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ORIGINAL SCIENTIFIC REPORT

Predictors and Time-Based Hospital Mortality in Patients with Isolated and Polytrauma Brain Injuries

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Abstract

Background Traumatic brain injury (TBI) is a major cause of morbidity and mortality worldwide. We studied the predictors and time-based mortality in patients with isolated and polytrauma brain injuries in a rapidly developing country. We hypothesized that TBI-related 30-day mortality is decreasing over time.

Methods A retrospective analysis was conducted for all patients with moderate-to-severe TBI who were admitted directly to a level 1 trauma center between 2010 and 2014. Patient's data were analyzed and compared according to survival (survived vs. not survived), time (early death [2 days], intermediate [3–7 days] versus late [>7 days]) post-injury, and type (polytrauma vs. isolated TBI). Cox proportional hazards models were performed for the predictors of mortality.

Results A total of 810 patients were admitted with moderate-to-severe TBI with a median age of 27 years. Traffic-related injury was the main mechanism of TBI (65%). Isolated TBIs represented 22.6% of cases and 56% had head AIS >3. The overall mortality rate was 27%, and most of deaths occurred in the intermediate (40%) and early period (38%). The incidence of TBI was greater in patients aged 21–30 years but the mortality was proportionately higher among elderly. The average annual incidence was 8.43 per 100,000 population with an overall mortality of 2.28 per 100,000 population. Kaplan–Meier curves showed that polytrauma had greater mortality than isolated TBI. However, Cox survival analysis showed that age [Hazard ratio (HR) 1.02], scene GCS (HR 0.86),subarachnoid hemorrhage (HR 1.7), and blood transfusion amount (HR 1.03) were the predictors of mortality regardless of being polytrauma or isolated TBI after controlling for 14 relevant covariates.

Conclusions The 30-day survival in patients with TBI is improving over the years in Qatar; however, the mortality remains high in the elderly males. The majority of deaths occurred within a week after the injury. Further studies are needed to assess the long-term survival in patients with moderate-to-severe TBI.

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Introduction

Traumatic brain injury (TBI) is a major public health challenge with a substantial morbidity and mortality worldwide [1, 2]. Around 9% of the global injury-related mortality has been attributed to head trauma [3]. TBI disproportionately affects the young and productive members of communities and often results in impaired quality of life [4, 5]. In the USA, where TBI statistics are well chronicled: 1.4 million TBI cases present yearly to the emergency departments with 275,000 hospital admissions and 52,000 deaths [6]. In the developing regions, such as Southeast Asia and Africa, higher fatality rates have been reported among males sustaining road traffic injuries, presumably with a greater proportion of severe TBI [2, 3]. In Saudi Arabia, motor vehicle collisions were found to be the most frequent cause of TBI among adults with a high proportion of severe TBIs (57%) and a mortality rate of 30% [7].

Qatar is a high-income, rapidly developing country with an estimated population of 2.6 million that has increased by a rate of 7–8% per annum over the last 5 years. The population is largely composed of expatriate workers who are exposed to a variety of environmental hazards at work and on the road [8, 9]. Road traffic injuries have been identified as a leading cause of death in Qatar [10], and head injuries are reported to be the main cause of injury-related deaths [11]. As such, it is imperative that locally relevant and accurate data on road traffic fatalities are used for healthcare policy formulation and planning.

Previous reports from Qatar have reported an incidence of TBI between 4.2 and 4.9 per 100,000 population with a marked increase during 2003–2007 [12]. El-Matbouly et al. [13] reported a noticeable variability in the incidence and outcome of TBI with respect to age in Qatar. The frequency of TBI was higher among young (34%) and middle age adults, whereas TBI-related fatality was higher among elderly (71–80 years) patients. The authors also documented a prominent role of MVCs in the incidence of TBIs among young road users. Thus, one main challenge for trauma research in Qatar is to minimize the burden of morbidity and mortality in patients with TBI. However, the frequency, pattern, and time-based mortality of TBI were not reported adequately. We aim to report the predictors and temporal patterns of death in moderate-to-severe isolated and polytrauma brain injuries in relation to their admission to the only national level 1 trauma center. We hypothesize that TBI-related 30-day mortality is decreasing over the years in the state of Qatar. This study was conducted in accordance with the STROBE checklist (Table 1).

Methods

A retrospective observational analysis was conducted on all patients with TBI who were admitted directly to the Hamad Trauma Center (HTC), from January 1, 2010 to December 31, 2014. The HTC is the only national level 1 tertiary trauma center in Qatar, with the capability to deliver high-quality, advanced treatment needed for polytrauma patients with state-of the-art life support facilities. The HTC trauma registry is a mature database, in existence since 2007 that is a participant in both the National Trauma Data Bank (NTDB) and the Trauma Quality Improvement Program (TQIP) of the American College of Surgeons-Committee on Trauma (ACS-COT). The data analyzed in this study are therefore nationally representative of all the moderate-to-severe TBI patients in Qatar, unusual for a single center but an important distinction in this instance.

