Potentially preventable road trauma in Victoria

March 2018
Potentially preventable road trauma deaths in Victoria

Relatively little is known about the majority of road traffic deaths, which occur at the scene of a crash, when compared to deaths that occur at hospital. A retrospective review of prehospital and early in-hospital (<24 hours) road trauma deaths that were attended by Ambulance Victoria between 2008 to 2014 was conducted. 589 of the 1,374 road traffic deaths had full autopsies. Paramedics had attempted resuscitation in 169 (29%) cases. Of these, 55 (33%) cases had ‘potentially survivable’ injuries, and underwent expert panel review. 45 cases were deemed not preventable, while 10 were considered potentially preventable (n=8) or preventable (n=2). There were no systematic problems identified in these cases, instead specific circumstances in which the system of care provided to the patient was suboptimal. This review has led to the identification of potential novel interventions, and a list of key recommendations. It is hoped that through improvements in the system of care provided to road trauma patients, we can continue to reduce road trauma mortality.

Key Words
Road Trauma, Road Traffic Deaths, Pre-Hospital Deaths, Early in-hospital Deaths, Potentially Survivable Injuries, Retrospective Review, Expert Review, Victoria.

Disclaimer
The research presented in this report has been commissioned and funded by RACV and is released in the public interest. The views expressed and recommendations made are those of the authors and do not necessarily reflect RACV policy.

Although the report is believed to be correct at the time of publication, RACV, excludes, to the maximum extent permitted at law, all liability for loss (whether arising under contract, tort, statute or otherwise) arising from the contents of the Report or from its use. Where such liability cannot be excluded, it is reduced to the maximum extent permitted at law. Discretion and judgement should be applied when using or applying any of the information contained within the Report.
The majority of road traffic deaths occur at the scene. However, when compared to patients that survive to hospital, relatively little is known about patients that die at the scene. In order to improve survival from severe traumatic injury, there is a need to understand causes of death in these patients and to identify opportunities to improve the system of care provided to these patients.

This project focused on the acute treatment of road trauma patients. Firstly, we aimed to provide an epidemiological profile of road trauma deaths in Victoria, Australia, identifying specific causes of death in these patients. From this, we aimed to identify situations in which targeted interventions may improve survival through expert panel reviews of individual cases.

We performed a retrospective review of prehospital and early in-hospital (<24 hours) road trauma deaths following traumatic out-of-hospital cardiac arrest (OHCA) that were attended by Ambulance Victoria during the period of 2008 to 2014. Patients were identified from the Victorian Ambulance Cardiac Arrest Registry (VACAR) and these data were linked with coronial data from the National Coronial Information System (NCIS) and, for those patients who were transported to hospital, to the Victorian State Trauma Registry (VSTR).

Over the 7 year study period, there were 1,374 deaths resulting from road traffic events that were included in the study. This comprised 858 (62%) vehicle occupant deaths, 251 (19%) motorcyclist deaths, 221 (16%) pedestrian deaths, 34 (2%) pedal cyclist fatalities and 10 (1%) deaths that occurred when the occupant was outside of their vehicle. Of the 1,374 road trauma deaths, 589 (45%) had a full autopsy. Overall, the most common medical causes of death were head injury (29%), multiple injuries (28%) and haemorrhage (20%).

A review was conducted to evaluate whether a proportion of these deaths were potentially preventable or preventable. This was conducted in a two phase review, where the first phase aimed to determine whether the anatomical injuries were ‘potentially survivable’ and the second phase used a multidisciplinary expert panel review methodology to identify opportunities for improvement in the system of care provided to road trauma patients.

Of the 589 deaths with full autopsies, 169 (29%) had attempted resuscitation from paramedics. Of these, 55 (33%) had ‘potentially survivable’ injuries. These 55 cases underwent expert panel review. Over the 7 year study period, there were 45 not preventable and 10 potentially preventable (n=8) or preventable (n=2) prehospital or early in-hospital road trauma deaths. Potentially preventable or preventable deaths represented 18% of those cases that had ‘survivable’ injuries (10 of 55 deaths), and 6% of all cases that had attempted resuscitation from paramedics (10 of 169 deaths).

