

# Traumatic spinal cord injury in Victoria, 2007–2016

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**The known:** Traumatic spinal cord injury (TSCI) is often debilitating and life-threatening.

**The new:** The crude and population-adjusted incidence of TSCI did not change during 2007–2016. However, the incidence of TSCI in people aged 65 years or more increased by 5% per year, and the proportion of cases that involved incomplete tetraplegia also increased.

**The implications:** As the incidence of TSCI has not declined, primary prevention must be improved. The increasing number of TSCI events in older adults has implications for planning prevention, acute and post-discharge care, and support activities.

While the worldwide incidence of traumatic spinal cord injury (TSCI) is low, its effects on individuals can be debilitating and life-threatening.<sup>1</sup> As the mortality associated with TSCI declines,<sup>2</sup> the number of people living with the condition is increasing, contributing to significant social and economic costs.<sup>3</sup> The total annual costs of TSCI in Australia is estimated to be \$2 billion, including those of prolonged hospitalisation, long term care, equipment, and productivity losses.<sup>3</sup>

Despite evidence that the incidence of TSCI in adults has declined in Australia,<sup>4</sup> rates may be underestimated because official statistics encompass only people admitted to dedicated spinal cord injury units. Accurate knowledge of the epidemiology of TSCI is essential for developing injury prevention strategies and providing health care and disability services. We therefore examined trends in the incidence and causes of hospitalisation for TSCI in all age groups in Victoria during 2007–2016.

## Methods

We undertook a retrospective review of Victorian State Trauma Registry (VSTR) data for people who sustained TSCIs during January 2007 – December 2016. The state of Victoria (population, 6.1 million) established the Victorian State Trauma System during 2000–2003. It is an inclusive, regionalised system with one major trauma service for children (under 16 years of age) and two for adults, as well as a specialist spinal cord trauma centre for adults (the Victorian Spinal Cord Service at Austin Health).<sup>5</sup>

The population-based VSTR collects data for all patients hospitalised in Victoria who meet any of the following criteria for major trauma:

- death after injury;
- an injury severity score (ISS) greater than 12 (calculated with the Abbreviated Injury Scale [AIS] 2005 – update 2008);
- admission to an intensive care unit (ICU) for more than 24 hours and requiring mechanical ventilation; or
- urgent surgery for intracranial, intrathoracic or intra-abdominal injury, or for fixation of pelvic or spinal fractures.<sup>6</sup>

## Abstract

**Objective:** To investigate trends in the incidence and causes of traumatic spinal cord injury (TSCI) in Victoria over a 10-year period.

**Design, setting, participants:** Retrospective cohort study: analysis of Victorian State Trauma Registry (VSTR) data for people who sustained TSCIs during 2007–2016.

**Main outcomes and measures:** Temporal trends in population-based incidence rates of TSCI (injury to the spinal cord with an Abbreviated Injury Scale [AIS] score of 4 or more).

**Results:** There were 706 cases of TSCI, most the result of transport events (269 cases, 38%) or low falls (197 cases, 28%). The overall crude incidence of TSCI was 1.26 cases per 100 000 population (95% CI, 1.17–1.36 per 100 000 population), and did not change over the study period (incidence rate ratio [IRR], 1.01; 95% CI, 0.99–1.04). However, the incidence of TSCI resulting from low falls increased by 9% per year (95% CI, 4–15%). The proportion of TSCI cases classified as incomplete tetraplegia increased from 41% in 2007 to 55% in 2016 ( $P < 0.001$ ). Overall in-hospital mortality was 15% (104 deaths), and was highest among people aged 65 years or more (31%, 70 deaths).

**Conclusions:** Given the devastating consequences of TSCI, improved primary prevention strategies are needed, particularly as the incidence of TSCI did not decline over the study period. The epidemiologic profile of TSCI has shifted, with an increasing number of TSCI events in older adults. This change has implications for prevention, acute and post-discharge care, and support.

## Definitions and data collection

TSCI was defined as an injury to the spinal cord with an AIS score of 4 or more, ensuring complete population coverage (given the VSTR inclusion criterion of an ISS exceeding 12). Cases of cauda equina and nerve root injury were excluded. Consistent with AIS codes, TSCIs were classified as complete or incomplete injuries in the cervical (subclassified: C3 or above, C4 or below), thoracic, or lumbar spine, with or without associated fractures or dislocations at the same level as the TSCI. Tetraplegia was defined as TSCI in the cervical spine, and paraplegia as TSCI in the thoracic or lumbar spine. AIS coding data were supplemented with information regarding the specific anatomic level of the injury and the type of incomplete cervical TSCI (central cord syndrome, other incomplete injury) derived from International Classification of Diseases, tenth revision, Australian modification (ICD-10-AM) coding. Isolated TSCI was defined as the absence of injuries with an AIS score greater than one in any other body region. TSCIs in patients injured outside Victoria were excluded from our analysis.