Amongst them, only patients with moderate (Glasgow Coma Scale (GCS) = 9–12) and severe (GCS ≤ 8) TBI were included. Scene GCS was recorded by emergency medical services (EMS) paramedics including critical care paramedics (CCP), whereas the admission or emergency department (ED) GCS was measured by the attending physician of the trauma room in the ED. All patients admitted to the HTC were assessed, resuscitated, and managed in accordance with the Advanced Trauma Life Support (ATLS) guidelines of the ACS-COT. Data were analyzed and compared between survivors and non-survivors, and isolated versus polytrauma TBI patients. Non-survivors were further categorized into three subgroups according to the time of death after admission in days (early: the first 2 days, intermediate: 3–7 days, and late death: >7 days). Patient's demographics, mechanism of injury (MOI), EMS and scene time, vital signs at the scene and on admission, injury severity score (ISS), GCS at the ED, abbreviated injury severity scores (AIS) for different body regions, type of TBI lesion {i.e., subarachnoid hemorrhage (SAH), subdural hemorrhage (SDH), epidural hemorrhage (EDH), and intraventricular hemorrhage (IVH)}, isolated TBI, associated injuries, blood transfusion, neurosurgical intervention (i.e., intracranial pressure monitor insertion (ICP), craniotomy, and craniectomy), hospital length of stay (LOS), and sepsis were analyzed and

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Table 1 STROBE statement—checklist of items that should be included in reports of *cohort studies*

	Item No.	Recommendation	Page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1–2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	1–2
Introduction			
Background/ rationale	2	Explain the scientific background and rationale for the investigation being reported	3–4
Objectives	3	State-specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4–5
		(b) For matched studies, give matching criteria and number of exposed and unexposed	–
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8[a]	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	Figure 3
Study size	10	Explain how the study size was arrived at	14
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	6
		(b) Describe any methods used to examine subgroups and interactions	6
		(c) Explain how missing data were addressed	–
		(d) If applicable, explain how loss to follow-up was addressed	–
		(e) Describe any sensitivity analyses	Figure 1 and Table 3
Results			
Participants	13[a]	(a) Report numbers of individuals at each stage of study—e.g., numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	
Descriptive data	14[a]	(a) Give characteristics of study participants (e.g., demographic, clinical, and social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	–
		(c) Summarize follow-up time (e.g., average and total amount)	Figures 2 and 3
Outcome data	15[a]	Report numbers of outcome events or summary measures over time	8–9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8–9
		(b) Report category boundaries when continuous variables were categorized	Tables 2–4
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	–
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	8–9
Discussion			
Key results	18	Summarize key results with reference to study objectives	9–13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13–14

Table 1 continued

	Item No.	Recommendation	Page #
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalizability	21	Discuss the generalizability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org

[a] Give information separately for exposed and unexposed groups

compared among the study groups/subgroups. TBI was diagnosed through the clinical assessment and CT scan examinations and was identified following the CDC case definition (any ICD-9-CM code of 800.0–801.9, 803.0–804.9, 850.0–854.1, 950.1–950). Polytrauma TBI (pTBI) was defined as TBI with at least one maximum AIS score >1 in a body region other than the head/neck or an ICD-9-CM code in the head/neck region, indicating at least a moderate extracranial injury. Isolated TBI (iTBI) was defined as TBI that did not have any maximum AIS score >1 in body regions other than the head/neck, and no indication of additional moderate extracranial injury.

The present analysis did not include prehospital or post-discharge mortalities. The annual TBI-related incidence and fatality rate per 100,000 population were determined for the study period using the official government population statistics from the Ministry of Development, Planning, and Statistics. A waiver of consent was granted for this study from the Medical Research Center (MRC) as there was no direct contact with patients and all data were retrieved retrospectively under full confidentiality to protect patients' privacy. The MRC at Hamad Medical Corporation, Qatar, granted ethical approval to conduct this study (IRB# 15051/15).

Statistical analysis

Data were presented as proportions, medians (minimum–maximum range), or mean (±standard deviation; SD) as appropriate. Study variables were analyzed and compared. Differences between categorical variables were analyzed using the Chi-square or Fisher's exact test, whereas Student's *t* test or one-way analysis of variance test (ANOVA) was performed to compare continuous variables whenever applicable. The survival analysis, with outcome being mortality and censoring occurred if discharged alive (within 30 days), was described graphically using Kaplan–Meier curves. Any differences between curves were explored using the log-rank, Breslow, and Tarone–Ware tests. For adjustment of relevant covariates over time between two groups of patients with TBI (iTBI vs pTBI), Cox proportional hazards models were used. Data were expressed as hazard ratio (HR) and 95% confidence interval (CI). Two-tailed p value <0.05 was considered significant. Data analysis was carried out using IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA.

Results

Over a 5-year period, a total of 7500 trauma patients were admitted to the trauma center, of which 810 (10.8%) sustained moderate-to-severe TBI and met the inclusion criteria. The mean age of patients was 29.4 ± 14.4 years and the majority of them were males (93%) with a male-to-female ratio of 13:1. In each gender, one-fifth of the deceased was due to falls, whereas 73% of death among females with TBI was due to MVCs and 47% of males had MVCs-related death. There were 217 in-hospital TBI-related deaths with an overall mortality of 27%. There were 457 (56.4%) patients with severe TBI (head AIS >3) and 183 (22.6%) who had isolated TBI. The ratio of iTBI to pTBI was almost constant across the 5 years as 1:3. Although the proportion of patients with TBI increased over the years from 14.3% in 2010 to 25.7% in 2014, the mortality decreased from 45% in 2010 to 27.8% in 2014.

