Trends in severe traumatic brain injury in Victoria, 2006–2014

Abstract

Objective: To describe the incidence and causes of hospitalisation for severe traumatic brain injury (TBI) in Victoria over a 9-year period.

Design, setting and participants: A retrospective review of data from the population-based Victorian State Trauma Registry for hospitalised cases of severe TBI, 2006–2014.

Main outcome measures: Temporal trends in the incidence of severe TBI and in causes of injury.

Results: There were 2062 patients hospitalised with severe TBI in Victoria during the 9-year study period. The incidence of severe TBI declined significantly over this period, from 5.0 to 3.2 cases per 100 000 population per year, mainly because of reductions in severe TBI resulting from motor vehicle crashes (incidence rate ratio [IRR], 0.89; 95% CI, 0.86–0.92; $P < 0.001$), which largely involved people in the 15–34-year-old age group (64.7%). A decline was also observed in severe TBI in motorcyclists, but this was not statistically significant (IRR, 0.94; 95% CI, 0.89–1.00; $P = 0.06$). The incidence of severe TBI resulting from low falls, which occurred mostly in people aged 65 years or more (68.1%), increased (IRR, 1.04; 95% CI, 1.00–1.08; $P = 0.03$). The overall incidence of severe TBI resulting from intentional events was 0.60 cases per 100 000 population, and declined over the study period (IRR, 0.95; 95% CI, 0.91–1.00; $P = 0.03$).

Conclusions: The decline in the incidence of motor vehicle-related severe TBI suggests that road injury prevention measures have been effective. Additional targeted measures for reducing the incidence of major head injuries from falls should be explored.

Traumatic brain injury (TBI) is the most significant cause of death and severe disability resulting from major trauma.[1] The economic burden of TBI is significant, with estimated annual hospital costs of $184 million in Australia.[2] Although severe TBI constitutes a small proportion of all TBI,[3] these injuries are a significant public health problem, associated with high mortality, profound long term disability, and significant long term health care costs.[4,5]

While there is evidence that mortality associated with severe TBI has not changed since 1990,[6] data on temporal trends in the incidence and causes of severe TBI are limited. Understanding the epidemiological patterns of severe TBI is necessary for developing targeted interventions and evaluating injury prevention strategies. This is particularly important given the worldwide focus on the prevention of falls and road trauma, the major causes of severe TBI.[5,7,8]

The aim of this study was therefore to examine trends in the incidence and causes of hospitalisations for severe TBI across a statewide population (Victoria) over a 9-year period (2006–2014).

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Methods

A retrospective review of severe TBI cases was conducted, using data from the Victorian State Trauma Registry (VSTR) for the period 1 January 2006 – 31 December 2014.

Victorian State Trauma Registry

The VSTR is a population-based registry that collects data about all patients hospitalised in Victoria with major trauma.[9] A case is included in the VSTR if any of the following criteria are met:

- the injury results in death;
- an injury severity score greater than 12 is determined using the Abbreviated Injury Scale (2005 version, 2008 update = AIS 2008[10]);
- the patient is admitted to an intensive care unit for more than 24 hours and mechanical ventilation is required for at least part of this stay; or
- the patient undergoes urgent surgery.

Definition of severe TBI

Severe TBI was defined as trauma with an AIS (2005 version, 2008 update) score for the head region of at least 3 and a Glasgow Coma Scale[11] (GCS) score of 3 to 8. A head region AIS score of 3 or more indicates an anatomical injury with a rating of serious or higher; a GCS score in the range 3 to 8 is often used as the criterion for severe brain injury.[5,7] The combination of anatomical and physiological measures to define severe TBI avoided including patients whose low levels of consciousness were not caused by a head injury, but by alcohol or drug intoxication, for example. Injury diagnoses coded before the introduction of the AIS 2008 were mapped from the AIS 1990, 1998 version to the AIS 2008 using a validated map.[12] When possible, the GCS score was recorded on arrival at the hospital to which the patient was initially transported (this occurred for 716 patients, or 35% of all cases analysed in our study). If this was unavailable, the pre-hospital GCS score recorded by paramedics (1080 patients, 52%) was used, or the GCS score recorded on arrival at the definitive hospital (the hospital at the highest service level in the tiered trauma system structure at which the patient was treated: six patients, 0.3%). The GCS score was coded as 3 when pre-hospital, primary hospital and definitive hospital GCS scores were all unavailable because the patient had been intubated (260 patients, 13%). Pre-hospital deaths and events experienced by patients outside Victoria subsequently transported to Victorian hospitals were excluded from analysis.

