Recent trends in hospitalization and in-hospital mortality associated with traumatic brain injury in Canada: a nationwide, population-based study.

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ABSTRACT

Background: Traumatic brain injury (TBI) is the leading cause of traumatic death and disability worldwide. We examined nationwide trends in TBI-related hospitalizations and in-hospital mortality between April 2006 and March 2011 using a nationwide, population-based database that is mandatory for all hospitals in Canada.

Methods: Trends in hospitalization rates for all acute hospital separations in Canada were analyzed using linear regression. Independent predictors of in-hospital mortality were evaluated using logistic regression.

Results: Hospitalization rates remained stable for children and young adults, but increased considerably among elderly adults (ages 65 and older). Falls and motor vehicle collisions (MVCs) were the most common causes of TBI hospitalizations. TBIs caused by falls increased by 24% ($p=0.01$), while MVC-related hospitalization rates decreased by 18% ($p=0.03$). Elderly adults were most vulnerable to falls, and experienced the greatest increase (29%) in fall-related hospitalization rates. Young adults (ages 15-24) were most at risk for MVCs, but experienced the greatest decline (28%) in MVC-related admissions. There were significant trends towards increasing age, injury severity, comorbidity, hospital length of stay, and rate of in-hospital mortality. However, multivariate regression showed that odds of death decreased over time after controlling for relevant factors. Injury severity, comorbidity, and advanced age were the most important predictors of in-hospital mortality for TBI inpatients.

Conclusions: Hospitalizations for TBI are increasing in severity and involve older populations with more complex comorbidities. Although preventive strategies for MVC-related TBI are likely having some effects, there is a critical need for effective fall prevention strategies, especially among elderly adults.

Study Design: Cross-Sectional; Level of Evidence: III.

Keywords: epidemiology, health policy, traumatic brain injury, hospitalization, injury prevention.

BACKGROUND

Traumatic brain injury (TBI) is the leading cause of traumatic death and disability globally, and it is involved in nearly half of all trauma deaths¹. Survivors of TBI face long-term neuropsychiatric sequelae including cognitive dysfunction, depression, anxiety, and behavioural disorders which require ongoing treatment and resource utilization. In the United States, an estimated 1.7 million people sustain a TBI annually, resulting in 275,000 hospitalizations and 52,000 deaths². In Canada, there are approximately 23,000 TBI-related hospitalizations annually, with 8% resulting in death^{3,4}.

An understanding of epidemiological patterns in TBI hospitalizations is important for targeting and evaluating injury prevention measures. However, there are no recent studies reporting hospitalization trends in a publicly-insured population, and none that have examined nationwide Canadian trends in hospitalization and in-hospital mortality in detail. We aim to build on previous studies from Canada that are non-peer reviewed agency reports^{3,4}, and other studies that have focused on specific subpopulations^{5,6}, severity levels⁷⁻⁹, or have not examined trends in detail¹⁰⁻¹².

The present study examines trends in TBI-related hospitalizations and in-hospital mortality between April 2006 and March 2011 using a nationwide, population-based database that is mandatory for all hospitals in Canada. The goals of this study are three-fold: (1) to describe recent trends in TBI-related hospitalizations and in-hospital mortality, (2) identify predictors of in-hospital mortality following TBI-related hospitalization, and (3) discuss the implications for public health policy and prevention.

METHODS

Study Design and Population

Incidence data was obtained from the Hospital Morbidity Database (HMDB), which contains detailed records on all hospital admissions from 692 acute care institutions across Canada. Each record reports information about the patient's age, sex, mechanism of injury, admission source, length of stay, and up to ten diagnosis codes. Several chart re-abstraction studies have verified the high quality of data maintained in these datasets, with the most recent study reporting 86% agreement for the most responsible diagnosis between database records and hospital charts¹³.

