A statewide system of trauma care in Victoria: effect on patient survival

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ABSTRACT

Objective: To determine whether the statewide system of trauma care introduced in 2000 has resulted in improved survival for all major trauma patients in Victoria.

Design, setting and participants: Population-based cohort study using data from the Victorian State Trauma Registry (VSTR), a registry of all hospitalised major trauma patients in Victoria. The study included major trauma patients with an Injury Severity Score > 15 captured by the VSTR between July 2001 and June 2006.

Main outcome measure: In-hospital mortality.

Results: The number of major trauma cases captured by the registry rose from 1153 in 2001–02 to 1737 in 2005–06. Adjusting for key predictors of mortality, there was a significant overall reduction between 2001–02 and 2005–06 in the risk of death for patients treated in the trauma system (adjusted odds ratio [AOR], 0.62 [95% CI, 0.48–0.80]). The reduced risk of death was also significant when road trauma cases (AOR, 0.56 [95% CI, 0.39–0.80]) and serious head injury cases (AOR, 0.62 [95% CI, 0.46–0.83]) were analysed separately. The proportion of road trauma patients definitively treated at one of the three major trauma service (MTS) hospitals in Victoria rose by 7% over the 5-year period. Direct transfers from the scene of injury to MTS hospitals rose by 8% for all cases and 13% for road trauma cases over the same period.

Conclusions: Introduction of a statewide trauma system was associated with a significant reduction in risk-adjusted mortality. Such inclusive systems of trauma care should be regarded as a minimum standard for health jurisdictions.

MJA 2008; 189: 546–550

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Treatment of critically ill patients with multiple injuries requires expert, multidisciplinary, high-cost, coordinated and timely interventions.[1-3] This is difficult to guarantee without a system of trauma care that integrates all regional health facilities. But few regions in the world have a fully integrated system of trauma care involving pre-hospital providers, all acute health services and rehabilitation facilities. The investment required to upgrade and maintain high-level centres necessary to support a trauma system has dissuaded many jurisdictions from undertaking the difficult political and organisational decisions required to implement a national or state-based system of care. In the United Kingdom, the development of regionalised trauma systems has progressed slowly.[4,5] Improvements in survival from traumatic brain injury have been particularly limited by this inertia.[6]

Trauma care has traditionally consisted of fragmented, complex individual therapies. As a result of military experience, many clinicians involved in trauma care developed the view that trauma centres with high-volume experience would provide better care than other centres.[1,3] The concept of identifying preventable trauma deaths and developing registries to monitor outcomes began in the 1970s and built momentum during the 1980s in North America.[7-9] Further experience from the United States suggested that a whole-of-system approach, involving hospitals with designated levels of service provision according to capability, would be best. This would result in "inclusive" rather than "exclusive" systems.[10-12]

The evidence for improved population-based outcomes after the introduction of a trauma system is limited.[13] Most population-based studies have assessed the impact of trauma system implementation by comparing outcomes over time between individual trauma centres; between non-trauma centres and trauma centres; or between different systems (eg, systems in adjacent states); or by analysing specific injury subgroups (such as motor vehicle crashes).[14-16] Although these approaches have reported benefits of implementing a trauma system for reducing mortality, the evaluations have been hampered by the use of administrative data or trauma registry data limited to selected institutions.

In the state of Victoria in Australia, a trauma centre was established at the Alfred Hospital in the early 1990s. At the time, there was no accepted guideline for hospital bypass or secondary transfer of patients and no central monitoring of trauma cases. Following a ministerial review, a statewide, inclusive system of trauma care was developed, and staged implementation began in 2000.[17] An essential component of the system was monitoring of every case in Victoria through a centralised, population-based trauma registry developed to capture detailed information for all major trauma cases in the state, irrespective of the hospital in which the patients were treated.[18-20]

The aim of our study was to determine whether the statewide system of trauma care introduced in 2000 has resulted in improved survival for all major trauma patients in Victoria.

