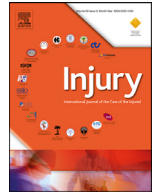




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## Over view of major traumatic injury in Australia--Implications for trauma system design

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### ABSTRACT

**Background:** Trauma registries are known to drive improvements and optimise trauma systems worldwide. This is the first reported comparison of the epidemiology and outcomes at major centres across Australia.

**Methods:** The Australian Trauma Registry was a collaboration of 26 major trauma centres across Australia at the time of this study and currently collects information on patients admitted to these centres who

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die after injury and/or sustain major trauma (Injury Severity Score (ISS) > 12). Data from 1 July 2016 to 30 June 2017 were analysed. Primary endpoints were risk adjusted length of stay and mortality (adjusted for age, cause of injury, arrival Glasgow coma scale (GCS), shock-index grouped in quartiles and ISS).

**Results:** There were 8423 patients from 24 centres included. The median age (IQR) was 48 (28–68) years. Median (IQR) ISS was 17 (14–25). There was a predominance of males (72%) apart from the extremes of age. Transport-related cases accounted for 45% of major trauma, followed by falls (35.1%). Patients took 1.42 (1.03–2.12) h to reach hospital and spent 7.10 (3.64–15.00) days in hospital. Risk adjusted length of stay and mortality did not differ significantly across sites. Primary endpoints across sites were also similar in paediatric and older adult (>65) age groups.

**Conclusion:** Australia has the capability to identify national injury trends to target prevention and reduce the burden of injury. Quality of care following injury can now be benchmarked across Australia and with the planned enhancements to data collection and reporting, this will enable improved management of trauma victims.

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## Introduction

Historically, systems for trauma care have been predicated on a military model. Military trauma has a high rate of penetrating injury and mostly involves young men. In the United States (US), in the 1970s, these systems were modified for inner city trauma, which also involved young men with penetrating injury. As the epidemiology evolved, systems were further modified to manage high-energy blunt trauma, which was mostly due to motor vehicle collisions. The epidemiology of major trauma and trauma deaths is continuing to evolve, as older patients injured from low falls are increasingly the predominant group experiencing major injury and death [1,2].

Ensuring the system of care is targeted, efficient, accessible, safe and responsive to clinical demands requires accurate data. The importance of trauma registries in driving improvements to trauma systems has been well documented [3,4]. There is consensus internationally that accurate data integrated into clinical care systems drives change. After state-wide developments and calls for a national trauma registry, Australia now has a national registry, which produces regular reports [5,6,7]. The importance of this registry has been recognised in a publication from the Australian Commission on Safety and Quality in Healthcare (ACSQHS), on the prioritisation of registries [8]. This registry has recently combined with New Zealand to become the Australia New Zealand Trauma Registry (ATR) (<https://atr.org.au/> accessed 24 March 2019).

The aim of this study was to describe the current epidemiology of major trauma across Australia, and identify opportunities for improvement and future directions in the system of trauma care in Australia, using data from the ATR.

## Methods

### Data

ATR data were submitted according to the bi-national trauma minimum dataset for Australia and New Zealand with 67 data items [9]. Initially 26 collaborating major trauma centres participated, however 24 sites provided data for this report, either directly from the site or via State-based registries. Data have been mapped to the minimum data set according to standard definitions and if data items were not already collected by existing data sources, they were not otherwise obtained by the ATR.

### Inclusion/exclusion

The ATR collected data on major trauma patients presenting to one of 24 level one designated or equivalent trauma centres across Australia during the study period.

Inclusion criteria were:

- patients with date of injury between 1 July 2016 to 30 June 2017
- patients admitted to these centres who subsequently died after injury
- or who sustained major trauma, defined as an Injury Severity Score (ISS) > 12 [10].