Figure 1 shows the overall incidence of TBI and hospital mortality among TBI patients based on the age-groups, MVC-related TBI and mortality among age-groups, and fall-related TBI and mortality in different age-groups.

Table 2 shows the demographics and clinical profiles of patients with moderate-to-severe TBI, stratified by outcome (survivors and non-survivors). Patients who died were on an average 5 years older than the survivors

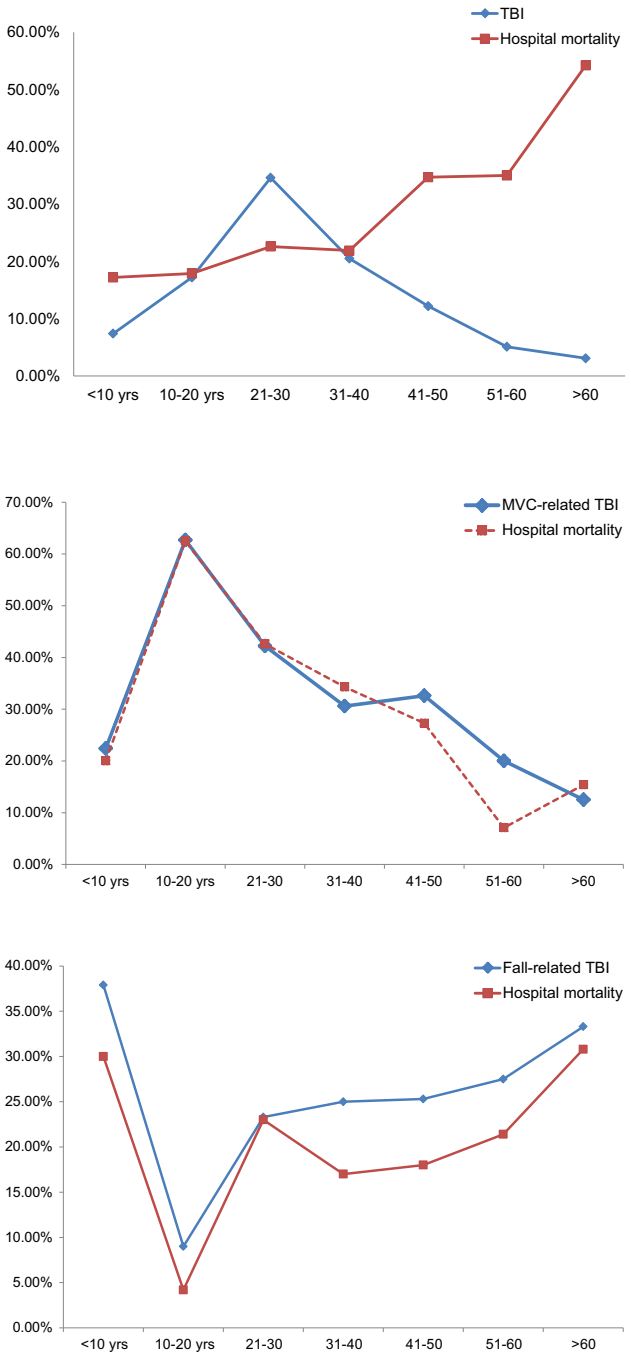

Fig. 1 Upper panel: overall incidence of TBI and hospital mortality among TBI patients based on the age-groups. Middle panel: MVC-related TBI and mortality among age-groups. Lower panel: fall-related TBI and mortality among age-groups

(33.5 ± 15.7 vs. 28.1 ± 13.6, $p = 0.001$). The two groups were comparable for gender and nationality. In regard to the MOI, non-survivors were more likely be pedestrians in comparison with survivors (28% vs. 17.7%, $p = 0.008$).

Non-survivors had significantly longer scene times ($p = 0.009$): however, the total EMS time was comparable between the two groups. Also, patients who died were hemodynamically unstable at their initial presentation to ED ($p = 0.001$). Non-survivors had greater head AIS and ISS but lower GCS ($p = 0.001$ for all). Moreover, the associated injuries, including chest and abdominal region, were significantly higher among non-survivors.

In general, skull fracture was the most commonly reported injury (65.6%), followed by brain contusion (59.0%) and SAH (40.2%). Brain edema, SAH, and SDH were the most frequently found lesions among non-survivors ($p = 0.001$ for all). Survivors were more likely to have isolated TBI, ICP catheter insertion, and neurosurgical interventions ($p = 0.001$ for all). In-hospital sepsis, prolonged mechanical ventilation, ICU, and hospital stay were more frequently observed in the survivor group ($p = 0.001$ for all).

Table 3 shows the demographics, MOI, clinical presentations, interventions, and outcomes in non-survivors stratified by the time of death. Most deaths occurred early (38% within 1–2 days) and between the third and seventh day (40%), whereas 22% died after the seventh day post-hospitalization. The three groups were comparable for age, gender, nationality, mechanism of injury, and initial vitals (i.e., systolic blood pressure).

A significantly higher proportion of patients who died within the first 2 days were ejected from vehicles ($p = 0.005$) and had shorter EMS time ($p = 0.01$). ICP catheter insertion ($p = 0.001$), neurosurgical intervention ($p = 0.002$), and in-hospital complications were more frequently observed in the late group (>1 week). The median number of the transfused blood units was higher in patients who died earlier ($p = 0.007$) than in the other groups.