The study population included all hospital admissions between April 1, 2006 and March 31, 2011 that contained a TBI code in any diagnosis field. We defined TBI using the following International Classification of Diseases, Tenth Revision (ICD-10) codes: open wound of head [S01(.7,.8,.9)], fracture of skull and facial bones [S02(.0,.1,.7-.9)], intracranial injury (S06.0-S06.9), crushing injury of head [S07(.1,.8,.9)], unspecified injury of head (S09.7-S09.9), injuries involving head with neck (T02.0,T04.0,T06.0), and sequelae of injuries of head [T90(.2,.5,.8,.9)]. The Centers for Disease Control and Prevention (CDC)² includes additional ICD-10 codes in their definition of TBI mortality. We chose a more conservative set of codes to capture TBI morbidity based on previous studies^{12,14} and the author's (M.C.) 30 years of clinical experience. Patients who registered but left without being seen were excluded from this study. Mechanisms of injury were defined using the CDC's External Cause of Injury Matrix¹⁵ and collapsed into several main categories: falls, struck by/against an object, motor vehicle collisions, and other causes. Fatal injuries were identified using the "discharge disposition" variable reported in the HMDB database.

Comorbidity was measured using the Charlson Comorbidity Index (CCI), a widely used measure that has been validated for use with ICD-10 coded administrative databases¹⁶. The calculation of CCI is based on 17 conditions such as diabetes, heart failure, and cancer that are significant predictors of morbidity¹⁷. All ten ICD-10 diagnosis fields were searched for these 17 conditions, and the total number of conditions present was used to reflect each patient's pre-existing comorbidity level. An injury severity score was also assigned to each hospitalization using the International Classification of Diseases Injury Severity Score (ICISS), a validated measure that has been used extensively in trauma research^{18,19}. The ICISS measures the survival probability of each patient on a scale of 0 to 1. It is calculated as the product of the survival risk ratios corresponding to all ICD-10 diagnosis codes for each individual patient. For example, an ICISS of 0.95 indicates a 5% probability of death from injury. We classified cases into three severity categories defined by the 33rd and 67th percentiles of all pooled patient ICISS scores (n=116,614). ICISS scores above 0.95 were categorized as "mild", those between 0.83 and 0.95 as "moderate", and those below 0.83 as "severe".

Statistical Analysis

Descriptive statistics were used to describe the patient population. Hospitalization rates were calculated using population data from Statistics Canada, and reported with 95% confidence intervals (CI). Linear regression was used to evaluate trends in hospitalization rates. A Chi-square test was used to compare survivors and non-survivors at time of discharge. Logistic regression was used to model in-hospital mortality (vs. discharged alive) as a function of predictor variables, including age group, sex, mechanism of injury, CCI, ~~hospital length of stay~~, ICISS, and fiscal year. Factors significantly associated with in-hospital mortality on univariable analysis were entered into a multivariable logistic regression model. Adjusted and unadjusted odds ratios (OR) were calculated with corresponding 95% CIs. Multicollinearity was assessed with a variance inflation factor over 4. All analyses were performed using SAS 9.4 (SAS Institute, Inc., Cary, NC, USA). A p-value of less than 5% was considered significant.

RESULTS

Table 1 shows the trends in TBI hospitalization rates across major groupings between 2006/07 and 2010/11. There were 116,614 TBI-related hospitalizations in Canada over the five-year study period, resulting in 10,185 deaths. The overall rate of TBI hospitalizations increased 4% from 69.5 to 72.7 per 100,000 from 2006/07 to 2010/11, although no significant linear trend was detected (p=0.2). The majority of patients (86%) were admitted via the emergency department, and the remaining 14% were clinic admissions or direct transfers from another healthcare facility. Most patients (65%) were discharged home with or without support services; an additional 12% were discharged to an inpatient hospital facility (e.g. acute/sub-acute care, inpatient rehabilitation), 10% were discharged to a long-term care facility, 9% died in hospital, and 4% were discharged to other outpatient facilities (e.g. hospice, palliative care). Over the study period, significant increasing trends were observed in the rates of patients discharged home with support services and to long-term care facilities (p=0.001 and p<0.001, respectively).