Procedures

Severe TBI cases were stratified by intent of the event causing the injury (those resulting from unintentional or intentional events), as the strategies for preventing TBI are different for these two categories. Unintentional events were classified as transport-related (involving motor vehicles, motorcycles, pedestrians or cyclists), falls (low falls from standing or no more than one metre, or unintentional high falls from a height of greater than one metre), or other. Intentional severe TBI cases were classified as interpersonal violence or self-harm events. Patient age was categorised into five bands (0−4, 5−14, 15−34, 35−64 and ≥ 65 years). Event locations were mapped to Victorian Government Department of Health regions[13] and classified as metropolitan or rural.

Statistical analysis

Population-based incidence rates and 95% confidence intervals (95% CIs) were calculated for each calendar year. Population estimates for Victoria for each year were obtained from the Australian Bureau of Statistics.[14] Comparisons of crude and age−sex-standardised incidence rates (standardised according to the five age categories) found substantial concordance (overall severe TBI incidence: Lin concordance correlation coefficient $\rho = 0.999$ [95% CI, 0.999−1.000; $P < 0.001$]). Crude incidence rates are therefore reported. Poisson regression was used to determine whether the incidence rate increased or decreased over the 9-year period. A check for potential overdispersion of the data was performed to ensure that the assumptions of a Poisson distribution were met. The incidence rate ratio (IRR) and 95% CIs were calculated, and $P < 0.05$ was deemed statistically significant. Stata 13 (StataCorp) was used for all analyses.

Ethics approval

The VSTR has approval from institutional ethics committees of all 138 hospitals receiving patients who have suffered a trauma (Department of Health Human Research Ethics Committee; reference, 11/14) and the Monash University Human Research Ethics Committee (MUHREC; reference, CF13/3040-2001000165). This study was approved by the MUHREC (reference, CF12/3965-2012001903).

Results

There were 2062 hospitalisations for severe TBI in Victoria during the 9-year study period, comprising 9% of all major trauma cases. Most patients were men, and 40% were aged 15−34 years; most incidents occurred in metropolitan areas (65%) and were the result of unintentional events (86%) (Box 1). The overall incidence of severe TBI was 4.20 cases per 100 000 population per year, with a significant decrease over the study period from 5.00 to 3.20 cases per 100 000 population per year (IRR, 0.95; 95% CI, 0.93−0.96; $P < 0.001$; Box 2). The overall proportion of patients who died in hospital was 42.5%, and was highest in those aged over 64 years (78%; Box 3). Annual incidence rates are provided in the Appendix.

Unintentional events

The overall incidence of severe TBI resulting from unintentional events was 3.60 cases per 100 000 population per year, and the incidence decreased 5% per year during the study period (IRR, 0.95; 95% CI, 0.93−0.96; $P < 0.001$; Box 2). The major causes of injury resulting from unintentional events were transport-related (58.1%) and falls (35.2%) (Box 4). Transport-related severe TBI involving motor vehicle crashes (51.9%) and pedestrians (23.3%) were the most frequent types (Box 3).