Patients' postcodes of residence were mapped to the Accessibility/Remoteness Index of Australia (ARIA)<sup>7</sup> and the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD).<sup>8</sup> Comorbidity status was defined with the Charlson Comorbidity Index,<sup>9</sup> mapped from ICD-10-AM codes.

Events were classified as transport-related, low falls (falls from a standing position or from a height of one metre or less), high

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falls (from more than one metre), or being struck by or colliding with an object or another person (including interpersonal violence). After reviewing the free text for the injury event, events classified as collisions with objects could be further specified as diving into shallow water or as water sports-related (including surfing and powered water sports).

WorkSafe Victoria and the Transport Accident Commission are the no-fault, third party insurers for work and transport injuries in Victoria, reimbursing the costs of treatment, rehabilitation, income replacement, and long term support services.

### Data analysis

Frequencies by sex, age group, and mechanisms of injury were compared in  $\chi^2$  tests. Population crude incidence rates (with 95% confidence intervals [CIs]) were calculated for each year, based on the total population on June 30 of the corresponding year (source: Australian Bureau of Statistics). Age- and sex-standardised incidence rates were calculated with the direct method.<sup>10</sup> Rates were standardised for 5-year age groups (to 85 years or more) using the 2011 Australian population as the population standard.<sup>11</sup> Changes in crude incidence rates over the 10-year period were assessed in individual Poisson regression models; data were checked for over-dispersion (variance greater than the mean) to ensure that the assumptions of a Poisson distribution were met, and the incidence rate ratio (IRR) and its 95% CI were calculated. Trends in the proportion of cases of TSCI for which WorkSafe Victoria or the Transport Accident Commission provided compensation, in the profile of neurological impairment, and in the proportion of patients discharged to the state rehabilitation service for spinal cord injury, were each assessed in  $\chi^2$  tests for trend. All analyses were conducted in Stata 14.2 (StataCorp);  $P < 0.05$  was deemed statistically significant.

### Ethics approval

Ethics approval was provided by the Human Research Ethics Committees (HRECs) of the Department of Health and Human Services (reference, DHHREC 11/14) and Monash University (reference, CF13/3040 – 2001000165), and by all trauma-receiving hospitals.

### Results

There were 706 cases of TSCI during 2007–2016, comprising 2.5% of all cases of major trauma recorded in the VSTR. The median age of the patients was 50 years (interquartile range, 31–68 years) and 560 were male (79%); comorbidity status, and residential socio-economic status and remoteness were similar for male and female patients, but the median age of women was higher (Box 1).

### Incidence

The overall crude incidence of TSCI was 1.26 (95% CI, 1.17–1.36) cases per 100 000 population, and did not change over the study period (IRR, 1.01; 95% CI, 0.99–1.04). The crude incidence of TSCI was higher among males (2.02 [95% CI, 1.86–2.20] cases per 100 000 population) than females (0.52 [95% CI, 0.44–0.61] cases per 100 000 population); it did not change over the study period for men (IRR, 1.01; 95% CI, 0.98–1.04) or women (IRR, 1.05; 95% CI, 0.99–1.11). The age- and sex-standardised incidence of TSCI was 1.25 (95% CI, 1.21–1.30) cases per 100 000 population. The incidence among people aged 65 years or more increased across the study period by 5% per year (95% CI, 1–10%), but was stable in younger age groups (Box 2). Among people aged 15 years or more, the incidence of TSCI was higher for males than females at all ages (Box 3).

#### 1 Demographic characteristics of patients who sustained traumatic spinal cord injuries in Victoria, 2007–2016, by sex

Characteristic	Total	Males	Females	<i>P</i>
Number of patients	706	560	146	
Age (years), median (IQR)	50.0 (31.0–68.0)	49.0 (31.0–68.0)	58.5 (31.0–72.0)	0.026
Charlson Comorbidity Index				0.68
0	493 (69.8%)	389 (69.5%)	104 (71%)	
≥ 1	213 (30.2%)	171 (30.5%)	42 (29%)	
Index of Relative Socio-economic Advantage and Disadvantage (quintiles)				0.43
1st (most disadvantaged)	107 (15.7%)	86 (16%)	21 (15%)	
2nd	95 (14%)	81 (15%)	14 (9.8%)	
3rd	131 (19.2%)	103 (19.1%)	28 (20%)	
4th	152 (22.3%)	114 (21.2%)	38 (27%)	
5th (least disadvantaged)	197 (28.9%)	155 (28.8%)	42 (29%)	
Missing data	24	21	3	
Accessibility/Remoteness Index of Australia				0.39
Major cities	463 (67.9%)	361 (67.1%)	102 (71%)	
Inner or outer regional/remote	219 (32.1%)	177 (32.9%)	42 (29%)	
Missing data	24	22	2	

