Traumatic Brain Injury Cases' Mortality Predictors, Association, and Outcomes in the Emergency Department at a Tertiary Healthcare Center in Saudi Arabia

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Abstract

Aim Incidence of traumatic brain injury (TBI) in Saudi Arabia has been estimated to be 116 per 1,00,000 population as incidence of TBI continues to rise in our region. We aim to study the demographics, mortality predictors, and factors influencing the outcome of TBI cases in a tertiary care center in Jeddah, Saudi Arabia.

Materials and Methods We retrospectively collected data from all consecutive patients treated at the Emergency Department of King Abdulaziz Medical City including all acute TBI adult cases (>18 years) from 2016 to 2019. Logistic regression models were used to identify significant predictors of mortality. A total of 423 individuals with TBI were enrolled in the study. Nearly, half of them were in age group of 18 to 29 (40.77). Most patients were males (76.83%).

Results Injuries were most commonly mild-to-moderate TBI (73.83%). Road traffic accident was the most common mechanism of injury (49.7%) followed by fall (39.5%). Most common mode of transportation was private cars (47.57%). Most patient required less than or equal to 24 hours of admission (61.23%). A total of 30 (7%) died in the hospital all of which were male with no death cases reported among females.

Conclusion In conclusion, this study reports a mortality rate related to TBI that is among the lowest in the region. Injuries were male predominant with more balanced male to female ratio. Patients who were delivered to the hospital via private cars had an improved survival. These finding should be interpreted in the context of retrospective noncontrolled study design, and further future studies are encouraged to consolidate these findings.

Keywords
► traumatic brain injury outcomes
► emergency department
► Saudi Arabia

Introduction

Traumatic brain injury (TBI) is the leading cause of mortality and long-term disability, particularly in younger people worldwide.[1] Road traffic accidents (RTAs) mostly affect young males, ranking first among the causes of disability-adjusted life in the age group of 10 to 49 years.[2] Trauma patients with head injury have a 10-fold higher mortality than in those without it.[3] Incidence of TBI is still globally increasing due to the wider use of motor vehicles in low-middle income countries with a notable increase in fall-related injuries among older people in high-income countries.[4] Reported global incidence of TBI ranges from 150 to 315 cases per 1,00,000 inhabitants.[5] Incidence of TBI in Saudi Arabia has been estimated to be 116 per 1,00,000 population.[6] The global prevalence of TBI continues to peak in males reflecting the gender differences in social roles and behaviors.[5]

TBI is one of the important causes of preventable deaths in Saudi Arabia.[6] It poses a serious problem for public health due to its high incidence rate, its associated economic burden, its high mortality rate, and disabling sequel.[5] Prognosis of patients with TBI varies; multiple studies attempted to identify predictors of outcome in these patients to guide preventive strategies and implement protective measure aiming to reduce the disease burden. In this study, we aim to study the mortality predictors of TBI, the association between TBI and age, gender, and other variables, as well as assessing the outcome of TBI cases presented to the emergency department of a tertiary medical facility in King Abdul Aziz Medical City—National Guard Western Region.

Methodology

This is a retrospective cross-sectional chart review that included all acute TBI adult cases ($>$18 years) presented to the Emergency Department of King Abdul Aziz Medical City—National Guard Western Region Jeddah, Saudi Arabia, from July 2016 to June 2019. Patients were identified through a hospital information system (BEST Care) and hospital data and business intelligence department. Studied variables included year of admission, age, gender, heart rate, respiratory rate, blood pressure, injury mechanism, mode of transportation, type of injury, associated injury, radiology findings, hospital length of stay (LOS), and Glasgow Coma Scale (GCS) that were used to classify the severity of TBI.