Age- and Sex-Specific Trends

A disproportionate number of TBI hospitalizations occurred among the elderly (ages 65 and over), who accounted for 38% of hospitalizations despite representing only 14% of the Canadian population. The hospitalization rate among the elderly was 3.8 times greater on average than the rate for those under age 65. Furthermore, there was a trend towards increasing

rates among the elderly (Table 1). Between 2006/07 and 2010/11, rates among the elderly increased 24% from 173.2 to 214.7, and significant increasing trends were observed among elderly subgroups, namely those ages 65-74, 75-84, and 85 and over ($p=0.04$, $p=0.01$, and $p=0.004$). In contrast, rates declined 8% among those under 65, and a significant decreasing trend was observed in the 15-24 age group ($p=0.02$). Together, these trends resulted in an increase in the median age of TBI patients from 48 to 56 years over the study period.

On average, hospitalization rates for males were 86% greater than those for females. However, the overall hospitalization rate remained stable among males, averaging 91.4 per 100,000 over the study period, while the rate increased 14% among females from 47.1 to 53.6 per 100,000. Consequently, the ratio of male to female rates declined steadily from 2.0 to 1.7 between 2006/07 and 2010/11, with an average ratio of 1.9. Stratifying by age revealed a similar distribution in hospitalization rates for both sexes, with a peak occurring in the 15-24 age group and a second larger peak among elderly adults (SDC 1). Among those ages 85 and older, rates increased 6.6% and 8.0% each year for males and females, respectively, and significant increasing trends in hospitalization rates were observed for both sexes ($p=0.003$ and $p=0.04$).

Trends in Mechanism of Injury

Falls and motor vehicle collisions (MVC) were the most common mechanisms of TBI, representing 51% and 27% of hospitalizations, respectively. A significant increasing trend was detected in the rate of TBI hospitalization caused by falls, which increased 24% from 2006/07 to 2010/11 ($p=0.01$). In contrast, a significant decreasing trend was observed for MVC-related hospitalization rates, which decreased 18% over the study period ($p=0.03$).

Elderly populations were most vulnerable to fall-related TBIs, with 61% of all falls occurring among those 65 and older (Figure 1). Falls accounted for 82% of hospitalizations among the elderly, but only 32% of hospitalizations among those under age 65. Among the elderly, the average fall-related hospitalization rate was 157.8 per 100,000, which was 9.7-fold greater than the rate among those under 65. In addition, the elderly experienced the greatest increase in hospitalization rates due to falls. The rate of falls increased by 29% among the elderly, compared to a 7% increase among those under 65 (Figure 2).

Young adults (ages 15-24) were most likely to suffer a MVC resulting in TBI hospitalization, with 27% of MVCs occurring among this age group (Figure 1). This age group also experienced the most significant decrease in MVC-related hospitalization rates, with a 28% decrease from 43.6 to 31.3 per 100,000 between 2006/07 and 2010/11 (Figure 2). The rate of MVCs also decreased among children and youth (ages 5-14), with a 21% rate decrease over the study period.

Trends in Injury Severity, Comorbidity, and Length of Stay

Over time, there was a trend towards increasing severity, comorbidity, and length of stay among TBI hospitalizations. The hospitalization rate for TBI classified as severe increased by 16%, with a significant increasing trend observed over the study period ($p<0.0001$). During the same period, the rate of mild and moderate TBI decreased by 3% and 4%, respectively, but no significant trends were detected (SDC 2). Patients with the highest comorbidity level (CCI over 5) experienced the greatest increase in TBI hospitalization rates (10.2%), and increasing trends were observed among those with a CCI of 3-4 and CCI over 5 ($p=0.01$ and $p=0.001$). In contrast, a significant decreasing trend in hospital admissions was observed among the least comorbid subgroup (CCI 0; $p=0.04$). There was also a trend towards longer hospitalizations, as the average

length of stay increased from 12.5 to 13.8 days over the study period. Furthermore, increasing trends were detected among patients hospitalized for the longest periods.