**2 Change in incidence of traumatic spinal cord injuries in Victoria, 2007–2016 (incidence rate ratio), by age group, mechanism of injury, and injury type**

Characteristic	Incidence rate ratio (95% CI)	P
<b>Age group (years)</b>		
0–14	0.94 (0.81–1.08)	0.38
15–34	0.98 (0.93–1.03)	0.35
35–64	1.01 (0.97–1.05)	0.68
≥ 65	1.05 (1.01–1.10)	0.026
<b>Mechanism of injury</b>		
Transport-related: motor vehicle	0.95 (0.89–1.01)	0.08
Transport-related: motorcycle	0.96 (0.89–1.14)	0.35
Transport-related: cyclist	1.02 (0.92–1.12)	0.75
Transport-related: pedestrian	0.96 (0.79–1.16)	0.71
Low falls (≤ 1 m)	1.09 (1.04–1.15)	0.001
High falls (> 1 m)	1.03 (0.97–1.10)	0.33
<b>Injury type</b>		
Complete spinal cord injury	0.95 (0.92–0.99)	0.017
Incomplete spinal cord injury	1.06 (1.02–1.09)	0.001

CI = confidence interval. ♦

**Mechanism of injury**

Most cases of TSCI (673, 96%) were caused by unintentional incidents. The mechanism of injury was a transport-related event in 269 cases (38%) and a low fall in 197 (28%). Eighteen TSCI cases (3%) resulted from diving into shallow water (14 at a beach, river or lake, four in pools), ten (1%) resulted from other water sport activities. One hundred and twenty cases of TSCI (17%) resulted from high falls, including 30 from ladders and 21 from roofs. A greater proportion of injuries in women than in men were caused by low falls (44% v 24%), while all 19 cases of being struck by a person and 48 of 51 cases of collisions with objects involved men (Box 4).

The proportion of TSCIs resulting from transport-related events was greater among younger patients (0–15, 16–34 years) than older patients (Box 5). There were no statistically significant changes in the incidence of TSCI resulting from transport-related events (Box 2), including motor vehicle-related incidents (Box 6, A).

Of 197 TSCIs resulting from low falls, 123 involved people aged 65 or more (55% of TSCIs in this age group; 62% of all low fall-related cases) (Box 5). While the incidence of TSCI resulting from high falls was steady, that for low falls increased by 9% per year (95% CI, 4–15% per year) (Box 2, Box 6, B). One hundred and sixty-two of 197 patients (82%) with TSCIs resulting from low falls had isolated TSCI injuries (Box 7).

**Profile of injury**

Incomplete cervical spinal cord injuries comprised the largest group of TSCI by anatomic

location (332 cases, 48%; Box 4), of which 161 of 221 cases of known injury type (73%) were classified as central cord syndrome (Supporting Information, table 1). The proportions of cases of incomplete cervical TSCI (65%), isolated spinal cord injury (82%), and cervical spinal cord injury without associated spinal column fractures or dislocations (44%) were each greatest for low falls, while the proportion of complete thoracic TSCI was greatest for high energy mechanisms (transport-related events and high falls, each 24%; Box 7). The frequency of TSCI by anatomic site and age group is reported in the Supporting Information, table 2.

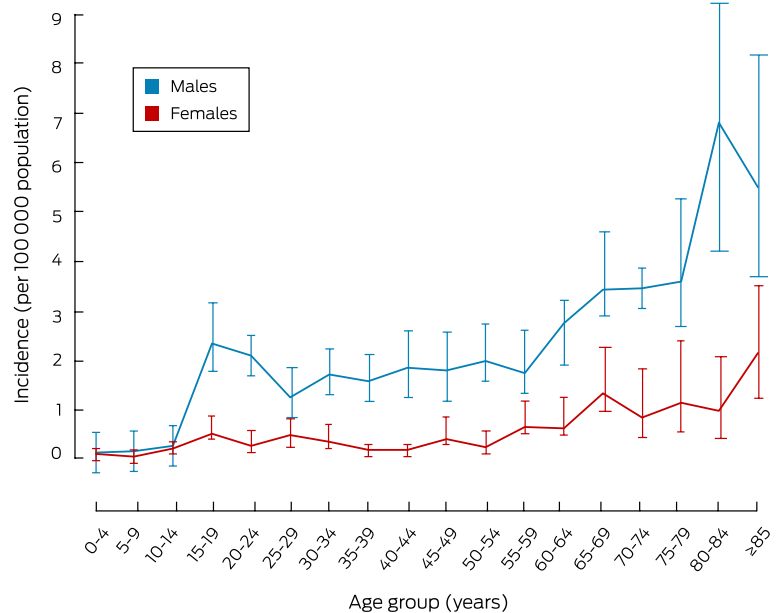
The incidence of complete TSCI declined by 5% per year (95% CI, 1–8%), while the incidence of incomplete TSCI increased by 6% per year (95% CI, 2–9%) (Box 2). More specifically, the proportions of complete tetraplegia (from 35% to 20%; P = 0.007) and complete paraplegia (from 18% to 13%; P = 0.034) declined, and that of incomplete tetraplegia increased (from 41% to 55%; P < 0.001) (Box 8).