Upon identifying areas for improvement in these cases, there were no identified systematic problems. Rather, we identified a number of specific circumstances in which the system of care provided to the patient was suboptimal. The identification of these areas for improvement provide opportunities to make incremental improvements that may reduce road trauma mortality.

A number of novel interventions were identified that may improve outcomes for critically injured trauma patients. Further work is required to explore the feasibility of these interventions in the system of care provided to these patients.

A number of key recommendations have been made as a result of this review. It is hoped that through improvements in the system of care provided to road trauma patients, we can continue to reduce road trauma mortality.
# Table of Contents

1. Background  
   1.1 Overall project aims  

2. Overall Methods  
   2.1 Study design  
   2.2 Data sources  
   2.3 Inclusion criteria  
   2.4 Ethical approval  

3. Epidemiology overview  
   3.1 Methods  

4. Results  
   4.1 Road user types  
   4.2 Medical cause of death  
   4.3 Profile of injury by road user type  

5. Potentially preventable road trauma deaths  
   5.1 Methods  
   5.2 Results  
   5.3 Summary  

6. Recommendations  

7. Acknowledgements  

8. References  

9. Supplementary material  
   9.1 Classification of medical causes of death  
   9.2 Injury classification  
   9.3 Specific areas for improvement  
   9.4 Novel interventions  


Road traffic crashes accounted for 1.4 million deaths globally and were the main contributor of injury-related disability adjusted life years (DALYs) in 2013. In Australia, road traffic crashes are the second leading cause of hospitalised injury and injury-related deaths. The majority of these deaths will occur either at the scene or on the way to hospital, highlighting the importance of rapidly providing high-quality critical care.

In order to improve survival from severe traumatic injury, we firstly need to understand causes of death in these patients. These causes of death may include massive haemorrhage, tension pneumothorax or cardiac tamponade; some of which may be potentially reversed with early identification and appropriate treatment. Determining specific causes of both prehospital and in-hospital deaths will provide opportunities to evaluate whether a proportion of these deaths may have been prevented. Some of these deaths may have been prevented through improvements in the system of care, such as faster ambulance response, better identification of specific injuries, improved diagnostic capabilities and specific clinical interventions. Previous Australian studies have estimated that potentially preventable death rates lie between 5% and 15% of all traumatic deaths, however these studies are over a decade old and the current magnitude may be significantly larger. There is a need to provide new evidence on whether a proportion of road trauma deaths could have been prevented and what care strategies should be implemented to reduce road trauma mortality. Such interventions include translating in-hospital treatment methods into the prehospital (or ambulance service) setting, such as the use of ultrasound and targeted case reviews and clinical debriefs.

1.1 Overall Project Aims

This project focused on the acute treatment of road trauma patients. Firstly, we aimed to provide an epidemiological profile of road trauma deaths in Victoria, Australia, identifying specific causes of death in these patients. From this, we aimed to identify situations in which targeted interventions may improve survival through expert panel reviews of individual cases. We also aimed to evaluate whether any of these deaths may have been prevented.
2 Overall Methods

2.1 Study design
We performed a retrospective review of prehospital and early in-hospital (<24 hours) road trauma deaths following a traumatic out-of-hospital cardiac arrest (OHCA) that were attended by Ambulance Victoria during the period of 2008 to 2014.

2.2 Data sources
Prehospital and in-hospital road trauma deaths were identified from the Victorian Ambulance Cardiac Arrest Registry (VACAR). To obtain causes of death and detailed injury information, data were linked with the National Coronial Information System (NCIS). For patients who were transported to hospital, but subsequently died in-hospital, data were linked the Victoria State Trauma Registry (VSTR).

2.2.1 Ambulance Victoria
The VACAR is a population-based registry of all OHCA events attended by emergency medical services (EMS) in the state of Victoria, Australia. The registry captures in-field treatment data electronically and a highly sensitive search filter is used to identify potential cardiac arrest cases before manual review by registry personnel. The registry methodology, including data capture and completeness, and quality assurance processes have been described previously. All deaths attended by paramedics are collected in VACAR.