Statistical Analysis

Descriptive statistics were used to identify differences in demographic, clinical characteristics, and outcome variables among patients with mild-to-moderate and severe brain trauma. For categorical variables, comparisons were made using chi-squared tests (χ^2) or Fisher's exact tests if any expected cell size was less than 5 and considered a p-value below 0.05 to be statistically significant; all tests were two sided. We first obtained univariate unadjusted esti-mates of the observed associations and then performed multivariate logistic regression models adjusted for potential confounders. A univariate binary analysis was used to identify the variables associated with hospital mortality (►**Table 1**). Only significant associated variables were included in multivariate analysis. Multivariate binary exact logistic regression models were used if any expected cell size was zero. Logistic regression models were used to examine the association of TBI and mortality, and to identify significant predictors of mortality. A p-value less than 0.05 was considered statistically significant for the multivariate analyses. All logistic regression models were adjusted for gender, GCS, injury mechanism, epidural hematoma, skull fracture, associated injury, mood of transportation, LOS, and cerebral hemorrhagic contusions. The magnitude of the association between the outcome and the independent variables was measured by the odds ratio (OR) and respective 95% confidence interval (CI). Multi-co-linearity effect of examined explanatory variables was ruled out using variance inflation factors. All statistics were performed using SAS 9.4.

Results

A total of 423 individuals with TBI were enrolled into the study. Nearly, half of the TBI patients were in age the group of 18 to 29 (40.8%). More than two-third of TBI patients were male (76.8%) with mild-to-moderate TBI (73.3%). RTA was the most common mechanism of injury (49.7%) followed by fall (39.5%). Nearly half of the patients were delivered to hospital by private car (47.57%). More than half of the TBI population spent less than a day in the hospital (61.23%). Most of the injuries were blunt (96.45%). Similar proportions of injured individuals were diagnosed with cerebral hemorrhagic contusions, epidural hematoma, and skull fracture (20.57, 20.57, and 22.46%), respectively. The most common associated injury was thoracic trauma (21.99%) followed by face or neck (13.59%). And a total of 30 (7.09%) patients reported noted to be younger, between the age of 18 to 29 (p-value $<$ 0.05) years, sustained RTA as the mechanism of injury (p-value $<$ 0.0001), had an associated intrathoracic injury (p-value $<$ 0.0001), was transferred by ambulance (p-value $<$ 0.0001), and had longer hospital stay more than 10 days.

Individuals with severe TBI were more likely to diagnosed with cerebral hemorrhagic contusions, epidural hematoma, and skull fracture (p-value $<$ 0.0001) and died at the hospital (p-value $<$ 0.0001) than those with mild-to-moderate TBI (►**Table 2**). There was no death among female; all deaths were noted among males (p-value $<$ 0.0003). There was no significant difference in admission year, respiratory rate, and initial blood pressure rate between mild-to-moderate and severe TBI (►**Table 2**).

In univariate analyses, the potential predictors of in-hospital mortality among individuals with severe TBI, there was a significant association between gender and mortality (p-value $<$ 0.0018). Similarly, associated injury (p-value $<$ 0.0021), injury mechanism (p-value $<$ 0.0013), mood of

Table 1 Association between mortality and severe TBI in KAMC (2016–2019) (univariate analyses)