Exclusion criteria were:

- patients with delayed admission greater than seven days after injury
- poisoning or drug ingestion that did not cause injury
- foreign bodies that did not cause injury
- injuries secondary to medical procedure
- isolated neck of femur fracture
- pathology directly resulting in isolated injury
- older adults (>64 years of age) who died with superficial injuries only

All cases reported to the ATR have an ISS reported, which is derived from the Abbreviated Injury Scale (AIS 2008) codes that have been allocated to each individual injury [11]. Injury coding is undertaken by trained coders at each site for their own registry and all codes and the ISS are submitted to the ATR as part of the required minimum dataset. The field is mandatory to ensure that meaningful analysis of the burden of injury can be undertaken [12].

### Data management

The ATR is a key component of the Australian Trauma Quality Improvement Program (AusTQIP), a collaboration of all major trauma centres in Australia. AusTQIP was formed in 2012 by the National Trauma Research Institute (NTRI) and is governed by a steering committee consisting of representatives from each State/Territory, professional bodies and funders. Each site has individual ethics and collaboration agreements. Reporting to the steering committee is a management committee to ensure operational targets are met, and a minimum data set working group.

In 2016, Monash University, Department of Epidemiology and Preventive Medicine were subcontracted by the NTRI (an Alfred Health and Monash University joint venture), to maintain and manage the ATR. All State and territory data are de-identified in order to maintain site confidentiality.

Data are submitted via a Secure File Transfer Protocol (SFTP), which each site or centralised body can access with a unique username and password. Files transferred to this server are automatically encrypted and this process, managed by the Health Data Platform at the School of Public Health and Preventive Medicine

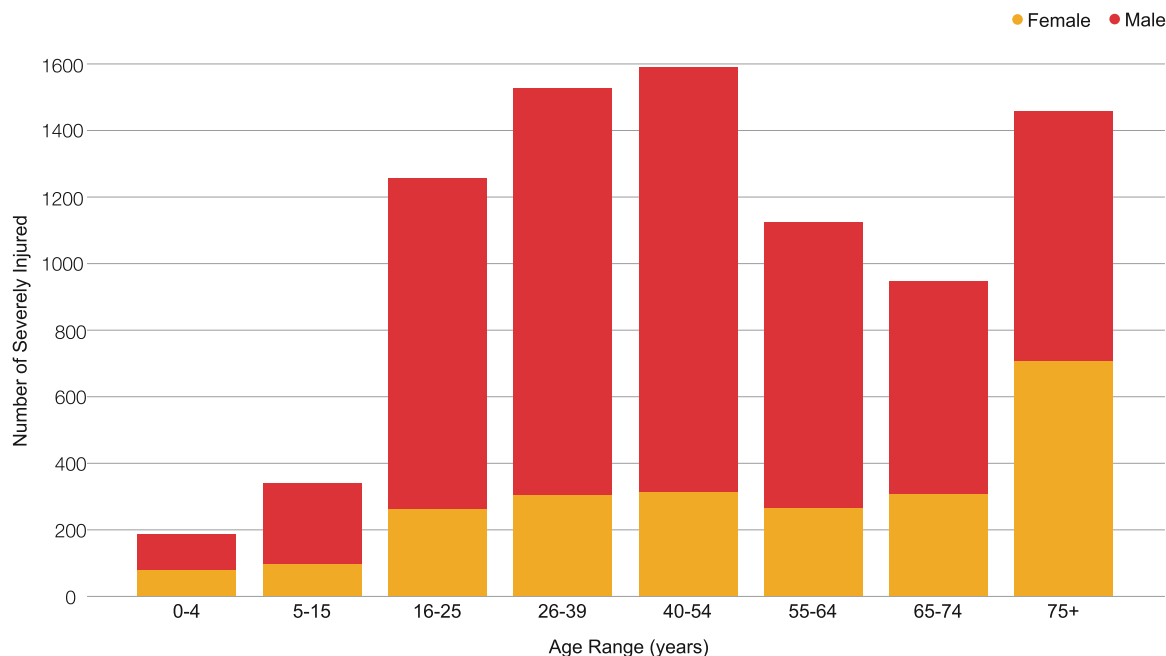


Fig. 1. Number of major trauma cases by age and gender, 2016-17.

Table 1

Baseline characteristics of the major trauma population across Australia.