Abbreviations

AIS	Abbreviated Injury Scale
ICU	Intensive care unit
ISS	Injury Severity Score
MTS	Major trauma service
VSTR	Victorian State Trauma Registry
VSTS	Victorian State Trauma System

METHODS

Setting

Victoria is a state of about 5 million people, with one major metropolitan area of 3.5 million people. The staged implementation of the Victorian State Trauma System (VSTS) began in 2000 and was completed in 2003. Two adult hospitals and one paediatric hospital were designated as major trauma services (MTSs) (Level I), and eight metropolitan and 10 regional health care services were effectively designated as Level II centres. The remaining 117 hospitals were also assigned roles within the system. Triage guidelines were developed for the rural, metropolitan and air ambulance services to direct all patients with major or potentially major trauma to an MTS if one was accessible

within 30 minutes. Similarly, non-MTS hospitals were instructed to transfer patients to an MTS if they fulfilled major trauma criteria.

The third party compulsory insurance agency for transport-related injury, the Transport Accident Commission, partially funded the upgrade of the trauma system, while the Victorian Department of Human Services directly funds the public hospitals responsible for the care of major trauma patients.

Definitions

Under the VSTS, major trauma is defined by any of the following criteria: death due to injury, an Injury Severity Score (ISS) > 15,[21] injury requiring urgent surgery, or an intensive care unit (ICU) stay of over 24 hours requiring mechanical ventilation.

Serious head injury is defined as a head injury that is assigned an Abbreviated Injury Scale (AIS) severity code > 2.[22]

Monitoring

The ministerial review recommended a monitoring process as a central component of the system. The Victorian State Trauma Registry (VSTR), which is integrated into the VSTS, is a population-based registry that collects information from the pre-hospital, hospital and post-hospital discharge phases of care for all major trauma patients in Victoria. Data collection commenced in July 2001. Cases are identified, and data collected, from emergency admission data, discharge data and review of hospital case notes. Data are also collected directly from ambulance case notes and the National Coroners Information System.

To allow linkage of data across trauma service providers and post-discharge follow-up of patients, identified data are used. Approval for the VSTR collection and analysis was received from the human research ethics committees of Monash University, the National Coroners Information System, and all the institutions and services providing trauma care. The VSTR uses an opt-off consent process, whereby all eligible patients are included on the registry unless they actively choose to have their data excluded. Patients, or their next of kin in the case of death, are sent an information sheet detailing their inclusion on the registry, the purpose of the registry, the information being collected, and the procedure to follow if they do not wish to participate. An opt-off policy, rather than individual written informed consent, is used to minimise recruitment bias related to difficulties in obtaining informed consent at discharge across over 100 health services — a problem highlighted by the experience of previous registries.[23] Only 0.3% of patients captured during the period July 2001 to June 2006 requested removal from the registry.

In addition to the VSTR, the monitoring process includes all trauma-related hospital admissions across the state, using administrative hospital discharge data to ensure accuracy of data and to monitor the effects of the trauma system on non-major trauma. The VSTR reports on a quarterly basis to the State Trauma Committee, which advises the Department of Human Services on improvements to trauma management processes.

Data analysis

For the purposes of our study, all VSTR cases with an ISS > 15 were extracted for analysis. Descriptive statistics were used to provide an overview of major trauma patients by year. Multivariate logistic