	Dead, n (%)[a]	Alive, n (%)	p-Value[c]
Age			0.62
18–29	14 (46.67)	166 (42.24)	
30–49	10 (33.33)	105 (26.72)	
50–69	3 (10)	68 (17.3)	
70+	3 (10)	54 (13.74)	
Gender			0.0018
Male	30 (100)	295 (75.06)	
Female	–[b]	98 (24.94)	
Injury mechanism			0.0013
Fall	4 (13.33)	163 (41.48)	
MVA	16 (53.33)	145 (36.90)	
Pedestrian	7 (23.33)	30 (7.63)	
Other mechanism	3 (10)	55 (13.99)	
Associated injury			0.0021
Abdomen	2 (6.67)	9 (2.29)	
Face and neck	2 (6.67)	57 (14.5)	
Thorax	14 (46.67)	79 (20.1)	
None	12 (40)	248 (63.1)	
Mode of transportation			< 0.0001
Ambulance	26 (86.67)	147 (37.4)	
Private car	4 (13.33)	193 (49.11)	
Not mentioned	–	53 (13.49)	
Length of hospital stay			< 0.0001
One day or less	6 (20)	253 (64.38)	
2–10 days	18 (60)	76 (19.34)	
More than 10 days	6 (20)	64 (16.28)	
Admission year			0.34
2016	10 (33.33)	90 (22.9)	
2017	12 (40)	142 (36.13)	
2018	8 (26.67)	148 (37.66)	
2019	–	13 (3.31)	
Type of injury			0.94
Blunt	29 (96.67)	379 (96.44)	
Penetrating	1 (3.33)	29 (96.67)	
Cerebral hemorrhagic contusions			< 0.0001
Yes	23 (76.67)	80 (20.36)	
No	7 (23.33)	313 (79.64)	
Epidural hematoma			< 0.0001
Yes	17 (56.67)	70 (17.81)	
No	13 (43.33)	323 (82.19)	
Skull fracture			< 0.0001
Yes	20 (66.67)	75 (19.08)	
No	10 (33.33)	318 (80.92)	

Table 1 (Continued)

	Dead, n (%)[a]	Alive, n (%)	p-Value[c]
Glasgow Coma Scale			< 0.0001
Mild-to-moderate TBI	7 (23.33)	356 (90.59)	
Severe TBI	23 (76.67)	37 (9.41)	

Abbreviations: KAMC, King Abdulaziz Medical City; MVA, motor vehicle accident; TBI, traumatic brain injury.
[a]Row percentage.
[b]Represents zero cells.
[c]p-Value from chi-squared test (χ^2) for more than five subjects per cell and Fisher's exact test for less than five subjects per cell.

transportation (p-value < 0.0001), LOS (p-value < 0.0001), cerebral hemorrhagic contusions (p-value < 0.0001), epidural hematoma (p-value < 0.0001), skull fracture (p-value < 0.0001), initial blood pressure (p-value < 0.0001), respiratory rate (p-value < 0.013), and GCS (p-value < 0.0001) were all associated with mortality. No significant differences in, age, admission year, and type of injury were detected between nonsurviving and surviving individuals with TBI (►**Table 1**).

In multivariate analyses (►**Table 3**), the potential predictors of in-hospital mortality among individuals with TBI, age, gender, GCS, injury mechanism, associated injury, mood of transportation, LOS, cerebral hemorrhagic contusions, epidural hematoma, and skull fracture were evaluated. Severe TBI was associated with significantly increased odds of mortality in TBI (adjusted OR = 46.01, 95% CI: 10.31–205.22). Similarly, pedestrian, 2 to 10 days of hospital stay, more than 10 days of hospital stay, and those diagnosed with cerebral hemorrhagic contusions were associated with significantly increased odds of mortality in TBI (adjusted OR = 16.9, 95% CI: 1.6–246.82; adjusted OR = 5.67, 95% CI: 1.03–31.28; adjusted OR = 15.71, 95% CI: 3.54–69.73; and adjusted OR = 3.78, 95% CI: 1.1–12.94, respectively) (►**Table 3**).

Discussion

Injury severity is the most important predictor of short-term mortality following TBI.[7] GCS is the most widely used system for classifying TBI severity at the time of injury. A GCS score of 13 to 15 is classified as mild TBI, 9 to 12 as moderate TBI, and 3 to 8 as severe TBI.[8] In our study, the majority of the cases (73.83%) fell into the mild-to-moderate TBI category, which can explain the lower mortality rate observed in our sample (7%) compared with the global mortality rate (12.9%)[9] and the national rate reported in Saudi Arabia (up to 16.54%).[2] This figure is also among the lowest mortality rates reported in the region, slightly higher than the rate reported from the United Arab Emirates (6%)[3] and much below the rate reported Lebanon (31%).[10] Thus, most fatalities in our report were observed among the severe TBI group. Nonetheless, higher mortality rates were observed among severe TBI group in this study. Most patient required less than or equal to 24 hours of admission (61.23%) pertaining to the high