The overall in-hospital mortality rate was 15% (104 deaths), and was greatest for people aged 65 years or more (70 deaths, 31%) (Box 5). Of the patients who survived to hospital discharge, 477 (79%) were discharged to inpatient rehabilitation (Box 4), of whom 294 (62%) were discharged to the state spinal cord injury rehabilitation service (the Royal Talbot Rehabilitation Centre); the proportion referred to this service declined from 75% (38 patients) in 2007 to 52% in 2016 (28 patients). The proportion of patients who survived to hospital discharge who were discharged home was greater for incomplete than for complete TSCI (20% [75 patients] v 3% [six patients]; P < 0.001).

**Injury compensation**

The proportion of patients who received financial compensation for the costs of their injuries from WorkSafe or the Transport Accident Commission declined from 37% in 2007 (27 cases) to 16% in 2016 (13 cases) (P < 0.001).

**3 Incidence of spinal cord injury, Victoria, 2007–2016, by 5-year age group and sex**



#### 4 Characteristics of injuries and care for patients who sustained traumatic spinal cord injuries in Victoria, 2007–2016, by sex

Characteristic	Total	Males	Females	P
Number of patients	706	560	146	
Nature of injury-causing incident				0.77
Unintentional	673 (96.1%)	533 (96.0%)	140 (96.6%)	
Intentional	27 (3.9%)	22 (4.0%)	5 (3%)	
Missing data	6	5	1	
Mechanism of injury				< 0.001
Transport-related: motor vehicle	131 (18.6%)	90 (16%)	41 (28%)	
Transport-related: motorcycle	73 (10%)	69 (12%)	4 (3%)	
Transport-related: cyclist	53 (7.5%)	51 (9.1%)	2 (1%)	
Transport-related: pedestrian	12 (1.7%)	10 (1.8%)	2 (1%)	
Low falls ( $\leq$ 1 m)	197 (27.9%)	133 (23.8%)	64 (44%)	
High falls ( $>$ 1 m)	120 (17.0%)	101 (18.0%)	19 (13%)	
Struck by or collided with person	19 (2.7%)	19 (3.4%)	0	
Struck by or collided with object	51 (7.2%)	48 (8.6%)	3 (2%)	
Other	50 (7.1%)	39 (7.0%)	11 (7.5%)	
Anatomic site of injury				0.33
Cervical: complete, C3 or above	37 (5.3%)	29 (5.3%)	8 (6%)	
Cervical: complete, C4 or below	120 (17.3%)	99 (18%)	21 (15%)	
Cervical: incomplete	332 (47.8%)	270 (48.9%)	62 (43%)	
Thoracic: complete	113 (16.3%)	89 (16%)	24 (17%)	
Thoracic: incomplete	44 (6.3%)	30 (5.4%)	14 (9.8%)	
Lumbar: complete	19 (2.7%)	14 (2.5%)	5 (4%)	
Lumbar: incomplete	30 (4.3%)	21 (3.8%)	9 (6%)	
Missing data	11	8	3	
In-hospital mortality	104 (14.7%)	87 (16%)	17 (12%)	0.24
Definitive care hospital service level				0.83
Victorian Spinal Cord Service	406 (57.5%)	325 (58.0%)	81 (56%)	
Major trauma centre	270 (38.2%)	212 (37.9%)	58 (40%)	
Other	30 (4.2%)	23 (4.1%)	7 (5%)	
Discharge destination (for survivors to discharge)				0.39
Home	84 (14%)	66 (14%)	18 (14%)	
Rehabilitation	477 (79.4%)	378 (80.1%)	99 (77%)	
Other	40 (6.7%)	28 (5.9%)	12 (9.3%)	
Missing data	1	1	0	

IQR = interquartile range. ♦

## Discussion

There was no change in the overall crude incidence of TSCI between 2007 and 2016, but the incidence of TSCI resulting from low falls increased by 9% per year, paralleled by a statistically significant increase in the proportion of incomplete tetraplegia TSCI cases.