Trends for In-Hospital Mortality

The rate of in-hospital mortality increased 15% from 5.7 to 6.6 per 100,000, with a significant increasing trend observed over the study period ($p=0.03$; Table 1). The increased mortality is likely related to trends of increased age, comorbidity level, length of stay, and injury severity. Survivors and non-survivors were different in terms of sex composition and mechanism of injury (Table 2). Additionally, non-survivors were older, and had greater comorbidity levels and injury severity on average compared to survivors.

On univariable analysis, increasing age (with the exception of ages 5-14), comorbidity, and injury severity were clearly associated with increased odds of death (Table 3). Female sex and falls were also associated with higher in-hospital mortality, while MVC ~~was and increasing length of stay were~~ associated with lower mortality. The odds of in-hospital death increased 3% each year over the study period ($p=0.0002$, 95% CI=1.01-1.04).

Controlling for other factors on multivariable analysis revealed a reverse trend, in which odds of in-hospital death decreased by 3% for each additional year over the study period ($p=0.001$, 95% CI=0.95-0.99). Males also had a 16% higher probability of dying than females ($p<0.0001$, 95% CI=1.09-1.22). Comorbidity level and injury severity were the most important predictors of in-hospital mortality. Patients with the greatest number of comorbidities (CCI over 5) were more than five times as likely to die compared to those without comorbidities (OR=5.87, $p<0.0001$, 95% CI=4.99-6.91), and those suffering a severe TBI were also five times more likely to die compared to those with a mild TBI (OR=5.05, $p<0.0001$, 95% CI=4.66-5.48). In terms of age, the probability of death fluctuated with no obvious trend. Patients ages 85 and older were at highest risk of death; they were more than twice as likely to die in hospital compared to those ages 0-4 (OR=2.06, $p<0.0001$; 95% CI=1.56-2.71). Falls and MVCs (vs. other causes) were independently predictive of decreased in-hospital mortality.

DISCUSSION

This research highlights the importance of monitoring trends in hospitalization and in-hospital mortality, as this information is essential for targeting and evaluating injury prevention programs. Furthermore, reliable baseline data is needed to accurately assess the healthcare burden of TBI-related admissions. Our study describes nationwide trends in TBI hospitalizations and in-hospital mortality in Canada over a five-year period from 2006/07 to 2010/11. We provide a critical update of the hospital burden associated with TBI, and highlight demographic groups at risk of TBI hospitalization who represent key target populations for injury prevention measures. During the study period, hospitalization rates remained stable for children and young adults, but increased significantly among elderly adults ages 65 and older. Elderly adults were most vulnerable to falls, and experienced the greatest increase (29%) in fall-related hospitalization rates. Young adults ages 15-24 were most at risk for MVCs, but experienced the greatest decline (28%) in MVC-related admissions. We also found significant trends towards increasing age, comorbidity, injury severity, and hospital length of stay, as well as a shift in mechanism of injury from MVCs to falls across nearly all age groups. The rate of in-hospital mortality showed a significant increasing trend, but multivariable analysis revealed that the odds of death decreased over time after controlling for other relevant factors. Injury severity, comorbidity, and advanced age were the most significant predictors of in-hospital mortality.

Comparisons with findings in the literature are difficult since hospitalization rates vary widely depending on time period and geographical location, and there are no other studies of nationwide hospitalization trends over a comparable period. To our knowledge, there are only a handful of reports summarizing hospitalization trends in Canada, most of which are provided by the Canadian Institute for Health Information (CIHI). A 2006 CIHI report⁴ described overall trends in head injuries in Canada between 1994 and 2004, noting a decrease in the rate of hospital admissions across all age groups. Rates of decrease ranged from 15% among those ages 60 and older, to 53% among those under age 20. Another CIHI report³ in 2007 found a 2.4% decrease in the number of hospitalizations for head injuries in Canada from 2000 to 2005. Earlier studies of subpopulations in Canada^{6,11,12} and the U.S.^{10,20} have also reported similar trends of decreasing hospitalization rates over the past few decades. Therefore, the recent shift towards increasing hospitalization rates in the present study emphasizes the need for renewed injury prevention efforts, and improved surveillance of national trends in TBI incidence and mortality.