Table 4 shows the demographics, mechanism of injury, clinical presentations, interventions, and outcomes of TBI in patients with iTBI versus pTBI. The two groups were comparable in terms of age, head AIS, brain lesions, EMS times, and sepsis. Patients with pTBI were more likely to have MVCs, longer scene times, lower SBP on admission, blood transfusion, and higher early death rate.

Kaplan–Meier survival and Cox regression analysis: Kaplan–Meier survival curves show a significantly higher mortality in the pTBI group than the iTBI group (log-rank: $X^2 = 18$, $p = 0.001$, Breslow: $X^2 = 22$, $p = 0.001$, and Tarone–Ware: $X^2 = 20.7$, $p = 0.001$) (Fig. 2).

The Cox survival analysis shows that pTBI patients had a higher 30-day mortality than iTBI patients with a HR of 2.4 (95%CI 1.56–3.70, $p = 0.001$). After controlling for the 14 relevant covariates (age, scene GCS, SBP, head AIS, isolated versus polytrauma TBI, SDH, SAH, EDH, IVH, ICP insertion, craniotomy, craniectomy, blood amount needed for transfusion, and sepsis), the predictors of mortality were age (HR 1.02), scene GCS (HR

Table 2 Demographics, mechanism of injury, presentation, and outcome of traumatic brain injury patients who survived and those who died

	Overall ($n = 810$)	Survivors $n = 593$ (73%)	Non-survivors $n = 217$ (27%)	p value
Age (mean ± SD)	29.4 ± 14.4	28.1 ± 13.6	33.5 ± 15.7	0.001
Males; *n*(%)	753 (93.0%)	550 (92.7%)	203 (93.5%)	0.96
Mechanism of injury; *n*(%)				
Motor vehicle crash	361 (44.6%)	267 (45.0%)	94 (43.3%)	0.008 for all
Fall	183 (22.6%)	143 (24.1%)	40 (18.4%)	
Pedestrian injury	166 (20.5%)	105 (17.7%)	61 (28.1%)	
Others	100 (12.3%)	78 (13.2%)	22 (10.1%)	
Scene time (median, range)	24 (1–110)	23 (1–110)	27 (1–90)	0.009
EMS time (median, range)	60 (3–234)	60 (7–234)	59 (3–144)	0.23
Systolic blood pressure ED	123 ± 30	127 ± 24	109 ± 40	0.001
Diastolic blood pressure ED	75 ± 21	78 ± 18	68 ± 27	0.001
Head AIS (median, range)	3.9 ± 1.2	3.7 ± 1.0	4.8 ± 1.3	0.001
Glasgow coma score ED (mean ± SD)	5 ± 3.0	5.0 ± 3.0	4 ± 2.0	0.001
Injury severity score (mean ± SD)	25 ± 10	22 ± 10	32 ± 9	0.001
Isolated TBI; *n*(%)	183 (22.6%)	154 (26.0%)	29 (13.4%)	0.001 for all
Polytrauma	627 (77.4%)	439 (74.0%)	188 (86.6%)	
Associated injuries; *n*(%)				
Chest	397 (49%)	277 (46.7%)	120 (55.3%)	0.03
Abdominal	213 (26.3%)	137 (23.1%)	76 (35.0%)	0.001
Brain lesions[a]; *n*(%)				
SDH	250 (31%)	157 (26.5%)	93 (43%)	0.001
EDH	133 (16.4%)	113 (19%)	20 (9.2%)	0.001
SAH	267 (33%)	169 (28.5%)	98 (45.2%)	0.001
Brain edema	230 (28.4%)	125 (21%)	105 (48.4%)	0.001
ICP monitoring; *n*(%)	162 (20.0%)	141 (23.8%)	21 (9.7%)	0.001
Neurosurgical intervention; *n*(%)	124 (15.3%)	105 (17.7%)	19 (8.8%)	0.002
Blood transfusion; *n*(%)	401 (49.5%)	243 (41.0%)	158 (72.8%)	0.001
Blood units transfused	5 (1–62)	4 (1–51)	7 (1–52)	0.001
Hospital stay (days) (median, range)	14 (1–304)	21 (1–304)	3 (1–101)	0.001
ICU stay (days) (median, range)	8 (1–155)	11 (1–155)	4 (1–74)	0.001
Ventilatory days (median, range)	4 (1–45)	6 (1–45)	2 (1–37)	0.001
Hospital complications; *n*(%)				
Acute respiratory distress syndrome	22 (2.7%)	13 (2.2%)	9 (4.1%)	0.13
Sepsis	72 (8.9%)	66 (11.1%)	6 (2.8%)	0.001

[a] More than one lesion could be seen in the same patient

0.86),subarachnoid hemorrhage (HR 1.7), and blood transfusion amount (HR 1.03) (Fig. 3, Table 5).

Discussion

This is a unique study from a rapidly developing country in the Middle East that provides information on the predictors and temporal trends of the mortality in patients with moderate-to-severe TBI over a 5-year period. The present work demonstrates that moderate-to-severe TBI accounts for one in ten trauma admissions; its proportionated incidence per 100,000 population increased by 32% but the in-hospital 30-day mortality has dropped by 17.2% during the study period. The average annual incidence of TBI per 100,000 population is 8.43 per 100,000 with a median age of 27 years. The overall mortality across the study period is 2.28 per 100,000 population.