Table 2 Clinical characteristics and injury-related variables of mild-to-moderate and severe TBI in KAMC (2016–2019)

	Mild-to-moderate TBI, n (%)[a]	Severe TBI, n (%)	p-Value[c]
Age			0.005
18–29	148 (40.77)	32 (53.33)	
30–49	94 (25.90)	21 (35)	
50–69	65 (17.91)	6 (10)	
70+	56 (15.43)	1 (1.67)	
Gender			0.0003
Male	268 (73.83)	57 (95)	
Female	95 (27.17)	3 (5)	
Injury mechanism			< 0.0001
Fall	159 (43.80)	8 (13.33)	
MVA	123 (33.88)	38 (63.33)	
Pedestrian	29 (7.99)	8 (13.33)	
Other mechanism	52 (14.33	6 (10)	
Associated injury			< 0.0001
Abdomen	5 (1.38)	6 (10)	
Face and neck	54 (14.88)	5 (8.33)	
Thorax	61 (16.80)	32 (53.33)	
None	243 (66.94)	17 (28.33)	
Mode of transportation			< 0.0001
Ambulance	121 (33.33)	52 (86.67)	
Private car	192 (52.89)	5 (8.33)	
Not mentioned	50 (13.77)	3 (5)	
Length of hospital stay			< 0.0001
One day or less	251 (69.15)	8 (13.33)	
2–10 days	73 (20.11)	21 (35)	
More than 10 days	39 (10.74)	31 (51.67)	
Admission year			0.2106
2016	85 (23.42)	15 (25)	
2017	127 (34.99)	27 (45)	
2018	138 (38.02)	18 (30)	
2019	13 (3.58)	[b]	
Type of injury			0.3955
Blunt	394 (96.14)	59 (98.33)	
Penetrating	14 (3.86)	1 (1.67)	
Cerebral hemorrhagic contusions			< 0.0001
Yes	62 (17.08)	41 (68.33)	
No	301 (82.92)	19 (31.67)	
Epidural hematoma			< 0.0001
Yes	61 (16.80)	26 (43.33)	
No	302 (83.2)	34 (56.67)	
Skull fracture			< 0.0001
Yes	57 (15.70)	38 (63.33)	
No	306 (84.3)	22 (36.67)	

(Continued)

Table 2 (Continued)

	Mild-to-moderate TBI, n (%)[a]	Severe TBI, n (%)	p-Value[c]
Mortality			< 0.0001
Dead	7 (1.93)	23 (38.33)	
Alive	365 (98.07)	37 (61.67)	

Abbreviations: KAMC, King Abdulaziz Medical City; MVA, motor vehicle accident; TBI, traumatic brain injury.
[a]Row percentage.
[b]Represents zero cells.
[c]p-Value from chi-squared test (χ^2) for more than five subjects per cell and Fisher's exact test for less than five subjects per cell.

percentage of mild-to-moderate injuries, which were likely stable and admitted for observation. Moreover, a positive correlation was found between prolonged LOS and mortality (LOS ≥ 2 days).

Age, as an unmodifiable risk factor, can predict mortality and survival. Elderly TBI patients have higher rates of mortality and worse functional outcome than nonelderly, with higher death rates apparent in moderate-to-severe TBI cases. However, when adjusted for sex, and TBI severity, elderly cases did not differ from younger adult cases with respect to either short- or long-term risk of death following TBI.[7] We found no significant correlation between age and mortality in this report, an observation that could be attributed to limited number of elderly patients in this study. According to the Saudi Arabian General Statistics Authority report in 2020, youth and children represent more than two-thirds of the Saudi population. Saudi youth in the age group of 15 to 34 years represent the highest percentage of Saudi population among all age groups.[11] In this study, the majority of TBI cases were in the age group of 18 to 29 (40.77%) year, which is consistent with local and regional studies from the Middle East and Africa with regard to the most frequent age group at risk of TBI.[8,10,12] On the other hand, recent global reports from United States, Europe, and South Korea indicated a marked decline in the rates of motor vehicle accidents over the past few decades have. This, in turn, contributed to declines in TBI incidence and in TBI-related mortality among younger individuals. The demographic shift toward older age in TBI epidemiology that is observed in the developed world can also be attributed to aging population in that particular part of the world.[4,7,13–16]