Age, median, Range	48 (IQR 28-68), (0-103)
Sex (male)	72%
Mechanism	
Transport	45%
Falls	35%
Other (incl penetrating)	20%
Arrival from Scene	
Road Ambulance	65%
Helicopter	11%
Private Vehicle	14%
Others	10%
Intubation prior to or after arrival at definitive care*	24%
Admission to ICU	37%
Injuries Sustained	
Multiple body regions	42%
Head plus other non-major associated injuries	26%
Isolated head injuries	15%
Extremity and/or spine injuries only	8%
Chest and/or abdominal injuries only	5%
Serious spinal cord injury	3%
Arrival Total GCS<9 including intubated patients**	18%
Arrival Systolic BP<90***	6%
Arrival Heart Rate≥100***	27%
Injury Severity Score, median, Range	17 (IQR 14-25), (1-75)

\* 86% patients with known intubation.

\*\* 93% patients with known arrival total GCS.

\*\*\* 96% patients with known arrival BP/HR.

(SPHPM) at Monash University, ensures that all data transfers meet best practice guidelines.

Data completeness was assessed across all variables. A high level of completeness (>80%) was recorded for patient demographic information, injuries sustained, in-hospital observations and discharge data. Data variables which need targeted improvement, include pre-hospital, procedures, complications, and comorbidities. (see appendix).

#### Data analysis

The primary endpoints were inpatient mortality and length of stay (LOS). For both endpoints, funnel plots were created as a visual representation of how individual sites fare compared to their peers and the overall average. Funnel plots allow identification of sites that are performing better or worse than the average. The funnel plot contours represent two standard deviations (95% control limits) and three standard deviations (99.8% control limits) from the mean, those above and below these lines are considered outliers, with a 5% and 0.2% chance of a false positive respectively.

Both crude and risk-adjusted funnel plots were generated. For inpatient mortality, the binary logistic regression model was used and for LOS, the linear regression with a logarithmic transformation was used due to right skewness in the data. We then back transformed the risk-adjusted LOS. The following risk factors were included in the model as they were deemed to be clinically significant *a priori*: age-group, cause of injury, arrival Glasgow coma scale (GCS) – motor component, shock-index grouped in quartiles and ISS score. In addition, we also evaluated the inclusion of gender and AIS head score, but found that only AIS score contributed significantly to inpatient mortality, but not LOS. We did not include interhospital and prehospital transfer times as these were part of the treatment process. We ran separate analysis for paediatric (age ≤ 15 years), adult (16 ≤ age ≤ 64) and older adults (age ≥ 65) to account for expected differences in processes and outcomes across these age groups. The analysis also included patients with missing covariates as a category. Data analysis was performed in Stata V14.0 (Stata Corp, College Station, Tx, USA) and level of significance set at 5%.

#### Results

Over the 12 month period 1 July 2016 to 30 June 2017 8423 records were submitted to the ATR from 24 trauma centres across seven states and territories.

**Table 2**

Outcomes by ISS Range, excluding transfers, burns, ISS&lt;13 deaths and unknown outcomes.

ISS Range	13–14 <i>n</i> = 1528	16–24 <i>n</i> = 2307	25–40 <i>n</i> = 1347	41–75 <i>n</i> = 302
In-hospital deaths <i>n</i> (%)	22 (1.4%)	80 (3.5%)	372 (27.6%)	133 (44.0%)
Unadjusted death odds ratio (95% CI)	Ref	2.46 (1.53–3.96)	26.12 (16.86–40.45)	52.87 (33.39–86.91)
<i>p</i> -value		<0.001	<0.001	<0.001
Survival ( <i>n</i> )	<i>n</i> = 1506	<i>n</i> = 2227	<i>n</i> = 975	<i>n</i> = 169
Discharged Home <i>n</i> (%)	1149 (76.3%)	1499 (67.3%)	427 (43.8%)	37 (21.9%)
Discharged Rehabilitation <i>n</i> (%)	228 (15.1%)	494 (22.2%)	417 (42.8%)	111 (65.7%)
Discharged other <i>n</i> (%)	129 (8.6%)	234 (10.5%)	131 (13.4%)	21 (12.4%)

Note: Ref=base reference category for odds ratio.