Although we have observed an increasing trend of the annual incidence of TBI, there was a decline in the hospital mortality from 33.1 to 21.2% among all TBI admissions from 2010 to 2014 (Fig. 4). The study shows that mortality was increasing with aging while the occurrence of TBI was decreasing after peaking at ages between 21 and 30 years

Table 3 Demographics, mechanism of injury, and presentation of traumatic brain injury patients stratified by the time of death

	Early death $n = 82$ (38%)	Intermediate $n = 87$ (40%)	Late death $n = 48$ (22%)	p
Age (mean ± SD)	29.7 ± 15.9	36.6 ± 13.4	32.4 ± 18.3	0.30
Males (%)	91.5	94.3	95.8	0.58
Scene time (median, range)	26 (1–65)	29 (1–90)	32 (3–79)	0.22
Systolic blood pressure (mean ± SD)	99 ± 40	115 ± 39	109 ± 40	0.06
Isolated TBI (%)	9.8	16.1	14.6	0.46
Type of head injury (%)				
Skull fracture	58.4	76.5	75.6	0.03
Subdural hemorrhage	27.0	66.2	56.4	0.001
Epidural hemorrhage	5.4	11.1	22.9	0.02
Subarachnoid hemorrhage	45.9	54.5	53.7	0.53
Intraventricular hemorrhage	5.6	14.5	19.4	0.07
Brain edema	37.3	66.7	57.5	0.001
Diffuse axonal injury	11.0	7.5	38.5	0.001
ICP monitoring (%)	1.2	5.7	31.3	0.001
Surgical intervention[a] (%)	1.2	10.3	18.8	0.002
Head AIS (mean ± SD)	5.0 ± 1.9	4.7 ± 0.6	4.6 ± 1.0	0.17
Glasgow coma score ED (mean ± SD)	3.4 ± 1.4	3.6 ± 1.8	3.8 ± 1.8	0.28
Injury severity score (mean ± SD)	32 ± 9	33 ± 9	32 ± 10	0.80
Blood transfusion (%)	78.0	67.8	72.9	0.32
Sepsis (%)	0.0	1.1	10.4	0.001
Number of units transfused (median, range)	9.5 (1–30)	5 (1–32)	5 (1–62)	0.007

ICP intracranial pressure

[a] Craniotomy or craniectomy

old. It also shows that TBI-related mortality was more evident in patients who sustained MVC in the young age and in those who sustained fall with age greater than 50 years. Consistent with our findings, it has been reported that advanced age is independently associated with a worse prognosis in terms of mortality and unfavorable outcomes after severe TBI [14]. Similarly, an earlier study from our center reported higher rate of mortality in the older group [13].

The mortality was 2.8 times greater in patients with polytrauma TBI than in those who had isolated TBI. However, the survival analysis showed that the age, scene GCS, SAH type of TBI, and amount of blood transfusion needed were the significant predictors of in-hospital mortality regardless of having iTBI or pTBI in the present study. ICP monitor insertion was a borderline significant predictor of mortality ($p = 0.050$).

Of note, one in four TBI cases died during the hospital course and more than three-fourths of the cases died within the first week, whereas 38% of deaths occurred within the first 2 days post-injury.

In spite of the high incidence and awareness of TBI and its hospital and community burdens, the accurate documentation and reporting of such injuries are still hindered by the inconsistency of TBI definition that remains as a major obstacle to outline and define the problem and its magnitude in many countries [1, 15–17].

Suffice it to say that in Qatar, with the dramatic changes in the population size and the marked improvement in prehospital and trauma services then the noted trends for TBI incidence and mortality are expected.

According to the US Centers for Disease Control, 16% percent of trauma patients in the USA are admitted with head injury [18], whereas the corresponding figure for overall TBI admissions in Qatar is 12.6%. There is a 32% increase in the TBI incidence as scene fatalities are 'transformed' into survivable TBIs with better prehospital care, and its concomitant in-hospital mortality has decreased with improvement of the in-hospital trauma system care.

The incidence of moderate-to-severe TBI in patients who are admitted to the HTC in Qatar is 8.43 per 100,000 population, which is compared favorably with the overall TBI incidence from France (17.3 per 100,000 population; 1996) [19] but is markedly higher than the reported incidence in Norway (4.1 per 100,000 population in 2010) [20]. The US estimates reported a higher overall incidence of 538 per 100,000 individuals [21], whereas the Europe's and Australian incidence rates were 235 per 100,000 person years [22] and 322 per 100,000, respectively [5]. On the other

Table 4 Demographics, mechanism of injury, clinical presentations, interventions, and outcomes in patients with polytrauma versus isolated TBI