1 Profile of major trauma patients* in Victoria, 2001–2006†

Characteristic	2001–02 (*n* = 1153)	2002–03 (*n* = 1131)	2003–04 (*n* = 1359)	2004–05 (*n* = 1565)	2005–06 (*n* = 1737)
Victorian population (millions)	4.86	4.92	4.98	5.05	5.13
Median age, in years (IQR)	33 (21–53)	37 (23–55)	40 (23–60)	40 (24–63)	40 (24–62)
Male	851 (74% [71%–76%])	848 (75% [72%–77%])	968 (71% [69%–73%])	1126 (72% [70%–74%])	1264 (73% [73%–75%])
Mechanism of injury‡					
Road trauma	719 (63% [60%–66%])	619 (56% [53%–59%])	766 (57% [54%–60%])	803 (51% [49%–54%])	920 (53% [51%–55%])
Low fall (from ⩽ 1m)	135 (12% [10%–14%])	132 (12% [10%–14%])	187 (14% [12%–16%])	265 (17% [15%–19%])	322 (19% [17%–21%])
High fall (from > 1m)	90 (8% [6%–10%])	142 (13% [11%–15%])	141 (11% [9%–13%])	200 (13% [11%–15%])	174 (10% [9%–11%])
Struck by or collision with object	52 (5% [4%–6%])	49 (4% [3%–5%])	71 (5% [4%–6%])	58 (4% [3%–5%])	84 (5% [4%–6%])
Struck by or collision with person	38 (3% [2%–4%])	43 (4% [3%–5%])	58 (4% [3%–5%])	78 (5% [4%–6%])	87 (5% [4%–6%])
Cutting or piercing object	38 (3% [2%–4%])	43 (4% [3%–5%])	29 (2% [1%–3%])	43 (3% [2%–4%])	37 (2% [1%–3%])
Horse-related	19 (2% [1%–3%])	25 (2% [1%–3%])	29 (2% [1%–3%])	33 (2% [1%–3%])	36 (2% [1%–3%])
Other mechanism	47 (4% [3%–5%])	58 (5% [4%–6%])	70 (5% [4%–6%])	78 (5% [4%–6%])	64 (4% [3%–5%])
Trauma type§					
Blunt	1075 (93% [92%–95%])	1031 (91% [90%–93%])	1268 (93% [92%–94%])	1456 (93% [92%–94%])	1647 (95% [94%–96%])
Penetrating	48 (4% [3%–5%])	54 (5% [4%–6%])	46 (4% [3%–5%])	59 (4% [3%–5%])	57 (3% [2%–4%])
Burn/other	30 (3% [2%–4%])	46 (4% [3%–5%])	45 (3% [2%–4%])	50 (3% [2%–4%])	32 (2% [1%–3%])
Median ISS (IQR)	22 (17–29)	22 (17–29)	24 (17–29)	22 (17–29)	22 (17–29)
AIS severity code					
⩽ 2	499 (43% [40%–46%])	515 (46% [43%–49%])	604 (44% [41%–47%])	719 (46% [44%–49%])	816 (47% [45%–49%])
3–4	461 (40% [37%–43%])	430 (38% [35%–41%])	499 (37% [34%–40%])	553 (35% [33%–37%])	633 (36% [34%–38%])
5–6	193 (17% [15%–19%])	186 (16% [14%–18%])	256 (19% [17%–21%])	293 (19% [17%–21%])	288 (17% [15%–19%])

AIS = Abbreviated Injury Scale. IQR = interquartile range. ISS = Injury Severity Score. * Patients with ISS > 15. † Figures in table represent number (% [95% CI]), except where otherwise specified. ‡ Data missing for 63 cases (< 1%). § Data missing for one case. ◆

2 Transfer, management and outcomes of major trauma patients* in Victoria, 2001–2006†

Characteristic	2001–02 (*n* = 1153)	2002–03 (*n* = 1131)	2003–04 (*n* = 1359)	2004–05 (*n* = 1565)	2005–06 (*n* = 1737)
Victorian population (millions)	4.86	4.92	4.98	5.05	5.13
Managed at an MTS					
All cases	966 (84% [82%–86%])	952 (84% [82%–86%])	1116 (82% [80%–84%])	1260 (81% [79%–83%])	1429 (82% [80%–84%])
Road trauma cases	612 (85% [82%–88%])	537 (87% [84%–90%])	691 (90% [88%–92%])	738 (92% [90%–94%])	850 (92% [90%–94%])
Transferred directly from scene of injury to an MTS‡					
All cases	570 (59% [56%–62%])	578 (61% [58%–64%])	735 (66% [63%–69%])	856 (68% [65%–71%])	956 (67% [65%–69%])
Road trauma cases	387 (63% [59%–67%])	367 (68% [63%–73%])	504 (73% [69%–77%])	549 (74% [70%–78%])	636 (75% [72%–78%])
Patient stayed in ICU	640 (56% [53%–59%])	620 (55% [52%–58%])	692 (51% [48%–54%])	770 (49% [47%–52%])	786 (45% [43%–47%])
Median length of stay in ICU, in days (IQR)	5 (2–11)	5 (2–12)	5 (2–12)	5 (2–10)	4 (2–10)
Median length of stay in hospital, in days (IQR)	9.0 (4.5–17.6)	9.8 (5.1–19.6)	9.0 (4.4–18.1)	8.3 (4.0–16.7)	8.3 (4.3–15.8)
In-hospital mortality	168 (15% [13%–17%])	137 (12% [10%–14%])	159 (12% [10%–14%])	199 (13% [11%–15%])	193 (11% [10%–13%])