### Demographic profile

The median age was 48 years with IQR 28–68. Males were predominant (72%) in all age groups except the extremes of age (Fig. 1).

### Type of trauma

Most major trauma admitted to Trauma Services was blunt (95%) and resulted from road traffic injury (45%). Penetrating injury made up only 3.5%. Less than one per cent were burns. The most prevalent injury category involved multiple body regions (42.0%) followed by head injuries (41.3%) (isolated head injuries and head plus other non-major associated injuries combined) (Table 1).

Table 2 demonstrates that mortality increased as ISS increased and the proportion of patients discharged home decreased as severity increased.

### Cause of injury

Cause of injury, or mechanism, was categorised according to ICD-10-AM external cause codes. Transport- and falls-related incidents accounted for 81% of major trauma cases (*n* = 6767) with known cause. Only 70 severely injured patients had an unknown cause of injury.

Transport-related cases accounted for 45% of major trauma (*n* = 3830). Using ICD-10-AM codes for further categorisation, 3678 (81%) of transport-related cases with known place of injury occurred on a road, street or highway. 152 had unknown place of injury. Falls were the second leading cause of major injury in Australia (*n* = 2937), accounting for 35.1% of major injuries [high falls (>1 metre) *n* = 1271 (15.2%), low falls (≤1 m) *n* = 1666 (19.9%)]. In-hospital mortality from high falls (9.4%), was similar to the national median (10.6%) while mortality from low falls was significantly higher at 16.6%. Low falls were more common in adults aged 65 years or older, accounting for 84% of deaths. Low falls were most common in the home (70.0% of patients with known place of injury).

### Transport of patients

Two-thirds of all major trauma were transported directly from the scene to definitive care at the major trauma service. Of those, 65% arrived via road ambulance, 11.1% via helicopter and 14% via private vehicle. Some were transported by fixed wing, but data are incomplete due to classification as road transport from airport.

The median (IQR) time from the time of injury to arrival at definitive care for patients conveyed directly was 1.42 (1.03–2.12) hours. There were similar variations across jurisdictions.

### Hospital length of stay (LOS) and intensive care length of stay (ICULOS)

The median (IQR) time spent in the emergency department (ED) was 4.27 (2.82–7.70) h.

The median (IQR) hospital LOS was 7.10 (3.64–15.00) days and the median (IQR) ICU LOS was 4.00 (2.00–9.00) days. When hospital LOS was risk adjusted for injury severity, age and mechanism, there was no difference between sites for children, adults or older adults. (Fig. 2a and b).

### Outcomes

Eight hundred and ninety-seven (10.6%) people with major trauma died in-hospital with 14.2% of those deaths occurring in the ED. Fig. 3 provides a snapshot of deaths by gender and age range. There are only a small number of deaths in the paediatric group. The mortality increases dramatically as patients age, particularly in the group above 75 years of age. Male deaths were greater across age groups but less so at extremes of age.

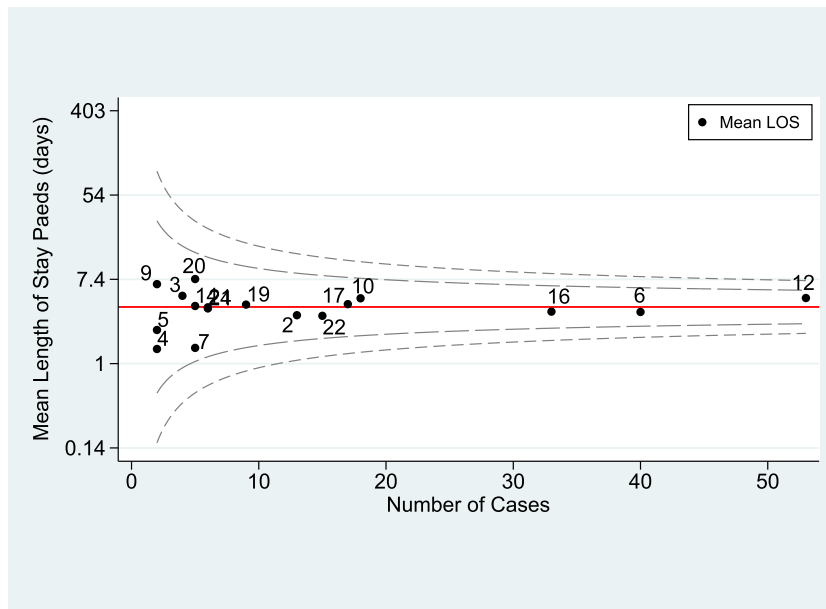
Of those who survived to discharge, 62.4% of patients were discharged home, 23.9% to rehabilitation, 5.9% to a hospital for convalescence and 6% other (e.g. special accommodation, prison, overseas).