2.2.2 National Coronial Information System
All deaths directly or indirectly resulting from injury or non-natural causes are reported to the coroner. The NCIS is an Internet-based data storage and retrieval system for Australian coronial cases (http://www.ncis.org.au) and includes every death reported to the coroner since 2000. The NCIS contains coded data fields for the intent, mechanism of injury, vehicle type, crash counterpart and event location. In addition to these coded data fields, the NCIS contains full text documents, including the police report on the circumstances of the death, the autopsy report, and the forensic toxicology report.

The coroner is responsible for making a determination about whether a full autopsy (complete internal and external examination) is required, or if an external examination only is sufficient to establish a cause of death. The senior next of kin has the right to object to an autopsy being performed.

2.2.3 Victorian State Trauma Registry
The population-based VSTR collects data about all hospitalised major trauma patients in Victoria. A case is included in VSTR if any of the following criteria are met: (1) death due to injury; (2) an ISS >12 (Abbreviated Injury Scale (AIS) 2005-2008 update); (3) admission to an intensive care unit (ICU) for more than 24 hours; and (4) urgent surgery. The VSTR collects AIS-coded injury information and data on the in-hospital management of major trauma patients.

2.2.4 Data linkage
Data linkage between VACAR and NCIS was achieved using a combination of deterministic and probabilistic linkage methods. Identifiable information (full name, date of birth, event date, event address, residential address) was available in both VACAR and NCIS to enable linkage. Where the full name or date of birth was not available in VACAR, the event date and event address were used for linkage.

2.3 Inclusion criteria
Road trauma deaths were identified as all cases that were coded as “Land Transport Traffic Injury Events” by NCIS. Deaths of all ages were included in the study.

2.4 Ethical approval
The VACAR has approval from the Victorian Department of Health and Human Services Human Research Ethics Committee (HREC) (No. 08/02). The VSTR has approval from the Victorian Department of Health and Human Services HREC for 138 trauma-receiving hospitals in Victoria (DHHREC 11/14) and the Monash University HREC (CF13/3040 – 2001000165). The present study was approved by the Victorian Department of Justice and Regulation HREC (CF/16/272) and the Monash University HREC (CF16/532 – 2016000259).
3 Epidemiology overview

This section aims to provide an overview of prehospital and early in-hospital road trauma deaths in Victoria, Australia, with a focus on road user types, crash counterparts, causes of death and the profile of injury.

3.1 Methods

3.1.1 Crash characteristics
NCIS codes were used to describe the occupant type (vehicle occupant, motorcyclist, pedestrian, pedal cyclist, occupant out of vehicle), the vehicle type (such as passenger car, pick-up truck, heavy transport vehicle), and the crash counterpart (such as other vehicle, telephone pole, barrier).

3.1.2 Profile of injury
For cases with a full autopsy, all injuries were coded using the AIS 2005 (2008 update). The AIS is an anatomical scoring system that ranks the severity of an individual injury of a scale from 1 (minor) to 6 (unsurvivable). The injury severity score (ISS) was calculated for each case. The ISS is an overall score of trauma severity on a scale from 1 to 75 that is calculated as the sum of the squares of the highest AIS code in each of the three most severely injured body regions. Coding was performed by clinical coders who were accredited in AIS coding.

For this study, injuries were reported as:

- Head injuries (any AIS 3+ injury to the head region)
- Cervical spine injuries (any AIS 3+ injury to the cervical spine)
- Chest organ injuries (any AIS 3+ injury to thoracic organs)
- Skeletal chest injuries (any AIS 3+ injury to the rib cage)
- Thoracolumbar spine injuries (any AIS 3+ injury to the thoracic or lumbar spine)
- Abdominal organ injuries (any AIS 3+ injury to an abdominal organ)
- Pelvic injury (any AIS 3+ injury to the pelvis)
- Vascular injuries (any AIS 3+ vascular injury in any body region)
- Upper extremity injuries (any AIS 3+ injury to the upper extremity)
- Lower extremity injuries (any AIS 3+ injury to the lower extremity, excluding pelvic injuries)

3.1.3 Medical cause of death
For cases with a full autopsy, the medical cause of death was classified by using a combination of both the pathologist’s cause of death and the coded injury information. This classification was developed in consultation with two emergency physicians and two injury epidemiologists. The medical cause of death was classified as follows:

- Head injury
- Head and other injuries
- Cervical spine injury
- Threat to breathing
- Haemorrhage
- Multiple injuries
- Other (including burns, smoke inhalation, poisoning, etc)
- Primary medical event (that subsequently resulted in a trauma event)

Further information on the classification of the medical cause of death is provided in the Supplementary Material.