Severe TBI resulting from motor vehicle crashes (Box 5) was most frequent in the 15−34-year-old age group (64.7%; Box 3). The incidence of severe TBI involving motor vehicle occupants declined over the study period (IRR, 0.89; 95% CI, 0.86−0.92; $P < 0.001$), as did those of severe TBI involving cyclists (IRR, 0.88; 95% CI, 0.80−0.96; $P = 0.003$) or pedestrians (IRR, 0.95; 95% CI, 0.90−1.00; $P = 0.04$). The incidence of severe TBI in motorcyclists declined by 6% per year, but this was not statistically significant (IRR, 0.94; 95% CI, 0.89−1.00; $P = 0.06$).

Seventy-two per cent of fall-related severe TBIs were the result of a fall from standing or from no more than one metre. The incidence of severe TBI from low falls increased over the study period (IRR, 1.04; 95% CI, 1.00−1.08; $P = 0.03$), while the incidence of severe TBI caused by high falls decreased (IRR, 0.94; 95% CI, 0.89−1.00; $P = 0.04$). Low falls were most frequent among people aged 65 years or more (68.1%; Box 3).

Intentional events

The overall incidence of severe TBI resulting from intentional events was 0.60 cases per 100 000 population per year (Box 2); this declined across the study period (IRR, 0.95; 95% CI, 0.91−1.00; $P = 0.03$). Intentional events resulting in severe TBI were classified as interpersonal violence (64.9%) or self-harm events (35.1%). Annual numbers in these subgroups were too small for analysing trends. The most common causes of severe TBI caused by self-harm were high falls (31.7%), transport-related events (26.9%), asphyxiation (19.2%), and firearm use (19.2%). The most common cause of severe TBI resulting from interpersonal violence was being struck by a person or object (84.9%).

Discussion

Our study investigated trends in the incidence and causes of severe TBI leading to hospitalisation over a 9-year period. The incidence of severe TBI resulting from unintentional and intentional events decreased by 5% per year. The reduction in severe TBI resulting from unintentional events was predominantly driven by reductions in transport-related severe TBI. Over the same period, the incidence of low falls-related severe TBI increased, and these injuries were mainly sustained by older adults.

This study is the first to specifically focus on the incidence of severe TBI in Australia across all age groups. The

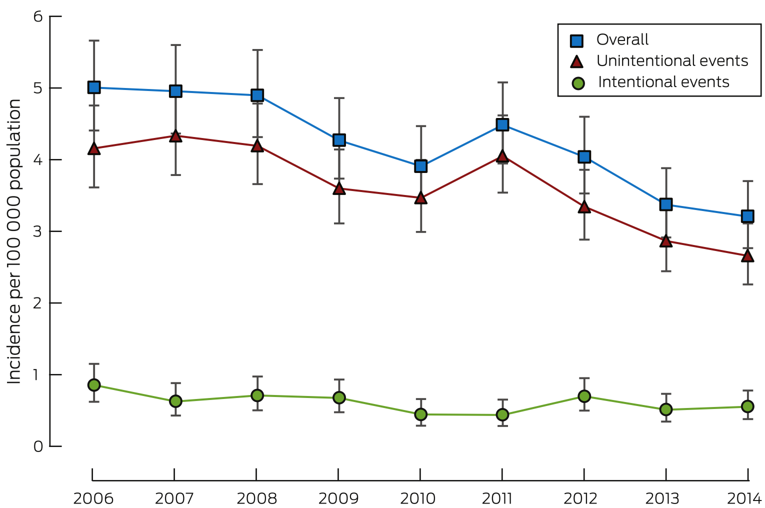
1 Profile of patients with severe traumatic brain injury in Victoria, 2006–2014, stratified by unintentional and intentional causal events