Risk adjusted mortality across sites was similar (Fig. 4) and was consistent across paediatric sites, and for older adults (>65 years). Site 21 was marginally above the first control line and the higher mortality is explained by a higher proportion of deaths in the older age group. If older patients are excluded from the analysis, there is no significant difference between the sites. Sites 13 and 19 are approaching the lower control line, suggesting a trend towards improved mortality, however a longer time frame (and larger numbers) would be necessary to see if there is a significant difference. Mortality for paediatric patients was low and risk adjustment models had wide intervals, thus the funnel plot was not included.

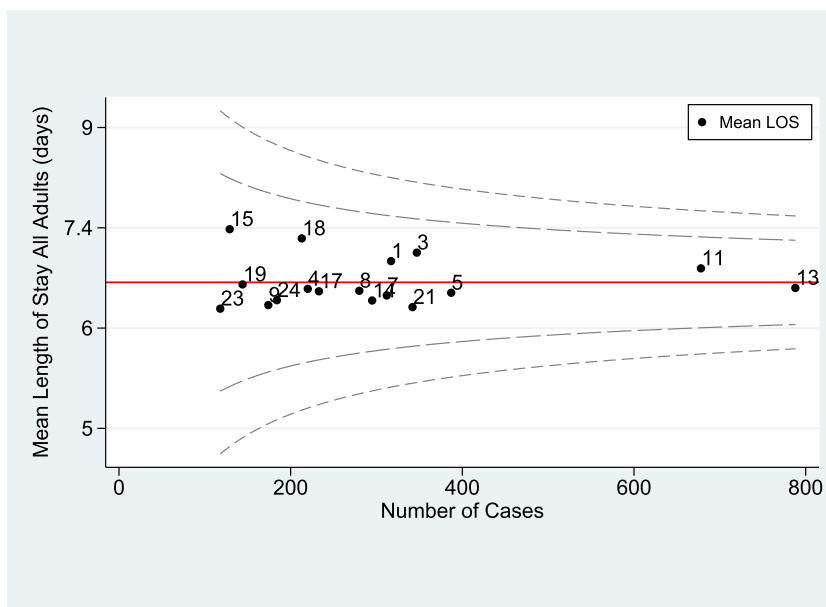
### Discussion

Australia now has a robust method for assessing the system of major trauma care across Australia. It is clear that major trauma in Australia involves a large percentage of older people following low falls. Although high energy mechanisms make up a substantial proportion of cases, older persons contribute to the largest number of deaths and adverse outcomes in hospital. This group of patients has more complex needs with pre-existent medical conditions, frailty, and frequently a lack of social/family supports [13]. The changing demographic has significant implications for future planning of our trauma systems.

Penetrating injuries make up a small proportion of major trauma cases, which means that the military model based on early life-saving surgical intervention is relevant to only a small pro-



a. Risk adjusted length of stay for paediatrics (age, mechanism, ISS, head injury)



b. Risk adjusted length of stay for adults (16+ years) (age, mechanism, ISS, head injury)

### Outcomes

**Fig. 2.** (a). Risk adjusted length of stay for paediatrics (age, mechanism, ISS, head injury). (b). Risk adjusted length of stay for adults (16+ years) (age, mechanism, ISS, head injury).

portion of cases. The vast majority of major trauma patients require coordinated prehospital and retrieval systems, early resuscitation, good supportive care, non time-critical surgical procedures (which are mostly orthopaedic) and increasingly interventional radiology. The long pre-hospital times beyond the golden hour reflect both geographic logistics, hospital bypass and advanced resuscitation prehospital. The optimal model of prehospital care requires further exploration.