3.1.4 Statistical analysis
Data were summarised using percentages for categorical variables and median and interquartile range (IQR) for non-normally distributed continuous variables. Data analysis was performed using Stata (Version 14.0, StataCorp, College Station, TX).
Over the 7 year study period, there were 2,752 prehospital and early in-hospital deaths following traumatic out-of-hospital cardiac arrest. Of these, 2,612 (95%) were successfully linked to NCIS data. For cases that were linked to NCIS data, 1,374 (53%) were classified as ‘Land Transport Traffic Injury Events’ (Figure 1). Of these, the majority were unintentional events (90%).

**Figure 1**
Table 1
Demographic characteristics of road trauma deaths in Victoria between 2008-2014.

Data are presented overall and for each road user group. Deaths that occurred when the occupant was out of the vehicle (n=10) are included in the ‘overall’ column, but are not presented separately.

<table>
<thead>
<tr>
<th>Data category</th>
<th>Overall</th>
<th>Vehicle occupant</th>
<th>Motor Cyclist</th>
<th>Pedestrian</th>
<th>Pedal Cyclist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>1,374</td>
<td>858 (62.5%)</td>
<td>251 (18.3%)</td>
<td>221 (16.1%)</td>
<td>34 (2.5%)</td>
</tr>
<tr>
<td>Age group (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4</td>
<td>17 (1.2%)</td>
<td>12 (1.4%)</td>
<td>0 (0%)</td>
<td>5 (2.3%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>5-15</td>
<td>36 (2.6%)</td>
<td>21 (2.5%)</td>
<td>2 (0.8%)</td>
<td>9 (4.1%)</td>
<td>4 (4.1%)</td>
</tr>
<tr>
<td>16-34</td>
<td>569 (41.4%)</td>
<td>388 (45.2%)</td>
<td>107 (42.6%)</td>
<td>65 (29.4%)</td>
<td>4 (11.8%)</td>
</tr>
<tr>
<td>35-64</td>
<td>533 (38.8%)</td>
<td>294 (34.3%)</td>
<td>129 (51.4%)</td>
<td>86 (38.9%)</td>
<td>21 (61.8%)</td>
</tr>
<tr>
<td>65 plus</td>
<td>219 (15.9%)</td>
<td>143 (16.7%)</td>
<td>13 (5.2%)</td>
<td>56 (25.3%)</td>
<td>5 (14.7%)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>994 (72.4%)</td>
<td>583 (68.0%)</td>
<td>235 (93.6%)</td>
<td>140 (63.4%)</td>
<td>28 (82.4%)</td>
</tr>
<tr>
<td>Female</td>
<td>379 (27.6%)</td>
<td>274 (32.0%)</td>
<td>16 (6.4%)</td>
<td>81 (36.6%)</td>
<td>6 (17.7%)</td>
</tr>
<tr>
<td>IRSAD (quintiles) a **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st (most disadvantaged)</td>
<td>242 (18.2%)</td>
<td>159 (19.3%)</td>
<td>34 (13.7%)</td>
<td>43 (20.0%)</td>
<td>4 (12.1%)</td>
</tr>
<tr>
<td>2nd</td>
<td>272 (20.5%)</td>
<td>177 (21.5%)</td>
<td>47 (18.9%)</td>
<td>44 (20.5%)</td>
<td>3 (9.1%)</td>
</tr>
<tr>
<td>3rd</td>
<td>291 (21.9%)</td>
<td>186 (22.6%)</td>
<td>53 (21.4%)</td>
<td>44 (20.5%)</td>
<td>6 (18.2%)</td>
</tr>
<tr>
<td>4th</td>
<td>309 (23.2%)</td>
<td>196 (23.9%)</td>
<td>63 (25.4%)</td>
<td>40 (18.6%)</td>
<td>7 (21.2%)</td>
</tr>
<tr>
<td>5th (least disadvantaged)</td>
<td>216 (16.2%)</td>
<td>105 (12.7%)</td>
<td>51 (20.6%)</td>
<td>44 (20.5%)</td>
<td>13 (39.4%)</td>
</tr>
<tr>
<td>ARIA a **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major cities</td>
<td>617 (46.3%)</td>
<td>303 (36.6%)</td>
<td>127 (52.1%)</td>
<td>160 (73.1%)</td>
<td>19 (57.6%)</td>
</tr>
<tr>
<td>Inner regional</td>
<td>568 (42.6%)</td>
<td>415 (50.1%)</td>
<td>90 (36.9%)</td>
<td>51 (23.3%)</td>
<td>10 (30.3%)</td>
</tr>
<tr>
<td>Outer regional / remote</td>
<td>149 (11.2%)</td>
<td>110 (13.3%)</td>
<td>27 (11.1%)</td>
<td>8 (3.7%)</td>
<td>4 (12.1%)</td>
</tr>
<tr>
<td>Intent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unintentional</td>
<td>1,240 (90.3%)</td>
<td>776 (90.4%)</td>
<td>247 (98.4%)</td>
<td>173 (78.3%)</td>
<td>34 (100%)</td>
</tr>
<tr>
<td>Intentional</td>
<td>76 (5.5%)</td>
<td>38 (4.4%)</td>
<td>3 (1.2%)</td>
<td>35 (15.8%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Other / unknown</td>
<td>58 (4.2%)</td>
<td>44 (5.1%)</td>
<td>1 (0.4%)</td>
<td>13 (5.9%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