The crude incidence of TSCI was 1.26 cases per 100 000 population, similar to figures reported for the Netherlands (1.40 per 100 000),<sup>12</sup> Denmark (1.02 per 100 000),<sup>13</sup> and Finland (1.38 per 100 000),<sup>14</sup> but substantially lower than in the United States (5.4 cases per 100 000

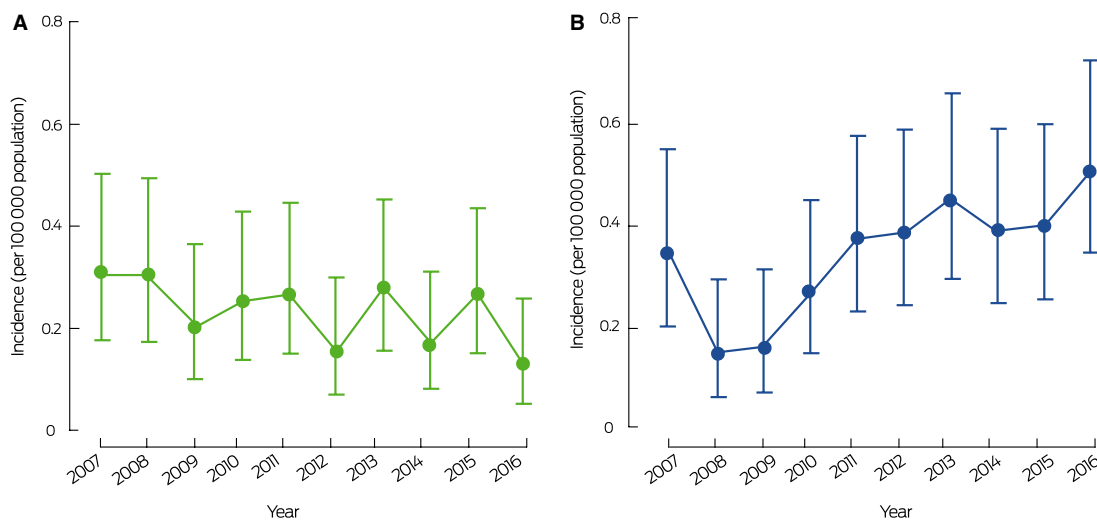
population),<sup>15</sup> perhaps reflecting higher rates of violence-related TSCI in the US (particularly with firearms).<sup>16</sup> Australia is recognised for its low levels of firearm-related injury.<sup>17</sup>

Our finding that an increasing number of older adults (65 years or more) are sustaining TSCIs is consistent with those of other studies.<sup>14,15,18</sup> It has been suggested that this reflects ageing populations,<sup>19</sup> but we found that the incidence of TSCI in older adults increased by 5% per year after adjusting for population increases. It has been reported in the United Kingdom that both the number and the proportion of cases of major trauma in older adults are increasing rapidly, largely because of the increase in low fall

**5 Mechanism of injury, neurological impairment, and deaths for 706 patients with traumatic spinal cord injuries in Victoria, 2007–2016, by age group**

	0–15 years	16–34 years	35–64 years	≥ 65 years	P
Number of patients	23	192	268	223	
Mechanism of injury					< 0.001
Transport-related	17 (74%)	100 (52%)	102 (38%)	50 (22%)	
Low falls (≤ 1 m)	1 (4%)	10 (5.2%)	63 (24%)	123 (55%)	
High falls (> 1 m)	0	30 (16%)	54 (20%)	36 (16%)	
Struck by or collided with object	2 (9%)	23 (12%)	23 (8.6%)	3 (1%)	
Other	3 (13%)	29 (15%)	26 (9.7%)	11 (4.9%)	
Neurologic impairment					< 0.001
Tetraplegia: complete	5 (22%)	40 (21%)	54 (20%)	60 (27%)	
Tetraplegia: incomplete	10 (44%)	56 (30%)	144 (54%)	122 (56%)	
Paraplegia: complete	3 (13%)	70 (37%)	36 (14%)	22 (10%)	
Paraplegia: incomplete	5 (22%)	22 (12%)	33 (12%)	15 (6.8%)	
Missing data	0	4	1	4	
Isolated spinal cord injury	13 (56%)	93 (48%)	148 (55%)	139 (62%)	0.044
In-hospital deaths	2 (9%)	8 (4%)	24 (9.0%)	70 (31%)	< 0.001