The historical model of trauma system configuration based on direct transport to a major trauma centre for all patients at high risk of death, is not necessarily relevant to older patients with falls. Priorities for patients may emphasise comfort, proximity to family

and dignity as well as access to surgical skills [14,15]. Upskilling in supportive care for older trauma patients in non-MTS hospitals may be necessary to manage this group of patients. Promotion of advanced care directives before the injury event and training of staff in ED to have a discussion around goals of therapy are increasingly important.

Injury continues to represent a major cost in both financial and societal measures in Australia. This is despite major reductions in incidence and significant measurable improvements in outcome [16,17,18]. In this report, we have shown that there are more than 8000 seriously injured people admitted to Major Trauma Services in Australia each year. This is an underestimate as we have incom-

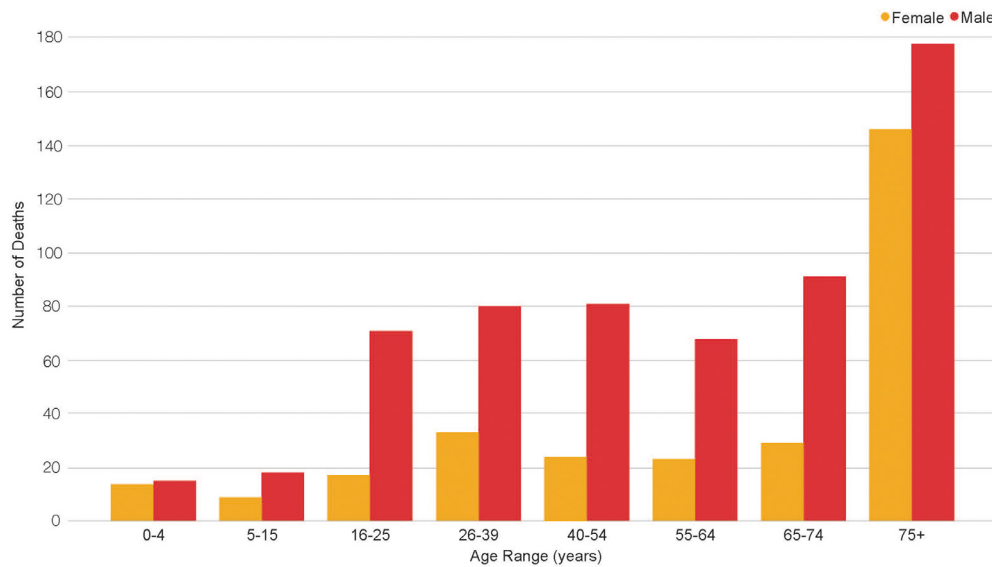


Fig. 3. Number of deaths by age range and gender.