* Note: Postcodes of residence were mapped to the Index of Relative Socioeconomic Advantage and Disadvantage (IRSAD). ** Note: Postcodes of the injury event were mapped to the Accessibility / Remoteness Index of Australia (ARIA). Missing data: a) n=1, b) n= 44, c) n= 40.
4.1 Road user types

Over the 7 year study period, there were 858 (62%) vehicle occupant deaths, 251 (19%) motorcyclist deaths, 221 (16%) pedestrian deaths, 34 (2%) pedal cyclist fatalities and 10 (1%) deaths occurred when the occupant was outside of their vehicle.

Vehicle occupants

Vehicle occupants were commonly aged 16-34 years (45%), male (68%) and occurred in inner regional areas (50%) (Table 1).

Of all vehicle occupant deaths, 77% (n=659) were drivers and 23% (n=199) were passengers. Vehicle occupant deaths commonly occurred in passenger cars (n=666; 78%), pick-up trucks (n=102;12%), heavy transport vehicle (truck or bus) (n=35; 4%) and four wheel drive vehicles (n=32; 4%).

The most common crash counterparts were a tree or pole (41%), car or 4WD (17%) or pick-up truck, truck or bus (18%) (Table 2).

Motorcyclists

Motorcyclists were commonly aged 35-64 years (51%), male (94%) and occurred in major cities (52%) (Table 1).

Of all motorcyclist deaths, 97% (n=243) were riders and 3% (n=8) were pillion passengers. Motorcyclist deaths commonly occurred in 2-wheeled motorcycles (n=238; 96%). There were 6 deaths that occurred on a motorised bicycle.

The most common crash counterparts were a car or 4WD (33%), pick-up truck, truck or bus (22%) or a tree or pole (13%) (Table 2).

Pedestrians

Pedestrians were commonly aged 35-64 years (39%), male (63%), occurred in major cities (73%) and had a higher proportion of intentional events compared to other road user groups (16%) (Table 1).

For pedestrian deaths, the most common crash counterparts were a car or 4WD (53%) or a pick-up truck, truck or bus (31%) (Table 2).