ICU = intensive care unit. IQR = interquartile range. MTS = major trauma service. * Patients with Injury Severity Score > 15. † Figures in table represent number (% [95% CI]), except where otherwise specified. ‡ Patients managed at an MTS. ◆

regression analysis was used to assess the association between in-hospital mortality and year, adjusted for known predictors of mortality in major trauma cases. The covariates used were age, ISS, presence of a serious head injury, and mechanism of injury. We did not adjust for comorbid conditions, as a previous study in the VSTR population had shown that such adjustment did not improve prediction of mortality over age-adjusted models alone.[24] Adjusted odds ratios (AORs) and 95% confidence intervals for each year, relative to 2001–02, were calculated. All data were analysed using SPSS for Windows, version 15.0 (SPSS Inc, Chicago, Ill, USA) and Stata, version 10.0 (StataCorp, College Station, Tex, USA).

RESULTS

A profile of hospitalised major trauma patients captured by the registry is presented in Box 1. The number of major trauma patients captured per annum increased by 51% over the study period, from 1153 to 1737 cases, while the population rose 5%, from 4.86 to 5.13 million. The sex distribution of major trauma patients remained stable, but there was an increase in the age of patients captured by the registry over the 5 years. The mechanisms of injury in the major trauma cases captured by the registry also changed, with a reduction in the proportion of road trauma cases and an increase in the proportion of low falls cases (ie, falls from ⩽ 1 m height). The overall severity of injury, measured by the ISS, was unchanged over the study period, and the proportion of cases involving a serious head injury (AIS severity score > 2) also remained stable.

The proportion of road trauma cases managed at an MTS rose 7% over the study period, although the proportion of all major trauma patients managed at an MTS was constant, with 81%–84% of cases managed at a Level I centre (Box 2). Of the patients definitively managed at an MTS, the proportion transferred directly from the scene of injury to the MTS rose 8% for all patients and 13% for road trauma patients over the 5-year period. Despite a stable level of injury severity over this period, there were reductions in the proportion of patients admitted to ICU, the length of stay in ICU and the overall length of stay in hospital.

The unadjusted in-hospital death rate fell over the study period from 15% in 2001–02 to 11% in 2005–06 (Box 2). The majority of deaths occurred in patients with serious head injuries, accounting for 73%–76% of deaths over the 5 years.

The odds of death for each year, adjusted for key predictors of mortality (age, mechanism of injury, ISS, and the presence of a serious head injury), are shown in Box 3 for all cases, for road trauma cases alone, and for serious head injury cases. The adjusted odds of mortality for all hospitalised major trauma patients in Victoria declined significantly from the third year of the implementation of the trauma system (Box 4) ($P = 0.004$). Significant reductions in the odds of in-hospital mortality were also apparent among road trauma patients ($P = 0.003$) and patients with serious head injury ($P = 0.018$).

DISCUSSION

Our study, using population-based trauma registry data, demonstrates a significant decrease in the adjusted odds of in-hospital death following the introduction of a statewide, inclusive trauma system. To our knowledge, our study is the first to demonstrate the benefit of an inclusive statewide trauma system outside of North America. Moreover, the improvement occurred despite the already high-level operation of the Victorian health care system[25] and despite the existence of one high-volume trauma centre before the introduction of the VSTS.

Previously, population-based studies using trauma registry data to assess the impact of trauma systems have been limited by the availability of data only from high-level trauma centres and designated institutions with trauma registries. Thus, trauma cases not referred to hospitals with existing registries have been missed.[26,27] This creates the potential for selection bias, in that triage and transfer policies could result in selection of patients with an improved chance of survival at the designated hospitals.[27]