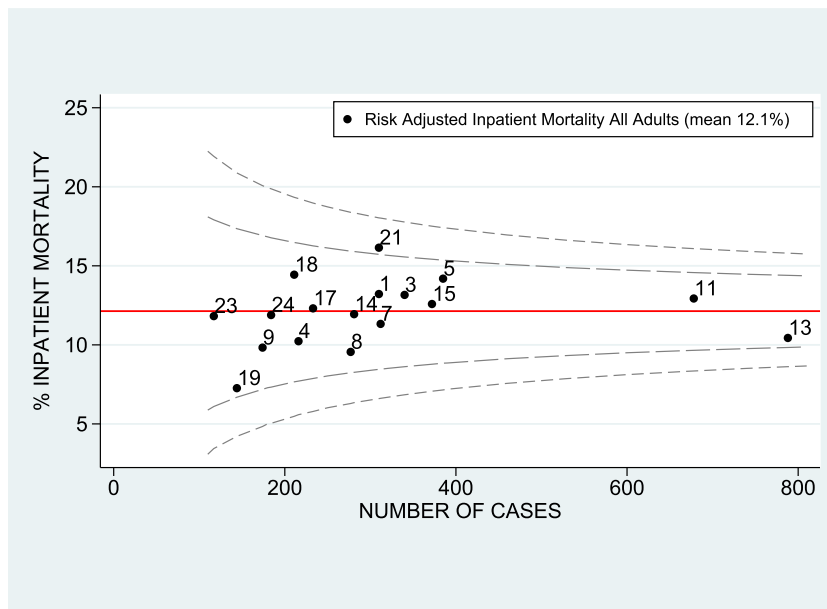


Fig. 4. Risk adjusted mortality for adults (16+ years) across sites, (adjusting for age, mechanism, ISS and Head Injury).

plete data from some states and we have not included patients dying at scene or admitted to non-major trauma services. In addition, there are many more patients admitted to hospitals with less severe and single system injuries. The long-term consequences of major injury for survivors, in terms of poor functional outcomes and mental health are significant [19,20,21], however we have not measured this in this registry.

As expected, high priority areas to reduce injury burden include road transport and falls. Injury remains the leading cause of death and disability in Australians up to 45 years old. Injury results in almost half a million hospitalisations annually [22] and is the second highest cause of hospital admissions expenditure at 4.1 billion (9.0%), following cardiovascular disease at \$5.0 billion (11.1%). Further, the findings from the recent 10-year nation-wide study of the 686,409 injury-related hospitalisations of Australian

children demonstrated that child injury hospitalisation rates have not changed over a ten-year period and result in more than twice the number of hospital childhood admissions than those due to cancer, diabetes and cardiovascular disease combined every year [23].

The ACQHS has prioritised national quality registries to improve outcomes across clinical domains [8]. The ATR has established the methodology and shown the feasibility of benchmarking and targeting improvements based on Australia wide data. This will lead to optimisation of survival and quality of life for patients following major trauma. Data from the registry will also enable more focused injury prevention strategies nationally as data collection, analyses and linkage procedures improve.

There is a large variation in the incidence and mortality following injury across Australia [24,25]. However, as demonstrated in

this report, once patients reach a major trauma service, the risk adjusted hospital outcomes do not differ significantly. For older adults particularly, in-hospital mortality may not be the best outcome measure. Across regional areas, transport distance, time in referral hospitals and quality of pre-hospital and retrieval care provided will also complicate benchmarking of outcomes. Monitoring the quality of care delivered for severe injury is essential to ensure that no matter where a person sustains their injury, they have timely access to the best acute hospital care, rehabilitation care and psychosocial support to ensure the best opportunity for survival and optimised outcome. Accurate, credible data collected through the Australian Trauma Quality Improvement Program and the National Trauma Registry will provide an essential mechanism for trauma system improvement.

### Limitations

There are several limitations to data collected in the initial stages of the ATR development. Despite cooperation from centres, we have ongoing problems with timeliness and completeness of data submissions using current data entry and collation methods. This is primarily related to local resourcing [12].

The data collected only applies to major trauma admitted to major trauma services. This is not linked to non-trauma centre data, prehospital/scene data and post discharge data. All these data are necessary to fully assess the function of a trauma system. Ideally insurance and Medicare Benefits Scheme (MBS) data would also be linked. So far this has only been performed in a limited way.

Routinely collected data including ICD coding has major issues with regard to accuracy and completion of coding of all injuries. Despite dedicated data collectors in most sites, it was not possible to find rudimentary documentation necessary for case comparisons on many patients. It is hoped that with better access to clinician documentation with electronic medical records this will improve.

### Future directions

Strong federal government leadership of a coordinated evidence-based national response to injury prevention must be enacted and resourced to achieve real reductions in injury hospitalisation rates [24].

For targeted evidence-based injury prevention strategies, we need more granular data on injury type, precipitating causes, geospatial mapping and social context. Routine, Australia-wide injury surveillance using record linkage of existing administrative data sources, such as police crash databases, ambulance dispatch systems, admitted episode data, social security and insurance data, should commence as a priority. This is a current recommendation of the national injury prevention strategy and under development. Injury surveillance should be timely, so that injury prevention strategies can be evidence-informed. To achieve this, the legislation and processes for data release in each State and Territory need to be standardised and appropriately resourced.