Pedal cyclists

Pedal cyclists were commonly aged 35-64 years (62%), male (82%), were in the highest quintile for socioeconomic advantage (39%), and occurred in major cities (58%) (Table 1).

For pedal cyclist deaths, the most common crash counterparts were a pick-up truck, truck or bus (63%) or a car or 4WD (23%) (Table 2).

Table 2

<table>
<thead>
<tr>
<th>Crash counterpart</th>
<th>Vehicle occupant</th>
<th>Motor Cyclist</th>
<th>Pedestrian</th>
<th>Pedal Cyclist</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>No counterpart</td>
<td>70 (8.2%)</td>
<td>16 (6.4%)</td>
<td>0</td>
<td>1 (2.9%)</td>
<td>87 (6.4%)</td>
</tr>
<tr>
<td>Car/4WD</td>
<td>148 (17.3%)</td>
<td>82 (32.7%)</td>
<td>117 (52.9%)</td>
<td>8 (23.5%)</td>
<td>355 (26.0%)</td>
</tr>
<tr>
<td>Pick-up truck / truck / bus</td>
<td>156 (18.2%)</td>
<td>54 (21.5%)</td>
<td>68 (30.8%)</td>
<td>22 (64.7%)</td>
<td>300 (22.0%)</td>
</tr>
<tr>
<td>Motorcyclist</td>
<td>0 (0.0%)</td>
<td>7 (2.8%)</td>
<td>2</td>
<td>0 (0.0%)</td>
<td>9 (0.7%)</td>
</tr>
<tr>
<td>Pedal cyclist</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Tree / pole</td>
<td>356 (41.5%)</td>
<td>32 (12.8%)</td>
<td>0</td>
<td>0 (0.0%)</td>
<td>388 (28.4%)</td>
</tr>
<tr>
<td>Barrier / guard rail</td>
<td>14 (1.6%)</td>
<td>8 (3.2%)</td>
<td>0</td>
<td>0 (0.0%)</td>
<td>22 (1.6%)</td>
</tr>
<tr>
<td>Train / tram</td>
<td>14 (1.6%)</td>
<td>0 (0.0%)</td>
<td>29 (13.1%)</td>
<td>1 (2.9%)</td>
<td>44 (3.2%)</td>
</tr>
<tr>
<td>Other</td>
<td>100 (11.7%)</td>
<td>52 (20.7%)</td>
<td>5 (2.3%)</td>
<td>2 (5.9%)</td>
<td>159 (11.7%)</td>
</tr>
</tbody>
</table>

Note: Deaths that occurred when the occupant was out of the vehicle (n=10) have been excluded from this table.
4.2 Medical cause of death

Of the 1,374 road trauma deaths, 589 (45%) had a full autopsy and underwent detailed medical review (Figure 1). Of the 420 vehicle occupants that had a full autopsy, the most common medical causes of death were head injury (27%), multiple injuries (27%) and haemorrhage (20%) (Table 3). For motorcyclists, the most common medical causes of death were head injury (30%), multiple injuries (29%) and haemorrhage (25%). For pedestrians, multiple injuries (34%) and head injury (33%) were the leading medical causes of death. Multiple injuries (50%) and head injury (33%) were the most common medical causes of death in pedal cyclists (Table 3).

Table 3
Medical causes of death stratified by road user type.