	All cases	Unintentional events	Intentional events
Total number	2062	1766 (85.6%)	296 (14.4%)
Sex			
Male	1482 (71.9%)	1236 (70.0%)	246 (83.1%)
Female	580 (28.1%)	530 (30.0%)	50 (16.9%)
Age			
0–4 years	74 (3.6%)	57 (3.2%)	17 (5.7%)
5–14 years	86 (4.2%)	84 (4.8%)	2 (0.7%)
15–34 years	827 (40.1%)	673 (38.1%)	154 (52.0%)
35–64 years	585 (28.4%)	475 (26.9%)	110 (37.2%)
≥ 65 years	490 (23.8%)	477 (27.0%)	13 (4.4%)
Region			
Metropolitan	1338 (64.9%)	1124 (63.7%)	214 (72.3%)
Rural	724 (35.1%)	642 (36.4%)	82 (27.7%)
Maximum head AIS score			
AIS 3	385 (18.7%)	328 (18.6%)	57 (19.3%)
AIS 4	588 (28.5%)	498 (28.2%)	90 (30.4%)
AIS 5	1051 (51.0%)	911 (51.6%)	140 (47.3%)
AIS 6	7 (0.3%)	6 (0.3%)	1 (0.3%)
AIS 9*	31 (1.5%)	23 (1.3%)	8 (2.7%)
Outcome			
In-hospital mortality	877 (42.5%)	757 (42.9%)	120 (40.5%)

AIS = Abbreviated Injury Scale. All percentages are column percentages, except first row ("total number"). * An AIS score of 9 indicates that there was not enough information for more detailed coding. ◆

rates reported by the few studies that have examined the incidence of severe TBI have varied (cases per 100 000 population per year: Norway, 4.1;[7] Switzerland, 10.6;[15] Canada, 11.4;[5] France, 17.3[8]). The overall incidence of severe TBI found by our study (4.20 cases per 100 000 population per year) was similar to that in the Norwegian study, which investigated patients hospitalised with severe TBI during 2009–2010, but was lower than in most other studies. This is at least partly explained by differences in the inclusion criteria applied; most studies used head AIS[8,15] scores alone to define severe TBI, whereas our study and the Norwegian investigation employed a combination of head injury classification (AIS scores or International Classification of Diseases, revision 10 codes) and GCS score. There may also be genuine differences between countries in the incidence of severe TBI resulting from differing exposures to high risk activities. We found a decline in the incidence of severe TBI over the 9-year period. This contrasts with earlier studies that included all degrees of TBI severity,[5,16] which found no significant changes in incidence. However, these studies were conducted over shorter time periods[5] or only at two time points,[16] potentially explaining the lack of detectable trends.

2 Incidence of severe traumatic brain injury in Victoria, 2006–2014



3 Profile of patients with severe traumatic brain injury in Victoria, 2006–2014, by age group and cause of injury*

	Age group					
	0–4 years	5–14 years	15–34 years	35–64 years	≥ 65 years	All
Unintentional events†						
Transport-related						
Motor vehicle crashes	17 (3.2%)	22 (4.1%)	345 (64.7%)	123 (23.1%)	26 (4.9%)	533 (51.9%)
Motorcycle crashes	0	10 (6.2%)	94 (58.0%)	55 (34.0%)	3 (1.9%)	162 (15.8%)
Cyclist	0	10 (13.0%)	24 (31.2%)	34 (44.2%)	9 (11.7%)	77 (7.5%)
Pedestrian	12 (5.0%)	23 (9.6%)	84 (35.1%)	63 (26.4%)	57 (23.8%)	239 (23.3%)
Other transport-related	0	2 (13.3%)	8 (53.3%)	1 (6.7%)	4 (26.7%)	15 (1.5%)
Falls						
Low (≤ 1 m)	13 (2.9%)	5 (1.1%)	29 (6.5%)	95 (21.3%)	303 (68.1%)	445 (71.7%)
High (> 1 m)	0 (0.0%)	6 (3.4%)	50 (28.4%)	59 (33.5%)	61 (34.7%)	176 (28.3%)
Intentional events						
Interpersonal violence	17 (8.9%)	0	110 (57.3%)	60 (31.3%)	5 (2.6%)	192 (64.9%)
Self-harm	0	2 (1.9%)	44 (42.3%)	50 (48.1%)	8 (7.7%)	104 (35.1%)
Outcomes‡						
In-hospital mortality	24 (32.4%)	16 (18.6%)	231 (27.9%)	225 (38.5%)	381 (77.8%)	877 (42.5%)