This study highlighted the highest rates of hospitalization among the elderly (ages 65 and over), who also experienced the most dramatic increase in rates over time. This finding is well supported in the literature^{2,4,8,10-12}. In addition, falls are known to be a primary cause of TBI, particularly among the elderly²¹. Our study showed that the elderly accounted for the majority of fall-related TBIs requiring hospitalization, and also experienced the greatest increase in fall-related hospitalization rates, with nearly ten-fold higher rates compared to those under 65. The rise in fall-related TBI among elderly adults is likely related to the rapid growth in this age segment combined with the fact that elderly adults are living longer with more complex comorbidities and a greater propensity for polypharmacy^{2,4,21,23,24}. Furthermore, multivariable analysis showed that the oldest segment of the population was most at risk of death following hospitalization for TBI. These trends, together with findings of increasing age, comorbidity, length of stay, and rate of discharge to long-term care, underline the importance of future prevention efforts targeted to the burgeoning elderly population. This study also highlights major challenges for health policy and resource planning, as elderly patients are known to experience higher mortality, worse functional outcomes, and a significantly slower, more costly recovery following a TBI²²⁻²⁶.

In contrast, the declining rate in MVCs particularly for children and young adults (ages 5-24) may be attributable to increased awareness and successful injury prevention policies. Over the past 15 years, most Canadian provinces have introduced some form of graduated licensing program (GLP), which includes requirements for adult supervision, lower demerit point thresholds, and zero blood-alcohol concentration limits for new and young drivers. Programs were implemented as recently as 2003 in Manitoba and Alberta, and 2005 in Saskatchewan and the Northwest Territories. A growing number of studies have demonstrated the effectiveness of GLPs, with overall reductions in crash rates ranging from 4% to 60%^{27,28}. Stricter federal impaired driving laws and improved enforcement over the study period could have further contributed to reduced MVC rates²⁹. In addition, the increased use of child safety seats and recent introduction of child safety seat legislation in Canada could account for the decline in MVC rates among young children³⁰. These results, while encouraging, underscore the need for continued injury prevention targeted to children and young adults, who remain the most at risk for hospitalization from MVCs.

Our study also highlighted a trend towards increasing injury severity, with a significant increase in the rate of severe TBI and concomitant decreases in the rate of mild and moderate injuries admitted to hospital. This trend may reflect changes in medical practice which have

shifted treatment of milder TBIs from hospitals to the outpatient setting, including emergency departments and physician offices^{10,31}. A more complete picture of the health system burden of TBI could be obtained by linking administrative data from hospital and emergency department databases. Additionally, these findings may be related to advancements in imaging and trauma care during the study interval, which may have increased the detection and management of critically injured patients who survived long enough to be admitted to hospital.

This study was based on administrative data from the HMDB database which may not capture certain groups at risk for TBI such as prisoners or aboriginal people served by federal agencies. Our data is also subject to potential miscoding, particularly given the number of hospitalizations (14% of admissions) coded as “other unspecified head injuries” (S09.7-S09.9), which may include admissions for other TBI or non-TBI diagnoses. Additionally, this study does not capture milder injuries treated in outpatient settings.

Despite these limitations, our study is the first to examine nationwide trends in hospitalizations and in-hospital mortality in detail. This study updates previous reports that are older and/or lack the detailed information required to inform prevention efforts and accurately assess changes to hospital practices, injury prevention programs, and other safety measures. Future studies with more longitudinal data are needed to investigate the impact of readmissions on hospitalization patterns, and analyze long-term outcomes following discharge from hospital. This study highlights both successes and areas of improvement for TBI prevention efforts. Prevention should continue to target vulnerable groups identified in this study, with an emphasis on the growing elderly population who are at increased ongoing risk of hospitalization for fall-related TBIs. Additionally, inpatient hospital and other care facilities should be prepared to manage more severe TBIs and older patients with more complex comorbidities.