The global prevalence of TBI continues to peak in males. Evidence suggests that males are 2.4 times more often to sustain a TBI in their lifetime than women, which is a reflection, in part, of their differing social roles and behaviors. For example, traffic incidents, violence, and sporting injuries are mostly related to more male-dominated activities.[5,8,17] Similar to the global observations in TBI, we report a male predominance among our study individuals, with a male:female ratio of approximately 3:1. Higher male-female

Table 3 Predictors of mortality in severe TBI (multivariate analyses)

	AOR	95% CI	p-Value[a]
Glasgow Coma Scale			
Mild-to-moderate TBI (Ref-)	–	–	–
Severe TBI	46.01	(10.31, 205.22)	<0.0001
Injury mechanism			
Fall	3.3	(0.28, 38.5)	0.34
MVA	2.3	(0.24, 22.4)	0.46
Pedestrian	16.9	(1.16, 246.82)	0.03
Other mechanism (Ref-)	–	–	
Associated injury			
Abdomen	1.9	(0.19, 20.9)	0.57
Face and neck	0.12	(0.01, 1.26)	0.07
Thorax	0.65	(0.17, 2.45)	0.52
None (Ref-)	–	–	
Mode of transportation			
Ambulance	0.95	(0.14, 6.36)	0.95
Private car (Ref-)	–	–	
Not mentioned	0.12	(0.21, 3.34)	0.95
Length of hospital stay			
One day or less (Ref-)	–	–	
2–10 days	5.67	(1.03, 31.28)	0.04
More than 10 days	15.71	(3.54, 69.73)	0.0003
Cerebral hemorrhagic contusions			0.03
Yes	3.78	(1.1, 12.94)	
No (Ref-)	–	–	
Epidural hematoma			
Yes	1.5	(0.46, 4.92)	0.49
No (Ref-)	–	–	
Skull fracture			
No (Ref-)	–	–	
Yes	1.7	(0.49, 5.8)	0.39

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; MVA, motor vehicle accident; Ref-, reference; TBI, traumatic brain injury.
[a]Exact logistic regression test.

ratio was reported from Saudi Arabia in the past, reaching up to 13:1, and reflecting the local driving regulations that restricted driving to males for decades.[18] In 2017 the ban on women driving was lifted and more women started to drive, explaining our lower male to female ratio observation in the current report. The effect of gender on mortality, outcome, and acute complications after severe TBI remains a controversial area of research. It has been suggested that a sexual dimorphism may exist which affects survival after TBI. The effects of specific hormones, like progesterone, was

hypothesized to have a neuro-protective role after TBI, experimental animal studies supported these assertions. Thus, this evidence has encouraged several phase III clinical trials, some still in the recruitment phase, to study the utility of progesterone administration in patients with severe TBI. In our study all fatalities were reported among males with no female deaths encountered.[5]

Intrathoracic injuries were the most common associated injury observed in our study, 21.99%, and was significantly associated with higher mortality. We are also report a predominance of blunt injuries (96.45%) over penetrating injuries, with no significant correlation with mortality observed among this group of the patients.

Local studies indicated that RTA accounted for over an 80% of all trauma admission in the country.[18] RTAs are the leading cause of TBI in Saudi Arabia.[6] Paralleling our local statistics, RTA was the main mechanism of injury in our report (49.7%), followed by falls (39.5%).