Accurate benchmarking of processes and outcomes between sites will improve as data accuracy and completion rates improve.

The Australian National Registry has now become a Binational registry, with the involvement of New Zealand. This will ensure a regional approach to this global problem.

### Conclusions

Australia now has the capability to identify national injury trends in patients admitted to major trauma services, optimising prevention and treatment strategies and potentially reducing the burden of injury. Quality of care following injury can now be benchmarked across Australia to improve management of trauma victims.

### Funding

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### Declaration of Competing Interest

None.

### Acknowledgements

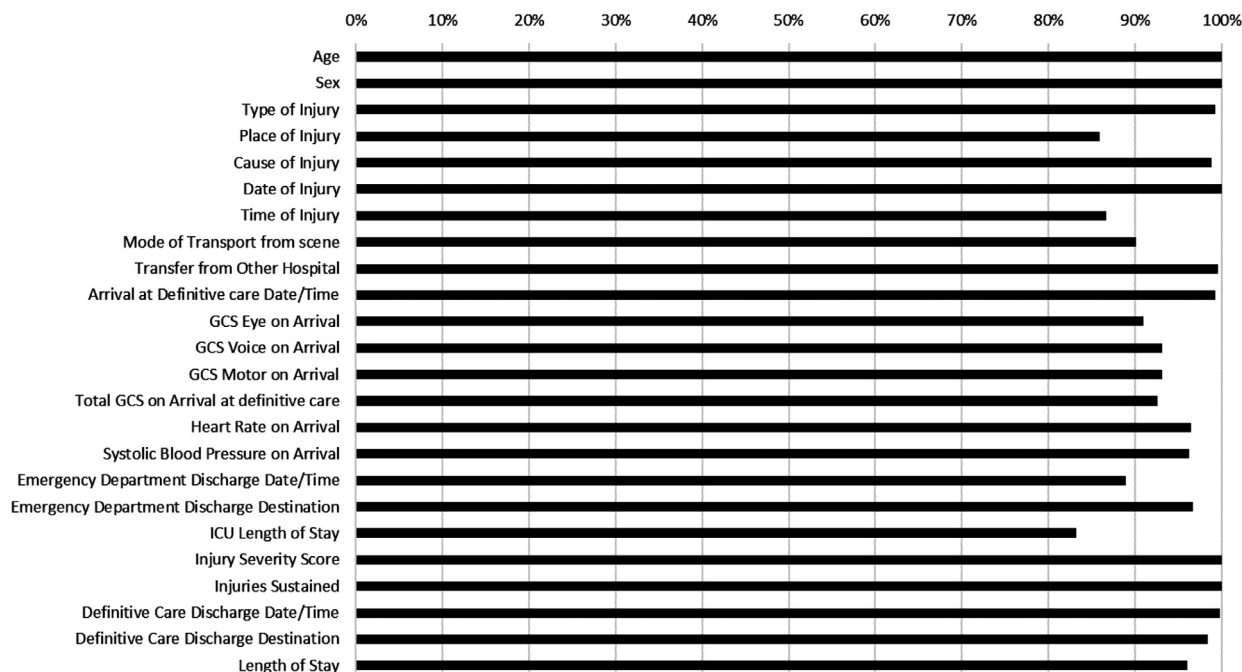
The authors would like to thank: the front-line registry staff and data managers who collect and submit data to the ATR, the New Zealand Major Trauma National Clinical Network, and the site investigators for their ongoing cooperation, the Department of Infrastructure, Regional Development & Cities, Bureau of Infrastructure, Transport and Regional Economics and the Department of Health for their continued support, the Australian Automobile Association, the members of the AusTQIP Steering Committee and ATR Management Committee, and past member of the steering committee Associate Professor Rodney Judson.

### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.injury.2019.09.036](https://doi.org/10.1016/j.injury.2019.09.036).

### Appendix

## 2016-17 Variables Utilised in the Report - Completeness (%)



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