**6 Incidence (with 95% confidence intervals) of traumatic spinal cord injury resulting from A. motor vehicle collisions and B. low falls, Victoria, 2007–2016**



event numbers.<sup>20</sup> We similarly found that low falls were the most common cause of TSCI in older adults. Low falls, as the leading cause of injury-related hospitalisations in Australia (2014–15: 198 576 people, 41% of injury-related hospitalisations<sup>21</sup>), are a significant public health problem. The frequency of fall-related spinal injuries in older adults has been attributed to a number of risk factors, including vulnerable spinal structure and anatomy (eg, spinal stenosis, pre-existing spinal cord pathology), poor balance, reduced muscle strength, and polypharmacy.<sup>22</sup> Continued efforts to avert falls are required, including group and home-based exercise programs, as well as improved home safety and design,<sup>23</sup> as most low falls happen in the home.<sup>24</sup>

column fracture or dislocation. Further, most cases of incomplete cervical spinal cord injury of known injury type were classified as central cord syndrome, which often impairs upper limb function more than mobility and reduces autonomy in activities of daily living. Older adults are often more susceptible to TSCI associated with reduced bone density and more severe spinal degeneration;<sup>25</sup> multimorbidity and reduced physiological reserve may also exacerbate both the acute and long term effects of TSCI in these patients.<sup>26,27</sup>

While low energy mechanisms were the most common cause of TSCI in older adults, high energy events (transport-related events, high falls) were the leading causes of TSCI in younger adults and children. Motor vehicle and motorcycle collisions remain key causes of TSCI, and their incidence did not decline over

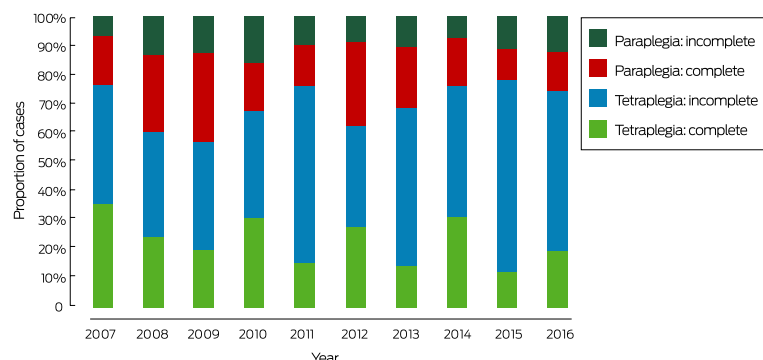
TSCIs resulting from low falls were typically isolated, incomplete injuries to the cervical spine, often without an associated spinal



## 7 Traumatic spinal cord injuries in Victoria, 2007–2016: injury profile, by mechanism of injury

	Transport-related	Low falls	High falls	Struck by or collision with object	Other	<i>P</i>
Number of patients	269	197	120	51	69	
Anatomic site of injury						< 0.001
Cervical: complete, C3 or above	16 (6.1%)	10 (5.2%)	5 (4%)	3 (6%)	3 (4%)	
Cervical: complete, C4 or below	47 (18%)	33 (17%)	15 (13%)	15 (29%)	10 (15%)	
Cervical: incomplete	103 (39%)	126 (65%)	43 (36%)	24 (47%)	36 (54%)	
Thoracic: complete	63 (24%)	10 (5.2%)	29 (24%)	3 (6%)	8 (12%)	
Thoracic: incomplete	18 (6.8%)	5 (3%)	12 (10%)	2 (4%)	7 (10%)	
Lumbar: complete	10 (3.8%)	1 (0.5%)	7 (6%)	1 (2%)	0	
Lumbar: incomplete	7 (3%)	9 (5%)	8 (7%)	3 (6%)	3 (4%)	
Missing data	5	3	1	0	2	
Isolated spinal cord injury	105 (39%)	162 (82%)	52 (43%)	34 (67%)	40 (58%)	< 0.001
Associated spinal column injury: cervical spinal cord injury						0.001
No fracture or dislocation	44 (28%)	71 (44%)	16 (26%)	8 (22%)	18 (42%)	
With fracture	46 (29%)	47 (29%)	27 (44%)	18 (49%)	11 (26%)	
With dislocation	9 (6%)	10 (6.3%)	1 (2%)	2 (5%)	2 (5%)	
With both fracture and dislocation	59 (37%)	32 (20%)	18 (29%)	9 (24%)	12 (28%)	
Missing data	10	2	9	5	8	
Associated spinal column injury: thoracic spinal cord injury						0.16
No fracture or dislocation	5 (6%)	2 (13%)	4 (10%)	0	3 (27%)	
With fracture	42 (54%)	11 (73%)	19 (46%)	2 (50%)	8 (73%)	
With dislocation	3 (4%)	1 (7%)	1 (2%)	0	0	
With both fracture and dislocation	28 (36%)	1 (7%)	17 (42%)	2 (50%)	0	
Missing data	3	0	0	1	4	