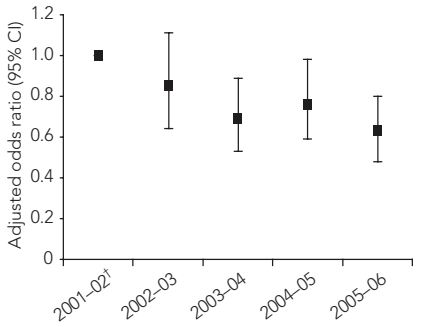
An alternative to registry data to evaluate the effectiveness of trauma systems in reducing mortality has been the use of administrative data, such as hospital admissions data.[26-29] However, administrative data are limited in the detail of information collected and the timeliness of data availability. Injury severity measures are not captured, creating difficulties in identifying patients with severe injury. Previous studies have attempted to overcome the issue of case identification by severity through the use of "index" injuries[26,29] or mapping of ICD-9-CM (International classification of diseases, 9th revision, clinical modification) diagnostic codes to AIS

3 Independent predictors of in-hospital mortality in major trauma patients* in Victoria, 2001–2006

Predictor	Adjusted odds ratio (95% CI) All ISS > 15 (*n* = 6881)†	Road trauma (*n* = 3827)	Serious head injury (*n* = 3737)‡
Year			
2001–02§	1.0	1.0	1.0
2002–03	0.85 (0.64–1.11)	0.85 (0.58–1.24)	0.86 (0.62–1.18)
2003–04	0.69 (0.53–0.89)	0.54 (0.37–0.79)	0.69 (0.51–0.94)
2004–05	0.76 (0.59–0.98)	0.66 (0.46–0.95)	0.78 (0.58–1.04)
2005–06	0.62 (0.48–0.80)	0.56 (0.39–0.80)	0.62 (0.46–0.83)
Age			
< 15 years§	1.0	1.0	1.0
15–24 years	0.80 (0.53–1.22)	0.46 (0.27–0.77)	0.83 (0.53–1.31)
25–34 years	0.90 (0.59–1.38)	0.50 (0.29–0.87)	0.90 (0.56–1.43)
35–44 years	1.01 (0.66–1.57)	0.51 (0.28–0.93)	1.14 (0.70–1.85)
45–54 years	1.21 (0.78–1.87)	0.66 (0.36–1.18)	1.49 (0.92–2.40)
55–64 years	1.96 (1.27–3.04)	1.00 (0.54–1.86)	1.95 (1.21–3.17)
65–74 years	2.63 (1.70–4.07)	1.58 (0.86–2.90)	2.40 (1.48–3.90)
75–84 years	4.97 (3.28–7.54)	2.66 (1.48–4.79)	4.05 (2.58–6.37)
⩾ 85 years	6.50 (4.10–10.31)	5.80 (2.58–13.02)	4.96 (3.03–8.15)
ISS			
16–25§	1.0	1.0	1.0
26–40	3.10 (2.55–3.77)	3.96 (2.82–5.54)	3.03 (2.40–3.82)
> 40	17.30 (13.57–22.05)	21.78 (15.43–30.74)	13.77 (10.24–18.53)
Head injury			
AIS severity code ⩽ 2§	1.0	1.0	na
AIS severity code > 2	2.11 (1.73–2.58)	1.72 (1.31–2.26)	na
Mechanism			
Road trauma§	1.0	na	1.0
Low fall (from ⩽ 1 m)	0.24 (0.18–0.33)	na	2.09 (1.56–2.82)
High fall (from > 1 m)	0.47 (0.32–0.68)	na	1.75 (1.28–2.39)
Cutting or piercing object	0.38 (0.26–0.55)	na	1.84 (0.49–6.88)
Struck by or collision with object	1.19 (0.71–1.99)	na	0.96 (0.55–1.67)
Struck by or collision with person	0.26 (0.15–0.45)	na	1.24 (0.72–2.14)
Other mechanism	0.32 (0.18–0.57)	na	4.44 (2.70–7.29)

AIS = Abbreviated Injury Scale. ISS = Injury Severity Score. na = not applicable for model. * Patients with ISS > 15. † Data missing for < 1% of cases. ‡ Data missing for 1.5% of cases. § Reference category. ◆

4 Adjusted odds ratios for death in hospitalised patients admitted with major trauma* in Victoria, 2001–2006, by year



* Injury Severity Score > 15. † Reference category. ◆

scores.[27,28] The use of index injuries provides only a surrogate measure of major trauma, while mapping of ICD-9-CM codes to AIS scores has resulted in substantial overestimation of injury severity.[27] Furthermore, there are no validated mapping systems for converting ICD-10 diagnostic codes to AIS codes, limiting the usefulness of this approach for many countries.