Variable	Polytrauma	Isolated TBI	*p* value
Age (mean ± SD)	29 ± 13	30 ± 17	0.41
Mechanism of injury			0.001 for all
Motor vehicle crash	48%	32%	
Pedestrian injury	21%	17%	
Falls	19%	34%	
Others	11%	17%	
Scene time (mean ± SD)	28.5 ± 17.9	23.5 ± 16.4	0.009
EMS time (mean ± SD)	63.4 ± 28.8	65.8 ± 31.2	0.44
GCS scene (mean ± SD)	7.7 ± 4.1	9.1 ± 4.4	0.001
Systolic blood pressure ED	120.6 ± 29.6	131 ± 27	0.001
Diastolic blood pressure ED	73.9 ± 21	79.6 ± 19	0.001
Head AIS (mean ± SD)	3.97 ± 1.2	4.04 ± 1.5	0.56
Blood transfusion	57.3%	23%	0.001
ICP insertion	21.4%	15.3%	0.07
Brain edema	36.6%	28.5%	0.07
SDH	36%	44%	0.06
SAH	40.3%	39.7%	0.91
EDH	22%	18%	0.34
IVH			
Neurosurgical interventions	14.2%	20.8%	0.04
Sepsis	9.3%	7.7%	0.50
Overall mortality	30%	15.8%	0.001 for all
Early death	39%	28%	
Intermediate	39%	48%	
Late death	22%	24%	

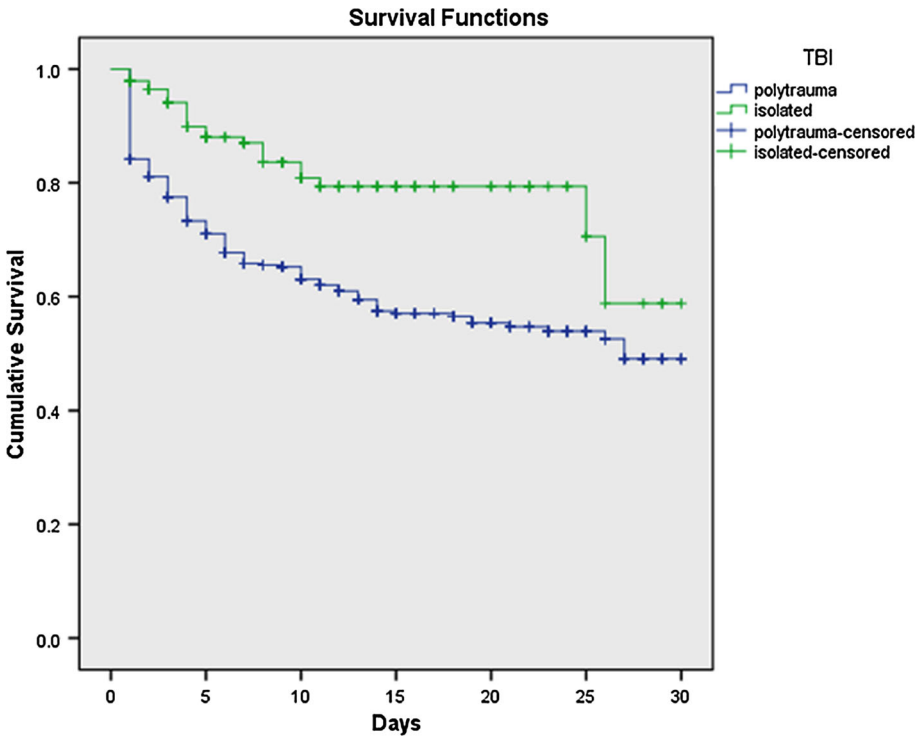

Fig. 2 Kaplan–Meier survival curves shows a significant difference between isolated and polytrauma TBI groups (Log-rank: $X^2 = 18$, $p = 0.001$, Breslow: $X^2 = 22$, $p = 0.001$ and Tarone-Ware: $X^2 = 20.7$, $p = 0.001$) for the moderate-to-severe TBI patients identified from trauma registry as per the study criteria