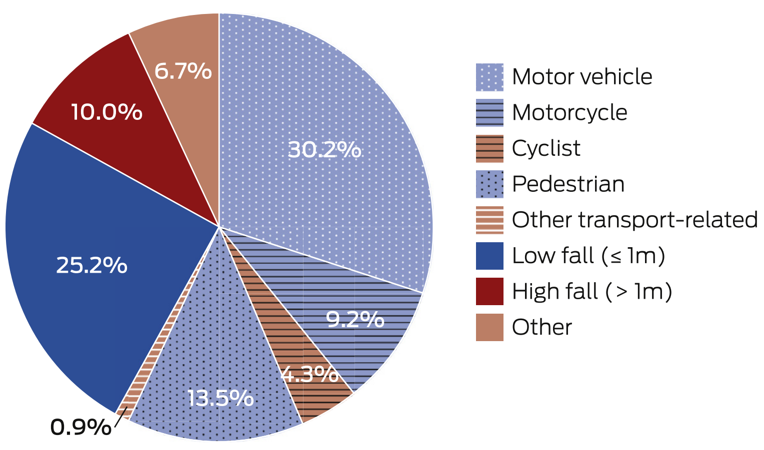
* All percentages are row percentages (ie, contribution of each age group to each cause category), except the final column ("All"), in which the contribution of each subcategory to transport-, fall- or intentional event-related traumatic brain injury is given. † Unintentional events resulting from "other" injury causes (not transport- or fall-related: 119 cases) are not included in this table. ‡ For all severe traumatic brain injury. ◆

Falls and transport-related events were the most common causes of severe TBI, and this is consistent with Australian[17] and international data.[5,7,8,16] It is notable that the incidence of severe TBI resulting from motor vehicle crashes declined over the study period. This reduction is possibly explained by continued improvements in vehicle safety, as well as road safety mass media campaigns. Active safety design measures, such as electronic stability control (ESC) and autonomous emergency braking substantially reduce crash risk;[18] ESC has been a mandatory safety feature in new vehicles sold in Victoria since 2011. Similarly, passive safety features, such as curtain airbags, substantially reduce head injuries in side impact crashes.[19]

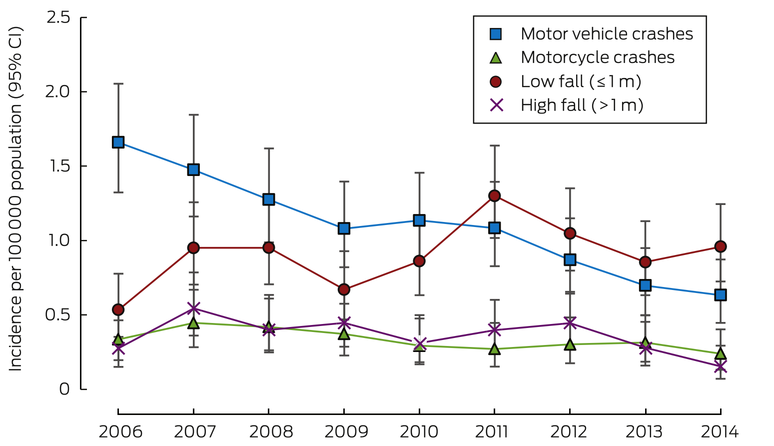
Declines in the incidence of severe TBI in pedestrians and cyclists were also noted. These declines may be associated with improvements to road infrastructure, such as pedestrian zones with lower speed limits, and separated bike lanes and paths. Continued efforts to improve infrastructure (including separating pedestrians and cyclists from motor vehicles) and safety (such as increasing helmet use and improving vehicle design to mitigate pedestrian injury) may lead to further declines in the incidence of severe TBI in these vulnerable road users.

