequences as being reported [5]. This study aims to assess the prevalence, etiology, and characteristics of CSI in patients who sustained TBI. Also, we will investigate other associated injuries in patients experienced combined TBI and CSI, and their effects on patients' mortality and course of hospitalization.

METHODOLOGY

This is a cross-sectional study that was aimed at determining the prevalence of cervical spine injury (CSI) among patients older than 14 years of age who were hospitalized due to traumatic brain injury (TBI). The authors assure the integrity of the data, accuracy of the analyses, and the suitability of the study to the protocol. The protocol was approved by the institutional review board at the same institution. Moreover, the level of TBI was measured clinically by first post-resuscitation Glasgow Coma Scale (GCS) score. Also, TBI was confirmed radiologically by computed tomography (CT) in all patients. All patients were managed by a multidisciplinary team approach and then admitted to surgical ward at the same institution. Reason for hospital admission was mainly multi-trauma including their TBI. Patients were excluded if they had had previous history of CSI.

The study was conducted in the health information management (HIM) department. The charts of all adult (>14 years old) patients with TBI presenting to the emergency department (ED) at King Abdulaziz Medical City in Jeddah or referred from other hospital over a four years period (January 2013 to December 2016) were reviewed. All data were collected from patients' records and "Centricity" database for radiological imaging details with the help of hospital information coding service. The diagnosis of TBI for each patient was prespecified in the study protocol and was based on clinical history *and* computed tomography (CT) scan results. Charts were reviewed and data was obtained that included demographic data, the presence of traumatic brain injury, the presence of other associated injuries with the trauma, and medical complications during hospital staying. In patients who had sustained CSI, more detailed data were documented regarding the morphology and location of CSI.

Pre-hospital management depends primarily on the severity of head injury, other associated injuries including CSI, and patients' cardiopulmonary stability. All patients were maintained in a spinal backboard, a rigid cervical collar, and supportive blocks placed on both sides of the head if CSI is suspected. During initial presentation to the ER a rapid establishment of an airway and maintained circulation were ensured. The presence or absence of cervical spine injury was assessed with the use of computed tomographic (CT) scan available in emergency department as per hospital protocol. The scans were interpreted by qualified radiologists and the location and distribution of cervical spine injury were documented. All patients with moderate or severe TBI were managed medically in the intensive care unit (ICU) after stabilization or after surgical intervention if indicated.

All patients who fulfilled study's criteria and presented to emergency department during the determined period were involved in the study. The prevalence of cervical spine injury and the associated injuries were calculated for the entire group of patients. To compare the baseline characteristics between patients with and those without cervical spine injury, we used the Chi-square test and Fisher's Exact test for categorical variables and Student's t-test for continuous variables. Odds ratios and P-values were calculated with 95% confidence intervals. All calculations were performed with the use of SPSS software, version 23.0 (SPSS).

RESULTS

Prevalence of cervical spine injury

A total of 292 patients admitted to the emergency department with traumatic brain injury. Out of 292 patients who were admitted, 41 presented with alteration level of consciousness that turned to be non-traumatic in origin or 31 did not have complete information in their records. Therefore, 220 patients with traumatic brain injury were included in the study. The main demographic and clinical characteristics of the patients are provided in *Table 1*. Most of the patients were young adult (median age 29 years). In 185 of the 220 patients (84.1%), a diagnosis of cervical spine injury was ruled out on the basis of the clinical presentation and computed tomography scans reports. in the remaining 35 patients, cervical spine injury was confirmed with the prevalence of 15.9%.

CSI morphology and location in TBI patients

Among the 35 patients in whom cervical spine injury was detected by computed tomography, the lower cervical C3-C7 were the most frequently injured segments, which were demonstrated in 22 (62.86%), 19 of them were isolated lower segments injury, and the remaining three patients were combined with upper cervical C1-C2 segment injury. The most common morphology of CSI was *lateral mass fracture* that was present in 11 (31.43%) patients, and prominent in the *upper segment* (C1-C2). *Transverse process* fracture follows that, seen in ten (28.57%) patients and commonly in the *lower segment* (C3-C7). Transverse foramen fractures were documented in eight (22.85%) patients and frequently in the lower segments (C3-C7), with percentage similar to odontoid fracture except that the latter is usually seen in upper segments (C1-C2). Articular facet fractures were reported seven (20%) times and all of them were present in the lower segments (C3-C7). Cervical spine fracture–subluxations were present in six (17.14%) patients half are associated with articular facet fracture and no one experienced subluxations without fractures. Pedicle fractures were seen in 4 patients recurrently in the lower segments (C3-C7), and also four (11.43%) patients had lamina fractures and all were in the lower segments (C3-C7). In the lower segments (C3-C7), teardrop fractures were seen in three (8.57%) patients, spinous process fractures were described in two (5.71%) patients and anterolithesis existed in one (2.86%) patient.

Other associated injury with traumatic brain injury

Other associated injuries were present in 150 of the 220 patients who had head injury (68.2%). Among all patients involved in the study the prevalence of the associated injuries are described in *Table 1*. The prevalence of facial was higher among the patients with cervical spine injury than among the patients without cervical spine injury, as were the prevalence of thoracic trauma, rib fractures, thoracolumbar fractures and abdominal injury. Of the 35 patients with cervical spine injury, five (14.3%) had no other associated injuries.