The VSTS has overcome the limitations of previous approaches to trauma system evaluation by capturing trauma registry data from all health services in the state. This involves checking of all trauma admissions against hospital case notes, discharge data, ambulance case notes and coroners records. Therefore, the significant reduction in risk-adjusted mortality observed in our study represents a real population-based improvement in outcome.

A recent study by McDermott et al of road trauma fatalities in Victoria, using case review and qualitative judgements of preventable deaths following major trauma, reported a reduction in preventable deaths over a similar timeframe to that reviewed in our study.[30] McDermott and colleagues showed that, over the period of the trauma system introduction, the proportion of preventable deaths did not fall at the Alfred Hospital (the MTS already in existence before the VSTS was introduced). However, a significant reduction in overall preventable deaths was attributed to a greater number and proportion of road trauma patients being managed primarily at MTSs, where the preventable death rates were consistently lower than at other hospitals.[30] While our study found that the proportion of all major trauma patients definitively managed at an MTS remained stable, the number and proportion of road trauma cases managed at MTSs increased over the study period, supporting the findings of McDermott and colleagues. More importantly, there was a significant increase overall, and for road trauma cases in particular, in the proportion of patients transported directly from the scene of injury to the MTS over the 5-year period. These changes suggest an improvement in prehospital triage and priority transport of the most severe cases to the highest-level treatment centres, providing a likely explanation for the reduced risk of death.

The vast majority of deaths during the study period were in patients with serious head injury, and although the severity of primary brain injuries was unchanged, the reduced risk of death was predominant in this patient group. Apart from enhanced triage of major trauma patients, it is possible that reduced secondary brain injuries in head-injury patients (through improved

early treatment) may have contributed to improved outcomes overall in the VSTS.

A strength of our study was the rigorous effort to include all major trauma cases from all acute health facilities in Victoria, thus eliminating potential selection bias. Moreover, we collected data across all cases in a standardised manner through the centralised trauma registry. However, while most facilities contributed data from the first year, one tertiary hospital did not join the registry until the third year, and another health service did not contribute until the fifth year. Data collection from the three MTSs was complete from the commencement of the registry, as data collection had begun before its introduction.

The increases in median age of major trauma patients and in the proportion of low falls cases over the study period suggest an improvement in data collection for elderly patients, in addition to the ageing population generally. Although this may have influenced measured outcomes over time, age and mechanism of injury were adjusted for in the multivariate model. We also analysed road-trauma and head-injury patient subgroups separately, and found concordant results. Although there was a strong association between the introduction of the VSTS and reduced risk-adjusted mortality, causality cannot definitively be determined. While no major changes in clinical management were noted during the study timeframe, the possibility of advances in medical and surgical care contributing to the observed reduction in mortality cannot be completely discounted.

CONCLUSIONS

There has been a significant reduction in the risk of death among major trauma patients in the state of Victoria since the introduction of a regionalised, inclusive trauma system. One central component of this system is a population-based monitoring process that allows feedback of information on organisational and clinical issues. In the future, it is likely that risk-adjusted improvements in measures of long-term disability will also be demonstrated. The reduced mortality over the study period suggests that regional trauma systems with integrated monitoring and quality improvement programs should now be regarded as the standard of care for health jurisdictions internationally.

ACKNOWLEDGEMENTS

The VSTR is funded and approved by the Victorian Department of Human Services and the Transport Accident Commission. Belinda Gabbe was supported by a National Health and Medical Research Council (NHMRC) Career Development Award and James Cooper by an NHMRC Practitioner Fellowship. We would like to acknowledge the considerable help provided by VSTR staff and members of the Steering Committee over the study period: Chris Atkin, Bill Barger, Stephen Bernard, Warwick Butt, Lisa Collins, Greg Cooper, Alex Currell, Peter Danne, David Eddey, Caroline Finch, Andrew Hannaford, Thomas Kossmann, Sue McLellan, Robert Henning, Joan Ozanne-Smith, Karen Smith, Ann Sutherland, David Taylor, Jason Winnett, Mimi Morgan and Owen Williamson. We would also like to thank the data collectors at each hospital site for their contribution.

COMPETING INTERESTS

None identified.

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(Received 23 Jun 2008, accepted 9 Oct 2008) ❑