## 8 Traumatic spinal cord injuries in Victoria, 2007–2016: degree of neurological impairment, by year



the 10-year study period. Road safety interventions (improved vehicle design, passenger restraints, enforced speed limits, preventing drink- and drug-impaired driving) have been associated with lower incidence of TSCI overseas.<sup>15</sup> The specific mechanisms of spinal injury in motor vehicle crashes must be better understood if the incidence of transport-related cases of TSCI is to be reduced. Protecting vulnerable road users should also be further emphasised, particularly as substantial increases in the number of seriously injured pedal cyclists have been reported.<sup>28</sup>

High falls accounted for 17% of all cases of TSCI, nearly half of which were from a ladder or roof. The incidence of ladder falls is increasing, and interventions that encourage avoiding risk, using safety equipment, and improving ladder setup have been recommended.<sup>29,30</sup>

Patients with spinal cord injuries face complex challenges during their care and recovery, including long stays in inpatient rehabilitation, high rates of hospital re-admission, and substantial post-discharge care needs.<sup>31–33</sup> In our study, the proportion of patients who received compensation from no-fault, third party insurers for work- and transport-related spinal injury was lower in 2016 than in 2007, reflecting the concurrent increase in the proportion of low fall-related and decline in that of transport-related TSCI cases.

This shift will increase the demand from patients under 65 on the recently established National Disability Insurance Scheme (NDIS) once it is fully implemented in late 2020. The NDIS does not provide support for people who acquire a disability at age 65 or older; these patients will need alternative types of support, such as that provided by the Home Care Packages program. Ensuring appropriate support for these patients is needed to optimise their recovery and function after a TSCI.<sup>33</sup>

## Limitations

The key strength of our population-based study is that it captured all cases of severe TSCI and was not limited to patients managed in dedicated spinal cord injury units. This is particularly important as only 58% of patients received definitive care at the dedicated spinal care centre. However, we did not have access to American Spinal Injury Association Impairment Scale data for classifying the extent of impairment, nor were we able to include pre-hospital deaths, so we may have underestimated the incidence of TSCI. Changes in imaging practices (eg, magnetic resonance imaging) may have improved the ability to detect TSCI, a factor for which we could not account.

## Conclusion

While TSCI cases comprise a small proportion of all cases of major trauma, their societal and economic impacts are profound.

We found that the epidemiologic profile of TSCI has shifted, with an increasing number of TSCI events in older adults and a parallel increase in the proportion of patients with incomplete tetraplegia. Better primary prevention strategies are required to reduce the incidence of TSCI.