There was also a decline in the incidence of severe TBI in motorcyclists, but this was not statistically significant. A review of motorcycle fatalities in Australia indicated that risky riding behaviour (excessive speed, the influence of alcohol and drugs, disobeying traffic control laws) was involved in 70% of events.[20] Interventions targeting these behaviours, including mass media campaigns and increased law enforcement, may further reduce severe TBI rates. Consideration should also be given to active safety features in motorcycles, such as antilock braking systems.

4 Causes of severe traumatic brain injury resulting from unintentional events



5 Incidence of severe traumatic brain injury in Victoria, 2006–2014, resulting from unintentional events



Falls were the second most common cause of severe TBI in our study. The incidence of severe TBI from low falls, which occurred mainly in those aged 65 years or more, increased between 2006 and 2014. Increases in this group have also been observed in New South Wales[21] and internationally.[5] This may be a result of ageing populations, increased rates of comorbidities, and more widespread use of anticoagulant and antiplatelet drugs.[16,21] These medications are effective in preventing stroke and thrombo-embolism,[22] but increase the complexity of managing trauma patients; further studies examining the incidence of trauma-related complications are needed. The proportion of the Australian population aged 65 years or more is expected to double between 2005 and 2050,[23] and our results and international data[3] show that TBI outcomes are noticeably worse in older than in younger people. It is therefore clear that further research is required to reduce the incidence of severe TBI in older people. While an overall increase in the incidence of severe TBI resulting from falls was observed across the entire study period, a decline was observed for 2011–2014. This suggests that recent fall prevention programs may have been effective, although further data are needed to explain this trend.

The incidence of severe TBI resulting from intentional events (14.4% of all severe TBI) was similar to that reported by an American study (17.8%).[24] We found that this incidence declined during the study period. Interpersonal violence was the primary cause of severe TBI resulting from intentional events, and this has been strongly associated with alcohol intoxication;[25] continuing targeted interventions for limiting alcohol consumption through education and by tighter controls at licensed venues may reduce its incidence. Self-harm events accounted for 35.1% of severe TBI resulting from intentional events, but numbers for this group were insufficient for assessing trends. Australian data indicate that suicide rates declined from 1999–2000 to 2010–11, but the incidence of hospitalisation after intentional self-harm remained steady.[26] While the number of patients hospitalised with severe TBI resulting from self-harm is small relative to that related to unintentional events, self-harm remains a significant public health problem, and further efforts to improve mental health care and provide early interventions are needed.

The major strength of our study was the use of the population-based VSTR to provide a comprehensive overview of the incidence of severe TBI. However, a number of limitations are acknowledged. Our study was observational, so that identifying causal explanations for the reported trends is beyond its scope; we can only postulate that certain factors may explain these trends. The denominator used to calculate crude incidence was the population of Victoria during the relevant year; we do not have data on the number of people undertaking specific activities (such as cyclists or pedestrians) or the actual time they were at risk of injury. Using the catchment population as the denominator, however, is a widely employed approach.[5,7,8,16] Pre-hospital deaths were excluded from this study, so that the true incidence of severe TBI may have been underestimated. Additionally, our analysis was under-powered for assessing combined age- and event-specific trends over time. Further research is needed to understand the mortality and functional outcomes for patients with severe TBI.

Conclusion

Given the devastating consequences of severe TBI, efforts in both primary and secondary prevention are critical to reducing mortality and non-fatal injury burden. In this study of patients hospitalised with major trauma between 2006 and 2014, the incidence of severe TBI resulting from motor vehicle crashes declined, while severe TBI resulting from falls increased over time. Ongoing efforts to reduce road trauma, interpersonal violence and intentional self-harm injury are warranted, while increased efforts to reduce falls-related injuries and injuries to vulnerable road users are needed.

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