The odd ratio (OR) of having other associated injuries with CSI were statistically insignificant for facial, upper limb and lower limb fractures. However, thoracic trauma, rib fractures, and abdominal injury associated with significantly higher odds of cervical spine injury. There was significant difference in length of hospitalization in patient sustained CSI compared with patients without CSI. When investigating the mortality of CSI patients compared with non CSI, it was not significant, but their odds were higher when patients have several associated injuries. There were 17 deaths among all patients, five of them sustained CSI. One patient had severe upper segment injury stayed in the ICU for six days before he died. The other four were poly-trauma patients and their CSI accompanied by four or more other injuries including abdominal injury in three patients.

Table-1: Demographics and injury characteristics in 220 patients with traumatic brain injury

Characteristics	All TBI Patients (N = 220)	CSI Confirmed (N = 35)	CSI Ruled Out (N = 185)	Odds Ratio (95% CI)	P Value
Gender					
Male sex — no. (%)	194 (88.2%)	29 (82.9%)	165	0.586	0.212*
Female sex — no. (%)	26 (11.8%)	6 (17.1%)	20	1.707	0.212*
Age (in years)					
Median (interquartile range) — yr.	29 (23)	32 (24)	28 (23)		
Level of TBI					
Mild (GCS: 13-15)	94 (42.7%)	11 (31.43%),	83 (44.9%)	0.563	0.141
Moderate (GCS: 9-12)	32 (14.5%)	4 (11.43%)	28 (15.1%)	0.724	0.568
Severe (GCS: 3-8)	94 (42.7%)	20 (57.14%)	74 (40%)	2.000	0.060
Etiology					
Motor vehicle accident	170 (77.2%)	35 (100%)	135 (73%)	1.259	0.001
Motorcycle accident	7 (3.2%)		7 (3.7%)		
Fall	29 (13.2%)		29 (15.7%)		
Car/pedestrian accident	7 (3.2%)		7 (3.7%)		
Physical assaults	3 (1.4%)		3 (1.6%)		
Unclassified direct trauma	4 (1.8%)		4 (2.2%)		
Associated injuries					
Facial trauma	65 (29.6%)	14 (40%)	51 (27.6%)	1.752	0.139
Injuries to upper limbs	52 (23.6%)	9 (25.7%)	43 (23.2%)	1.143	0.752
Thoracic trauma	58 (26.4%)	14 (40%)	44 (23.9%)	2.136	0.046
Fractures of lower limbs	30 (13.6%)	5 (14.28%)	25 (13.5%)	1.067	0.540*
Hip fracture	20 (9.1%)	5 (14.28%)	15 (8.1%)	1.889	0.194*
Rib fractures	35 (15.9%)	14 (40%)	21 (11.4%)	5.2	0.001
Thoracolumbar fractures	38 (17.3%)	7 (20%)	31 (5.9%)	1.242	0.642
Abdominal injury	7 (3.2%)	4 (11.4%)	3 (1.6%)	7.828	0.013*
Complications					
Pneumonia	8 (3.64%)	2 (5.71%)	6 (3.2%)	1.808	0.372*
Urinary tract infection	3 (1.37%)		3 (1.6)		
Sepsis	3 (1.37%)	1 (2.86%)	2 (1.1%)	2.691	0.407*
Respiratory failure	2 (0.91%)	1 (2.86%)	1 (0.5%)	5.412	0.293*
DVT/PE	9 (4.09%)	2 (5.71%)	7 (3.8%)	1.541	0.434*
Seizure	4 (1.81%)		4 (2.2%)		
Hospital course					
Mean — days	32	69	24		
Need for ICU admission — no. (%)	135 (61.4%)	30 (85.7%)	105 (56.8%)	4.571	0.001
Deaths — no. (%)	17 (7.7%)	5 (2.3%)	12(6.4%)	2.403	0.111*

*P values in these cohorts were calculated using Fisher's Exact Test.

DISCUSSION

Data about the prevalence, demographic, level of traumatic brain injury and etiology of cervical spine injury is useful in approaching high risk patients with traumatic brain injury in emergency department. Our study used medical records and computed tomography CT scans of these patients and showed a high prevalence of cervical spine injury; that was confirmed in approximately one of every six patients (15.9%). Not surprisingly, young males with motor vehicle related injury were more likely to have cervical spine injury, as were those with severe head injury. However, the proportion of patients who sustained cervical spine injury, and did not show the previous features was not negligible.

The high prevalence of cervical spine injury among our patients with traumatic brain injury contradicts with that reported elsewhere [5-7] . It should be noted, recent studies did not account for the difference in age between children and adults, and the clinical distinct entity of pediatrics' cervical spine and skull injuries resulting from trauma. Also, they did not include patients who sustained mild traumatic brain injury which may have resulted in a potential underestimation of the prevalence when their cervical spine injury go undetected, because of a low energy mechanism type injury. In contrast, our study involved adult patients; all of them underwent computed tomography for diagnosis of cervical spine injury, regardless of level of traumatic brain injury suggested clinically.