<table>
<thead>
<tr>
<th>Medical cause of death</th>
<th>Vehicle occupant (n=420)</th>
<th>Motor Cyclist (n=92)</th>
<th>Pedestrian (n=67)</th>
<th>Pedal Cyclist (n=6)</th>
<th>Overall (n=585)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head injury</td>
<td>115 (27.4%)</td>
<td>28 (30.4%)</td>
<td>22 (32.8%)</td>
<td>2 (33.3%)</td>
<td>167 (28.6%)</td>
</tr>
<tr>
<td>Head and other injuries</td>
<td>40 (9.5%)</td>
<td>8 (8.7%)</td>
<td>5 (7.5%)</td>
<td>0</td>
<td>53 (9.1%)</td>
</tr>
<tr>
<td>Cervical spine injury</td>
<td>24 (5.7%)</td>
<td>2 (2.2%)</td>
<td>1 (1.5%)</td>
<td>0</td>
<td>27 (4.6%)</td>
</tr>
<tr>
<td>Threat to breathing</td>
<td>37 (8.8%)</td>
<td>4 (4.4%)</td>
<td>9 (13.4%)</td>
<td>0</td>
<td>50 (8.6%)</td>
</tr>
<tr>
<td>Haemorrhage</td>
<td>85 (20.2%)</td>
<td>23 (25.0%)</td>
<td>7 (10.5%)</td>
<td>1 (16.7%)</td>
<td>116 (19.8%)</td>
</tr>
<tr>
<td>Multiple injuries</td>
<td>112 (26.7%)</td>
<td>27 (29.4%)</td>
<td>23 (34.3%)</td>
<td>3 (50.0%)</td>
<td>165 (28.2%)</td>
</tr>
<tr>
<td>Other</td>
<td>5 (1.2%)</td>
<td>0 (0.5%)</td>
<td>0 (0.0%)</td>
<td>0</td>
<td>5 (0.9%)</td>
</tr>
<tr>
<td>Primary medical event</td>
<td>2 (0.5%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0</td>
<td>2 (0.3%)</td>
</tr>
</tbody>
</table>

Note: Deaths that occurred when the occupant was out of the vehicle (n=4) have been excluded from this table.

4.3 Profile of injury by road user type

For vehicle occupants, the most commonly observed AIS 3+ injuries were thoracic organ (70%), head (59%), and thoracic skeleton injuries (55%) (Table 4).

For motorcyclists, the most commonly observed AIS 3+ injuries were thoracic organ (75%), head (59%), and thoracic skeleton injuries (58%).

For pedestrians, the most commonly observed AIS 3+ injuries were thoracic organ (80%), head (70%), and thoracic skeleton injuries (59%).

For pedal cyclists, the most commonly observed AIS 3+ injuries were thoracic organ (100%), thoracic skeleton (100%) and head injuries (83%).
### Table 4
Profile of injury by road user type.

<table>
<thead>
<tr>
<th>Profile of injury</th>
<th>Vehicle occupant (n=418)</th>
<th>Motor Cyclist (n=91)</th>
<th>Pedestrian (n=66)</th>
<th>Pedal Cyclist (n=6)</th>
<th>Overall (n=581)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury severity score (ISS) median (IQR)</td>
<td>50 (30-75)</td>
<td>45 (34-75)</td>
<td>49 (38-75)</td>
<td>49 (38-75)</td>
<td>48 (33-75)</td>
</tr>
<tr>
<td>Head</td>
<td>247 (59.1%)</td>
<td>54 (59.3%)</td>
<td>46 (69.7%)</td>
<td>5 (83.3%)</td>
<td>352 (60.6%)</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>56 (13.4%)</td>
<td>9 (9.9%)</td>
<td>5 (7.6%)</td>
<td>3 (50.0%)</td>
<td>73 (12.6%)</td>
</tr>
<tr>
<td>Thoracolumbar spine</td>
<td>25 (6.0%)</td>
<td>5 (5.5%)</td>
<td>2 (3.0%)</td>
<td>0</td>
<td>32 (5.5%)</td>
</tr>
<tr>
<td>Thoracic organ</td>
<td>293 (70.1%)</td>
<td>68 (74.7%)</td>
<td>53 (80.3%)</td>
<td>6 (100%)</td>
<td>420 (72.3%)</td>
</tr>
<tr>
<td>Thoracic skeletal injury</td>
<td>231 (55.3%)</td>
<td>53 (58.2%)</td>
<td>39 (59.1%)</td>
<td>6 (100%)</td>
<td>329 (56.6%)</td>
</tr>
<tr>
<td>Abdominal organ</td>
<td>139 (33.3%)</td>
<td>31 (34.1%)</td>
<td>25 (37.9%)</td>
<td>3 (50.0%)</td>
<td>198 (34.1%)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>66 (15.8%)</td>
<td>19 (20.9%)</td>
<td>21 (31.8%)</td>
<td>1 (16.7%)</td>
<td>107 (18.4%)</td>
</tr>
<tr>
<td>Vascular injury</td>
<td>149 (35.7%)</td>
<td>35 (38.5%)</td>
<td>29 (43.9%)</td>
<td>3 (50.0%)</td>
<td>216 (37.2%)</td>
</tr>
<tr>
<td>Lower extremity</td>
<td>75 (17.9%)</td>
<td>28 (30.8%)</td>
<td>19 (28.8%)</td>
<td>1 (16.7%)</td>
<td>123 (21.2%)</td>
</tr>
</tbody>
</table>