AUTHOR CONTRIBUTION STATEMENT

All authors contributed extensively to the work presented in this paper. T.S.F., R.J., and M.D.C. jointly conceived the study design; S.R.M. and R.J. collected and analyzed the data; T.S.F. interpreted the results and prepared the manuscript under supervision from M.D.C.; R.J. and S.R.M. provided technical support and conceptual advice; all authors discussed the results and implications, and edited the manuscript.

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Table 1. Characteristics of TBI hospital admissions in Canada, 2006-2010.

	Incidence		Rate (95% CI)*		Percent change	P-value[†]
	2006	2010	2006	2010		
Overall	22651	24706	69.5 (68.6-70.4)	72.7 (71.7-73.6)	4%	0.2
Age						
0-4	1050	1231	60.6 (56.9-64.2)	65.7 (62.0-69.4)	8%	0.2
5-14	1633	1359	41.6 (39.6-43.7)	36.2 (34.3-38.2)	-13%	0.2
15-24	3498	2801	78.4 (75.8-81.0)	61.3 (59.0-63.5)	-22%	0.02
25-34	2092	2054	48.0 (46.0-50.1)	44.3 (42.3-46.2)	-8%	0.1
35-44	2125	1819	42.2 (40.4-44.0)	38.8 (37.0-40.6)	-8%	0.1
45-54	2533	2566	50.1 (48.1-52.0)	47.4 (45.5-49.2)	-5%	0.6
55-64	2253	2577	61.0 (58.5-63.6)	60.4 (58.0-62.7)	-1%	0.9
65-74	2294	2828	100.5 (96.4-104.6)	109.6 (105.6-113.7)	9%	0.04
75-84	3089	4088	203.1 (196.0-210.3)	255.8 (247.9-263.6)	26%	0.01
85+	2084	3383	410.8 (393.2-428.4)	547.2 (528.9-565.6)	33%	0.004
Gender						
Male	14910	15516	92.4 (90.9-93.8)	92.1 (90.6-93.5)	0%	0.9
Female	7741	9190	47.1 (46.1-48.2)	53.6 (52.5-54.7)	14%	0.1
Mechanism of injury						
Fall	10561	13679	32.4 (31.8-33.0)	40.2 (39.6-40.9)	24%	0.01
Struck	2633	2379	8.1 (7.8-8.4)	7.0 (6.7-7.3)	-13%	0.1
MVC	6842	5863	21.0 (20.5-21.5)	17.2 (16.8-17.7)	-18%	0.03
Other [‡]	2615	2785	8.0 (7.7-8.3)	8.2 (7.9-8.5)	2%	0.7
Comorbidity index						
0	10846	9615	33.3 (32.7-33.9)	28.3 (27.7-28.8)	-15%	0.04
1-2	4211	4605	12.9 (12.5-13.3)	13.5 (13.2-13.9)	5%	0.1
3-4	4157	5192	12.8 (12.4-13.2)	15.3 (14.9-15.7)	20%	0.01
5+	3437	5294	10.6 (10.2-10.9)	15.6 (15.1-16.0)	48%	0.001
ICISS						
Above 0.95	7905	7891	24.3 (23.7-24.8)	23.2 (22.7-23.7)	-4%	0.9
0.83 to 0.95	5327	5372	16.4 (15.9-16.8)	15.8 (15.4-16.2)	-3%	0.1
Below 0.83	9419	11443	28.9 (28.3-29.5)	33.7 (33.0-34.3)	16%	<0.0001
Length of stay (days)						
1	6283	6185	19.3 (18.8-19.8)	18.2 (17.7-18.6)	-6%	0.4
2-3	2567	2917	7.9 (7.6-8.2)	8.6 (8.3-8.9)	9%	0.5
4-6	4201	4542	12.9 (12.5-13.3)	13.4 (13.0-13.7)	4%	0.2
7-14	3392	3743	10.4 (10.1-10.8)	11.0 (10.7-11.4)	6%	0.03
15-30	3902	4599	12.0 (11.6-12.4)	13.5 (13.1-13.9)	13%	0.05
30+	2306	2720	7.1 (6.8-7.4)	8.0 (7.7-8.3)	13%	0.01
Discharge disposition						
Inpatient facility [§]	2767	2821	8.5 (8.2-8.8)	8.3 (8.0-8.6)	-2%	0.3
Long-term care facility	2044	2853	6.3 (6.0-6.5)	8.4 (8.1-8.7)	34%	<0.001
Home	13495	13517	41.4 (40.7-42.1)	39.7 (39.1-40.4)	-4%	0.6
Home with support services	1603	2378	4.9 (4.7-5.2)	7.0 (6.7-7.3)	42%	0.001
Other	888	892	2.7 (2.5-2.9)	2.6 (2.5-2.8)	-4%	0.7
Died	1854	2228	5.7 (5.4-6.0)	6.6 (6.3-6.8)	15%	0.03