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- Bickenbach JR, Officer A, Shakespeare T, et al. International perspectives on spinal cord injury. Geneva: World Health Organization; International Spinal Cord Society, 2013. [http://apps.who.int/iris/bitstream/10665/94190/1/9789241564663\\_eng.pdf?ua=1](http://apps.who.int/iris/bitstream/10665/94190/1/9789241564663_eng.pdf?ua=1) (viewed May 2017).
- O'Connor PJ. Prevalence of spinal cord injury in Australia. *Spinal Cord* 2005; 43: 42–46.
- Access Economics, for the Victorian Neurotrauma Initiative. The economic cost of spinal cord injury and traumatic brain injury in Australia. June 2009. <http://www.spinalcure.org.au/pdf/Economic-cost-of-SCI-and-TBI-in-Au-2009.pdf> (viewed May 2017).
- Australian Institute of Health and Welfare. Spinal cord injury, Australia, 2014–15 (Cat. No. INJCAT 193; Injury Research and Statistics Series No. 113). Canberra: AIHW, 2018.
- Department of Health and Human Services (Victoria). Victorian State Trauma System. 2018. <https://www2.health.vic.gov.au/hospitals-and-health-services/patient-care/acute-care/state-trauma-system> (viewed Jan 2019).
- Cameron PA, Gabbe BJ, Cooper DJ, et al. A statewide system of trauma care in Victoria: effect on patient survival. *Med J Aust* 2008; 189: 546–550. <https://www.mja.com.au/journal/2008/189/10/statewide-system-trauma-care-victoria-effect-patient-survival>
- Australian Bureau of Statistics. The Australian statistical geography standard (ASGS) remoteness structure. Updated Mar 2018. <http://www.abs.gov.au/websitedbs/d3310114.nsf/home/remoteness+structure> (viewed Jan 2019).
- Australian Bureau of Statistics. 2033.0.55.001. Census of population and housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2016: IRSAD. Mar 2018. <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2033.0.55.001-2016-Main%20Features-IRSAD-20> (viewed Jan 2019).
- Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987; 40: 373–383.
- Australian Institute of Health and Welfare. Age-standardised rate. METeOR Metadata Online Registry; Mar 2005. <http://meteor.aihw.gov.au/content/index.phtml/itemId/327276> (viewed Sept 2016).
- Australian Bureau of Statistics. 3101.0. Australian demographic statistics, Mar 2013. Sept 2013. <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Mar%202013?OpenDocument> (viewed Aug 2016).
- Nijendijk JH, Post MW, Van Asbeck FW. Epidemiology of traumatic spinal cord injuries in The Netherlands in 2010. *Spinal Cord* 2014; 52: 258–263.
- Bjørnshave Noe B, Mikkelsen EM, Hansen R, et al. Incidence of traumatic spinal cord injury in Denmark, 1990–2012: a hospital-based study. *Spinal Cord* 2015; 53: 436–440.
- Ahoniemi E, Alaranta H, Hokkinen E, et al. Incidence of traumatic spinal cord injuries in Finland over a 30-year period. *Spinal Cord* 2008; 46: 781–784.
- Jain NB, Ayers GD, Peterson EN, et al. Traumatic spinal cord injury in the United States, 1993–2012. *JAMA* 2015; 313: 2236–2243.
- Lee B, Cripps R, Fitzharris M, et al. The global map for traumatic spinal cord injury epidemiology: update 2011, global incidence rate. *Spinal Cord* 2014; 52: 110–116.
- Chapman S, Alpers P, Jones M. Association between gun law reforms and intentional firearm deaths in Australia, 1979–2013. *JAMA* 2016; 316: 291–299.
- DeVivo MJ, Chen Y. Trends in new injuries, prevalent cases, and aging with spinal cord injury. *Arch Phys Med Rehabil* 2011; 92: 332–338.
- Bárbara-Bataller E, Méndez-Suárez JL, Alemán-Sánchez C, et al. Change in the profile of traumatic spinal cord injury over 15 years in Spain. *Scand J Trauma Resusc Emerg Med* 2018; 26: 27.
- Kehoe A, Smith J, Edwards A, et al. The changing face of major trauma in the UK. *Emerg Med J* 2015; 32: 911–915.
- Australian Institute of Health and Welfare. Trends in hospitalised injury, Australia 1999–00 to 2014–15 (Cat. No. INJCAT 190; Injury Research and Statistics Series No. 110). Canberra: AIHW, 2018.
- Ambrose AF, Paul G, Hausdorff JM. Risk factors for falls among older adults: a review of the literature. *Maturitas* 2013; 75: 51–61.
- Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev* 2012; CD007146.
- Beck B, Cameron P, Lowthian J, et al. Major trauma in older persons. *BJS Open* 2018; 2: 310–318.
- Fehlings MG, Tetreault L, Nater A, et al. The aging of the global population: the changing epidemiology of disease and spinal disorders. *Neurosurgery* 2015; 77 (Suppl 1): S1–S5.
- Heffernan DS, Thakkar RK, Monaghan SF, et al. Normal presenting vital signs are unreliable in geriatric blunt trauma victims. *J Trauma* 2010; 69: 813–820.
- Kehoe A, Smith J, Bouamra O, et al. Older patients with traumatic brain injury present with a higher GCS score than younger patients for a given severity of injury. *Emerg Med J* 2016; 33: 381–385.
- Beck B, Cameron P, Fitzgerald MC, et al. Road safety: serious injuries remain a major unsolved problem. *Med J Aust* 2017; 207: 244–249. <https://www.mja.com.au/journal/2017/207/6/road-safety-serious-injuries-remain-major-unsolved-problem>
- Ackland HM, Pilcher DV, Roodenburg OS, et al. Danger at every rung: epidemiology and outcomes of ICU-admitted ladder-related trauma. *Injury* 2016; 47: 1109–1117.
- Cabilan C, Vallmuur K, Eley R, et al. Impact of ladder-related falls on the emergency department and recommendations for ladder safety. *Emerg Med Australas* 2018; 30: 95–102.
- Gabbe BJ, Nunn A. Profile and costs of secondary conditions resulting in emergency department presentations and readmission to hospital following traumatic spinal cord injury. *Injury* 2016; 47: 1847–1855.
- Munce SE, Wodchis W, Guilcher SJ, et al. Direct costs of adult traumatic spinal cord injury in Ontario. *Spinal Cord* 2013; 51: 64–69.
- Braaf SC, Lennox A, Nunn A, et al. Experiences of hospital readmission and receiving formal carer services following spinal cord injury: a qualitative study to identify needs. *Disabil Rehabil* 2018; 40: 1893–1899. ■

## Supporting Information

Additional Supporting Information is included with the online version of this article.