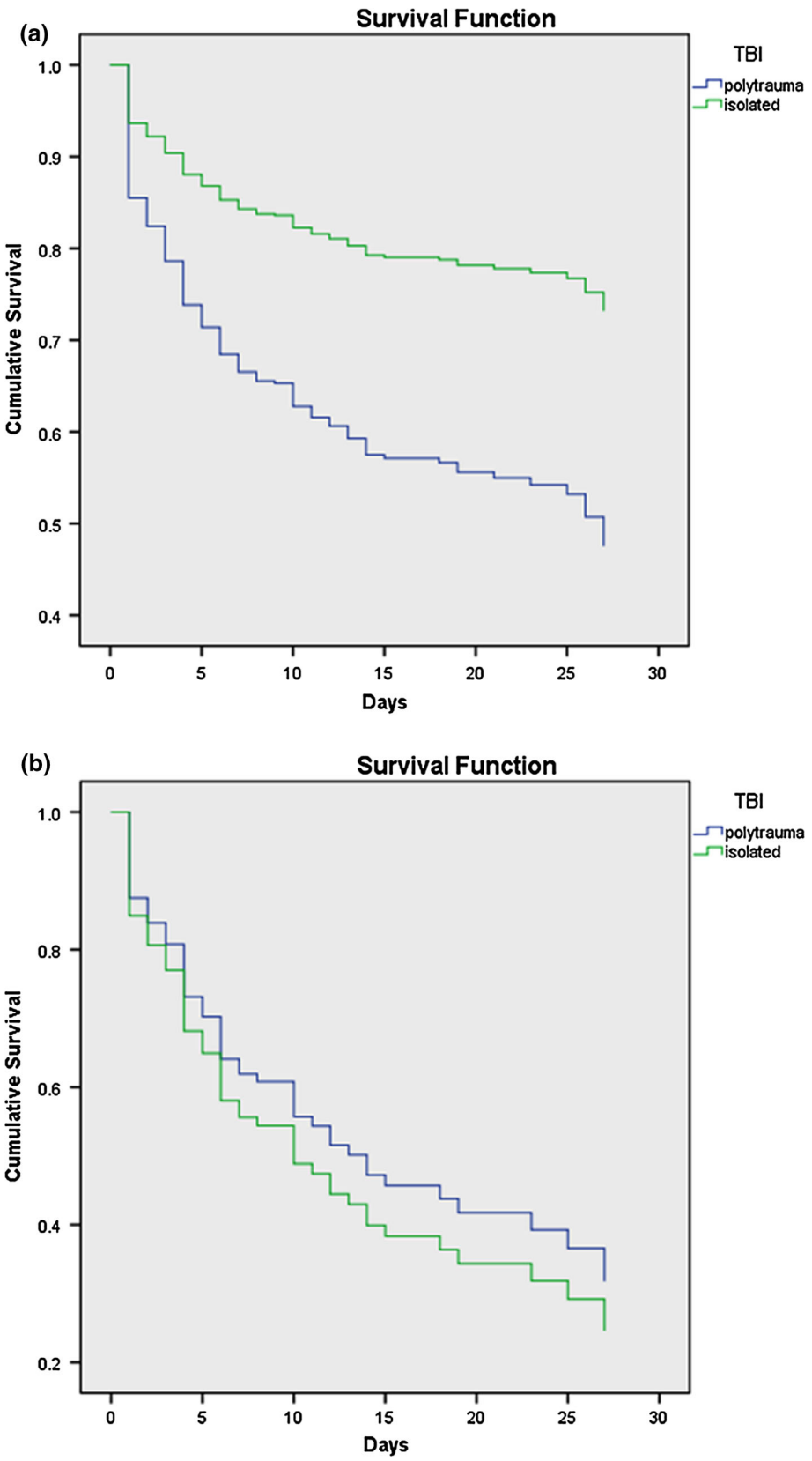

Fig. 3 **a** Cox survival analysis shows that patients with polytauma TBI had higher 30-day mortality than isolated TBI patients (unadjusted), and **b** after controlling for relevant covariates ($X^2 = 102$, DF = 13, $p = 0.001$)

Table 5 Cox regression survival analysis

Variable	Hazard ratio	95% confidence interval		*p*
Age in years	1.025	1.005	1.045	0.001
GCS scene	0.863	0.792	0.940	0.001
Systolic blood pressure Scene	0.998	0.991	1.005	0.511
Head AIS	1.092	0.872	1.366	0.443
Isolated versus polytrauma	1.224	0.389	3.850	0.730
Subdural hemorrhage	1.483	0.844	2.606	0.170
Subarachnoid hemorrhage	1.684	1.011	2.807	0.045
Epidural hemorrhage	0.620	0.232	1.660	0.342
Intraventricular hemorrhage	0.817	0.303	2.207	0.691
ICP monitor insertion	0.415	0.174	0.988	0.050
Craniotomy	0.520	0.105	2.573	0.423
Craniectomy	0.530	0.174	1.614	0.264
Blood units transfused	1.032	1.006	1.058	0.015
Sepsis	0.490	0.146	1.648	0.249

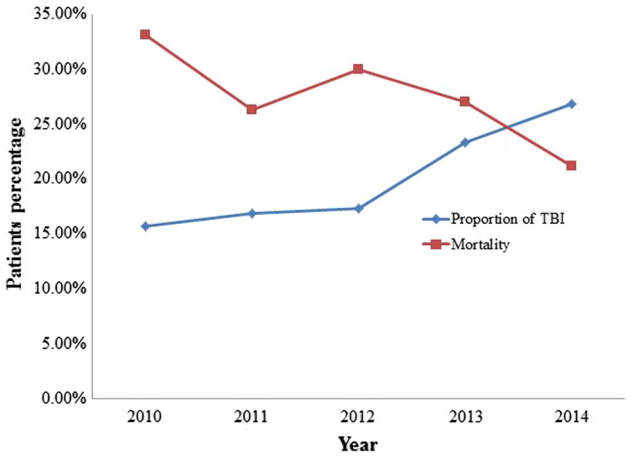

Fig. 4 Trend of TBI incidence and its mortality rate in Qatar by year (2010–2014)

hand, estimates from China showed much lower incidence ranging from 55.4 to 64.1 per 100,000 population with a mortality rate of 6.3 to 9.7:100,000 population [23]. The variation in the reported incidence in different studies and countries can be attributed to the difference in the injury severity criteria where some studies limited its inclusion to moderate-to-severe TBI, like the current study, while others included the emergency visits, discharges, and coroner reports [2]. There is also variation in the policies and guidelines used for admission and imaging tools in different studies. Heterogeneity of the study's methodology, reported sampling, and prehospital and hospital services may complicate the studies comparisons and make it practically difficult [6].

In high-income countries such as Sweden, Italy, France, and Norway, the improved awareness and strict regulations resulted in a similar decline in the incidence of MVCs-related TBI over time [24]. However, in Scotland 47% of TBI cases were due to falls [25], whereas falls accounted for 22.6% of the TBI cases in Qatar.