Abbreviations: TBI, traumatic brain injury; ICISS, ICD-based Injury Severity Score.

* Per 100,000; calculated using population data from Statistics Canada.

† Tested for trend significance using linear regression analysis.

‡ Cut/pierce; drowning/submersion; firearm; machinery; pedal cyclist, pedestrian, or transport (not motor vehicle crash-related); natural/environmental; other specified; unspecified; and adverse effects.

§ Transferred to facility providing inpatient care (e.g. other acute, sub-acute, inpatient rehabilitation).

|| Transferred to other healthcare facility (e.g. palliative care, hospice), signed out against medical advice, unknown disposition.

Table 2. Comparison of survivors and non-survivors following TBI hospitalization.

	Survivors	Non-survivors	P-value
Overall, n (%)	106,429 (100%)	10,185 (100%)	
Age, mean (SD)	48.9 (27.2)	68.8 (22.5)	<.0001
Sex, n (%)			
Female	37,424 (35%)	3,880 (38%)	<.0001
Male	69,005 (65%)	6,305 (62%)	
Mechanism of injury, n (%)			
Other	12,817 (12%)	941 (9%)	<.0001
Fall	52,378 (49%)	7,035 (69%)	
Struck	12,194 (11%)	265 (3%)	
MVC	29,040 (27%)	1,944 (19%)	
Comorbidity index, median (IQR)	1.0 (4.0)	4.0 (4.0)	<.0001
Length of stay (days), median (IQR)	4.0 (12.0)	4.0 (12.0)	0.19
ICISS, mean (SD)	0.86 (0.13)	0.76 (0.16)	<.0001
Year, n (%)			
2006	20,797 (20%)	1,854 (18%)	0.0002
2007	20,655 (19%)	1,943 (19%)	
2008	20,471 (19%)	1,950 (19%)	
2009	22,028 (21%)	2,210 (22%)	
2010	22,478 (21%)	2,228 (22%)	

Abbreviations: TBI, traumatic brain injury; IQR, interquartile range; ICISS, ICD-based Injury Severity Score.

Table 3. Predictors of in-hospital mortality following TBI hospitalization.