Our study reported high proportion of cervical spine injury in young adult, that is not statically significant compared to elderly patients. Unexpectedly, a study found older patients had significantly higher risk of developing cervical spine injury in motor vehicle related injury, but with falls the effect of age was not significant [7]. However, this may be explained by both high-energy trauma and age-associated cervical spondylosis that predisposes the elderly patients to develop cervical spine injury. Although the severity of traumatic brain injury proportionally related to cervical spine injury, clinical GCS score should not be used as a predictor of the probability of concomitant cervical spine injury due to its imprecision that can be affected by other factors e.g. drugs such as alcohol and sedatives, and/or intubation.

Several studies showed an overall interaction between CSI and injury mechanism, and found patients with vehicular-related head trauma were significantly more likely to have sustained CSI than those who suffered non-vehicular-related trauma [5,8]. This can be attributed to the excessive force directed to the skull and then transmitted to the cervical spine, or affecting the cervical spine directly. Particularly, when a safety belt is not fastened, the passenger is susceptible to secondary cervical spine trauma as the head is easily hyperflexed or hyperextended by a collision with structure inside the vehicle such as the windshield or steering wheel [9,10].

The association of cervical spine injury in patients sustained head injury TBI is anticipated because of the distinctive anatomical location. Unexpectedly, we found that the lower segments (C3-C7) were more likely to be affected in trauma than the upper segments (C1-C2). However, this contrasts those studies that suggested upper CSI was more likely injured [5,6,8]. Anatomically, the articulating margins of the atlas and axis are more horizontal in orientation than in the remainder of the cervical spine. The axis forms the pivot upon which the first cervical vertebra (the atlas), rotates. These features allow a wide range of rotating motion but susceptible to certain traumatic forces [11]. Hence, any axial force tends to impose stress upon atlas's weakest point at the junction of anterior arch and the lateral mass. This may explain that lateral masses are common to be injured in upper segments as we described.

When other injuries occur alongside with traumatic brain injury, it may result in higher morbidity, impair quality of life, and increase length of hospitalization. Hence, our secondary objective is to characterize these individuals and investigate the possible risk factors. The Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) are usually used for rating the severity of injury in poly-trauma patients. An AIS method is based on six anatomic regions of injury, including head/neck, face, thorax, abdomen, extremity and external soft tissue [12,13]. ISS, determined by rating each injury with the AIS, was proved to correlate significantly with mortality for the most severe injured cases [14]. Unfortunately, we could not find the documented AIS or ISS for the patients in this study. However, we categorized the other associated injuries into eight groups detailed in *table 1* based on computed tomography findings. An association between facial injuries and cervical spine injury was commonly expected, but cohort showed the association was not statically significant, as well as for upper and lower extremities fractures. However, rib fractures, thorax trauma and abdominal injury were associated with significantly higher odds of cervical spine injury. This confirms out the idea that mechanism of injury is the most important predictor of cervical spine injury in patients with traumatic brain injury.

Few limitations in our study needed to be documented. First, data were collected from medical record department in non-random method. Second, patients were included in the study if they were admitted to the hospital after being examined in the emergency department for traumatic brain injury. As a result, this study did not include patients who visited the emergency department but for whom hospitalization was not considered necessary. Third, several patients were referred from other local hospitals to our center due to the severity of their injuries that may contributed to the overall high number of prevalence and the increased rate of complications. Fourth, Crashworthy systems and devices also impact injury risk in trauma patients. Therefore, adjusting for this confounding factor might affect the association between traumatic brain injury and cervical spine injury. Finally, we did not collect information on management decisions and patient follow-up after completion of the diagnosis of cervical spine injury because this was not a study objective.

CONCLUSION

In conclusion, among adult patients who were hospitalized for traumatic brain injury and who, cervical spine injury was confirmed in 15.9% commonly in the lower segment (C3-C7) of the cervical vertebrae. The rate of cervical spine injury was highest among young adult (men greater than women) who sustained motor vehicle related injury, and usually associated with thoracic, thoracolumbar trauma and abdominal injury that only explained by mechanism of injury. Complete and rapid cervical spine evaluation is required in these patients. In this regards, investments in raising awareness of the importance of traffic laws and the use of safety equipment are vitally important.

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Declarations

List of abbreviations

TBI =Traumatic brain injury
CSI = Cervical spine injury
GCS = Glasgow comma scale
CT = computed tomography
HIM = health information management
ER = emergency department
ICU = intensive care unit
AIS = The Abbreviated Injury Scale
ISS = Injury Severity Score

Ethics approval and consent to participate: The research was approved by IRB in the same institution with reference number SP16/322/J.

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Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Authors' contributions: AZ collected the data, ensured their entry and analysis, also was a major contributor in writing the manuscript. AJ supervised AZ and had a major role in editing and drawing the conclusions. FB analysed the data and helped in interpreting it. MA helped in collecting data and manuscript synthesis. SS helped the students in radiological findings and participated in manuscript synthesis. All authors read and approved the final manuscript.

Endnotes: Not applicable.

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