In the current analysis, data reflected an increasing trend in the TBI incidence and a declining mortality pattern with a sustained impact on the younger age-groups. The overall mortality of 27% in Qatar is similar to the rate of TBI-related mortality (30%) from the Saudi Arabia [7] and Switzerland (26.4%) [26]. On the other hand, the rate of mortality in the present study is comparatively higher to the CDC-reported mortality in the USA (19%). These lower rates of fatality can be attributed to the inclusion of less severe TBIs in their reports [6].

The predominance of males and the higher male-to-female ratio in our series is a known finding that reflects the unique population-age distribution in Qatar as well as the exposure on the roads and the workplace, likewise, risk-taking behaviors by the young and active age-groups as previously reported [7, 9, 13].

Most of the TBI patients in our study were from the 19-50 years age-group (80% of TBI patients), in contrast to the internationally reported majorities in the older age-groups [6] but in alignment with a regional report of TBI [7] from countries with similar population-age distributions. Notably, in the context of population census, the majority of population in Qatar is between 25 and 45 years old. This leads to a major impact of TBI on the economics and healthcare costs for similarly populated countries and suggests the inclusion of TBI prevention program as a global priority for road and occupational safety.

In this cohort, MVCs are the leading mechanism/cause of moderate-to-severe TBI and its mortality which is similar to a report from Saudi Arabia. Al-Habib et al. [7] reported a high proportion of MVCs (69.4%) causing TBIs followed by pedestrian crashes (16.8%), with an overall mortality of 30%. In another report from Al-Ain, from the United Arab Emirates, MVC caused 67.1% of TBIs and falls ranked second at 11.9% [27]. Falls were the most common mechanism of injury for TBI in the high-income countries affecting a greater proportion of the elderly populations [1, 18, 28].

Also, we reported a very low incidence of penetrating, sports, and assault-related TBI which is similar to reports from the neighboring Gulf States [7, 27].

The majority of TBI-related deaths occurred during the first week of hospitalization, highlighting the importance of this period as a focus of performance improvement for clinical care. The 38% of deaths that occur within 48 h of admission could represent the severe or 'unsalvageable' TBI patients as manifested by the neurosurgical service's almost nil utilization of ICP monitoring or neurosurgical interventions and higher head AIS and incidence of vehicle ejection and greater need for blood transfusion for this group. On multivariate analysis with a propensity score analysis, a previous study showed a twofold increase in the mortality within the first week for patients without ICP monitoring [29].

TBI prevention requires the effective road safety programs to focus on road traffic injuries, involving drivers, passengers, and pedestrians. Performance improvement programs can reduce the mid- to late-term TBI mortalities through the implementation of standard protocols for their clinical management that will reduce variations in care and provide a framework for the continued evaluation of the processes and outcomes. This will describe the areas that need focused interventions from all members of the multidisciplinary teams that are involved in the management and care of TBI patients.

Study limitations

While the registry data analysis may share the known limitations of any retrospective data analysis, the use of the Ministry of Development Planning and Statistics as the source of population data and the existence of a national ambulance service within the national trauma system reduces the likelihood of missing any moderate-to-severe TBI patients during the study period. There is a low rate of intracranial monitoring and interventions in our cohort, and even in those who underwent these procedures, the time to intervene is lacking. We acknowledge that our cohort excluded TBI patients who died at the scene or during prehospital transport and our study also lacked autopsy reports; this might lead to underestimation of the true burden of TBI-related mortality. The great diversity in the definition and classification of the severity of TBI used by various authors creates a difficulty to define and compare the regional incidence and outcomes of TBI [1, 14–16]. Identifying the heterogeneity of the captured data with the use of various coding methods and the quality assessment of prehospital services and postmortem examination are important to accurately describing the health burden of TBI in different age-groups. [22]. We did not determine the sample size initially for this study; however, post hoc power analysis was calculated based on the rate of mortality in the polytrauma versus isolated TBI which was found to have a good study power (98.3% at alpha = 0.05 and beta = 80%).

Conclusions

Despite the reported increase in its proportionate burden on trauma services, there is a trend for improved in-hospital survival in patients with TBI in Qatar. However, TBI-related mortality remains high in elderly males. The majority of deaths occurred within a week after the injury. Predictors of mortality in TBI patients, regardless of being isolated or polytrauma, are the patient age, initial GCS, type of injury, and the severity of bleeding. Primary prevention should focus on the leading injury mechanisms such as MVCs, pedestrian injuries, and falls. Road and occupational safety measures should focus on speed reduction, seat belt use, directed education and enforcement for high risk groups, and falls prevention to develop a comprehensive safety culture in Qatar. Implementation of clinical protocols for TBI care would reduce variability in clinical care, facilitate monitoring of the processes and outcomes, and lead to further reductions in mid- to late-term mortality from TBI. Further studies are needed to better assess the long-term sequelae of survivors, develop more effective primary prevention measures at all levels to sustain reduction of morbidity and mortality in patients presenting with TBI.

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Authors' contributions Authors have contributed to AE acquisition of data conception and design of the study, interpretation of data, writing manuscript, and critical review of manuscript; RC acquisition of data conception and design of the study, interpretation of data,

writing manuscript, and critical review of manuscript; RL design of the study, interpretation of data, writing manuscript, and critical review of manuscript; HAR acquisition of data conception and design of the study, interpretation of data, writing manuscript, and critical review of manuscript; BW interpretation of data, writing manuscript, and critical review of manuscript; HAL study design, acquisition of data, and critical review of manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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