	Odds Ratio (95% CI)	p- value	Adj. Odds Ratio (95% CI)	Adj. p- value
Age				
0-4	1.00		1.00	
5-14	0.72 (0.53-0.97)	0.03	0.63 (0.45-0.88)	0.008
15-24	2.61 (2.09-3.27)	<.0001	1.48 (1.16-1.90)	0.002
25-34	2.34 (1.85-2.96)	<.0001	1.35 (1.04-1.74)	0.02
35-44	2.66 (2.11-3.36)	<.0001	1.48 (1.15-1.91)	0.002
45-54	3.57 (2.86-4.46)	<.0001	1.50 (1.16-1.94)	0.002
55-64	5.17 (4.15-6.44)	<.0001	1.45 (1.11-1.90)	0.006
65-74	7.24 (5.83-8.99)	<.0001	1.35 (1.03-1.77)	0.03
75-84	11.14 (9.00-13.79)	<.0001	1.60 (1.22-2.11)	0.001
85+	16.24 (13.12-20.11)	<.0001	2.06 (1.56-2.71)	<.0001
Sex				
Female	1.00		1.00	
Male	0.88 (0.85-0.92)	<.0001	1.16 (1.10-1.22)	<.0001
Mechanism of injury				
Other	1.00		1.00	
Fall	1.83 (1.71-1.96)	<.0001	0.75 (0.68-0.81)	<.0001
Struck	0.30 (0.26-0.34)	<.0001	0.75 (0.68-0.83)	<.0001
MVC	0.91 (0.84-0.99)	0.0008	0.33 (0.28-0.39)	<.0001
Comorbidity index				
0	1.00		1.00	
1-2	2.08 (1.92-2.26)	<.0001	1.61 (1.42-1.83)	<.0001
3-4	4.12 (3.83-4.42)	<.0001	2.89 (2.46-3.38)	<.0001
5+	8.45 (7.90-9.04)	<.0001	5.87 (4.99-6.91)	<.0001
ICISS				
Above 0.95	1.00		1.00	
0.83 to 0.95	2.22(2.04-2.41)	<.0001	1.80 (1.63-1.98)	<.0001
Below 0.83	6.78(6.33-7.26)	<.0001	5.05 (4.66-5.48)	<.0001
Year	1.03 (1.01-1.04)	0.0002	0.97 (0.95-0.99)	0.001

Abbreviations: TBI, traumatic brain injury; ICISS, ICD-based Injury Severity Score.

Model performance was assessed, with area under the receiver operating characteristic curve (AUROC) = 0.8048;

Wald $\chi^2 = 6501.1879$, $p < 0.001$.

Figure 1. Relative proportions of fall- and MVC-related hospitalizations for TBI by age group, HMDB, 2006/07 to 2010/11.

Abbreviations: TBI, traumatic brain injury; MVC, motor-vehicle crash; HMDB, Hospital Morbidity Database.

Figure 2. Percent change in fall- and MVC-related TBI hospitalizations by age group, HMDB, 2006/07 to 2010/11.

Abbreviations: TBI, traumatic brain injury; MVC, motor-vehicle crash; HMDB, Hospital Morbidity Database.

Supplemental Digital Content 1. Trends in TBI hospitalization rates by age and sex.

Age	Male				Female			
	Total		Avg. Annual Change [*]	P-value [†]	Total		Avg. Annual Change [*]	P-value [†]
	2006	2010			2006	2010		
Overall	92.4	92.1	0.0%	0.86	47.1	53.6	3.4%	0.11
0-4	69.1	72.9	1.6%	0.51	51.6	58.1	4.0%	0.30
5-14	53.8	46.2	-3.6%	0.06	28.9	25.7	-1.6%	0.42
15-24	117.0	89.2	-6.5%	0.01	37.7	32.3	-3.6%	0.32
25-34	73.6	67.2	-2.2%	0.05	22.1	21.2	-0.8%	0.66
35-44	62.8	57.9	-1.9%	0.08	21.2	19.6	-1.7%	0.99
45-54	74.7	68.0	-2.3%	0.17	25.7	26.6	1.2%	0.50
55-64	87.5	86.0	-0.3%	0.97	35.2	35.2	0.1%	0.06
65-74	131.9	144.3	2.3%	0.05	72.1	77.8	2.1%	0.06
75-84	250.1	309.1	5.5%	0.01	169.1	215.0	6.4%	0.09
85+	526.9	678.4	6.6%	0.003	359.3	485.9	8.0%	0.04

Abbreviations: TBI, traumatic brain injury.

^{*} Annual percent change in hospitalization rate was calculated as $[100 \times (\text{rate}^{n+1} - \text{rate}^n) / \text{rate}^n]$

[†] Tested for trend significance using linear regression analysis.

Supplemental Digital Content 2. Trends in TBI hospitalization rates by level of injury severity, HMDB, 2006/07 to 2010/11.

Abbreviations: TBI, traumatic brain injury; ICISS, ICD-based Injury Severity Score; HMDB, Hospital Morbidity Database.