Epidemiological studies from Europe, United States, and South Korea reported reduction in the incidence of TBI caused by RTA overtime, which was eventually replaced by falls as the main mechanism of injury for TBI. This was attributed to the success of public safety measures and preventive strategies for RTA in these countries.[4,7,13–16,19] Driver behavioral factors, such as speeding, are associated with a major proportion of traffic accidents. Compliance to seat belts among drivers is known to reduce of the risk of sustaining major injuries as well as risk of death by approximately 50 and 45%, respectively.[20]

Among various public safety measures and preventive strategies, safety precaution techniques have evolved in Saudi Arabia over the past decade. After the implementation of the SAHER camera ticketing system in 2010, a governmental hospital in Riyadh reported a significant reduction in injury severity and mortality among TBI patients treated in their facility.[21] In 2016, and as part of the 2030 vision projects for Saudi Arabia, stricter traffic regulations were adopted that include regulations on speeding, seat belt wearing, and prohibited mobile use while driving, providing that these regulations are strictly enforced by the most advanced traffic management technologies. Following that, encouraging observation with steady declines noted in cases of RTA-related TBI was reported from Asser Province in Saudi Arabia, indicating reductions in the number of cases per year from 203 in 2010 to 45 in 2019, replacing RTA for falls as the primary cause of TBI after 2016 in their study.[2]

A large proportion of the reported casualties from TBI are observed in pedestrians worldwide. In low- and middle-income countries, over half of deaths are of vulnerable road users, including pedestrians that are particularly vulnerable to serious head trauma.[22] The risk of a pedestrian receiving an intracranial injury after being hit by a car increases steadily with age and increases even more for elderly pedestrians. In the current study, reported pedestrian mortality among TBI patients ranges from 14 to 40%. We observed mortality rates among this subgroup of approximately 23%, a rate similar to the numbers reported from Europe.[12] Also, the time immediately following injury can be vitally important

to the clinical outcomes of severely injured trauma patients. The spectrum of prehospital care provided to injured patients ranges from no intervention to advanced life support, fluid resuscitation, and endotracheal intubation with mechanical ventilation.[23] Several studies investigated the effect on the mode of transportation and prehospital care on the patient outcome following TBI with conflicting results. Among our study individuals, nearly half of the patients were delivered to hospital by private car (47.57%) with statistically significant lower mortality observed in this group. Studies from United States, Germany, and South Africa reported an increased mortality rate among trauma patients transported by ground emergency medical services (EMS) compared with those transported by private cars.[24,25] Nonetheless, two regional studies from Riyadh and Oman reported no substantial differences in mortality among injured patients transported by EMS compared with private cars.[26,27] Several important variables should be considered, such as the severity and nature of injuries in patients delivered by EMS, the extrication time, and scene time in patients requiring immediate pre-hospital care. Thus, due to the lack of strong evidence, we are only able to speculate on the possible reasons for our finding of decreased mortality with private transportation of TBI cases, encouraging future reports to further investigate the variables associated with increased mortality among EMS transported patients.

This study reports younger population majority, with mild-to-moderate TBI. The mortality rate related to TBI reported in this study is among the lowest in the region. Interestingly, a more balanced male-to-female ratio was observed, an expected observation with increasing number of female drivers in Saudi Arabia. Patients who were delivered to the hospital via private cars had an improved survival, a finding that requires further exploration of its cofounders.

The main limitation to our study is that it might not accurately represent the population as it is a hospital-based retrospective review. Such design allows for no control over confounders, and increases the possibility of confounding bias. However, the data provided can guide further investigations to address and implement primary preventive measures against TBI and is sequala in the future.

Conclusion

This study reports a mortality rate-related TBI that is among the lowest in the region. Injuries were male predominant with more balanced male to female ratio. Patients who were delivered to the hospital via private cars had an improved survival. These finding should be interpreted in the context of retrospective noncontrolled study design, and further future studies are encouraged to consolidate these findings.

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