Note: Patients could sustain an injury to more than one body region; therefore, column totals do not sum to 100%. Note: detailed injury information was available on 581 (99%) of the 589 cases that underwent detailed medical review. IQR = interquartile range. All injury groups reflect AIS 3+ injuries. Note: Deaths that occurred when the occupant was out of the vehicle (n=4) have been excluded from this table.
Potentially preventable road trauma deaths

This section aims to provide an overview of the review of potentially preventable trauma deaths. In this section, we detail a two-phase review; firstly, a review to determine whether the anatomical injuries were ‘survivable’, and secondly, the use of an expert panel review methodology to identify opportunities for improvement in the system of care provided to trauma patients.

5.1 Methods
For this section, all cases of prehospital and early in-hospital (<24 hours) deaths that had a full autopsy and received attempted resuscitation from paramedics were included.

5.1.1 Survivability of injuries
Cases that had attempted resuscitation by paramedics underwent a detailed review to determine whether the anatomical injuries were ‘survivable’; that is, cases in which the anatomical injuries were potentially survivable in ideal situations, but the patient subsequently died. Two clinicians with experience in trauma management generated a list of injuries that were deemed unsurvivable. This list was adapted from Davis et al.\(^\text{12}\) and is shown in Table 5. Two clinicians independently reviewed each autopsy to determine whether the anatomical injuries were survivable. Any disagreement was resolved through discussion.

Table 5
List of injuries deemed unsurvivable

<table>
<thead>
<tr>
<th>Injuries considered unsurvivable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laceration to the heart (cardiac rupture)*</td>
</tr>
<tr>
<td>Laceration to the aorta or thoracic great vessels*^</td>
</tr>
<tr>
<td>Massive brain tissue damage*</td>
</tr>
<tr>
<td>Massive brain hematoma*</td>
</tr>
<tr>
<td>Brainstem herniation*</td>
</tr>
<tr>
<td>Diffuse brainstem haemorrhage</td>
</tr>
<tr>
<td>Spinal column dissociation</td>
</tr>
<tr>
<td>C1 to C3 fracture or dislocation associated with spinal cord involvement (compression, tear or hematoma)</td>
</tr>
<tr>
<td>Cranio-cervical (or atlanto-occipital) fracture or dislocation with spinal cord involvement</td>
</tr>
<tr>
<td>Complete tracheal rupture</td>
</tr>
<tr>
<td>Fatal chemical exposure</td>
</tr>
<tr>
<td>Burns with charrings*</td>
</tr>
</tbody>
</table>

* Injuries used by Davis et al.\(^\text{12}\). ^ Vessels included: 1) aorta (thoracic or abdominal), 2) innominate artery, 3) subclavian artery, 4) thoracic or diaphragmatic vena cava. Therefore, carotid, vertebral, renal and femoral lesions (arteries and veins) were considered survivable.
5.1.2 Expert panel review

An expert panel review methodology was employed for individual cases that were deemed to be ‘survivable’ to determine whether the death was: not preventable, potentially preventable or preventable.

Multidisciplinary panels were used to identify components of the system of care where current best evidence care was not delivered. Four sub-panels were utilised to review these cases and comprised at least the following:

- 1 Mobile Intensive Care Paramedic (MICA) paramedic
- 1 emergency physician / trauma surgeon
- 1 other (e.g. advanced life support (ALS) paramedic, nurse, forensic pathologist, injury epidemiologist, etc)

Two weeks prior to the review, panellists were provided with all relevant data related to each case, in de-identified form. This included the full autopsy, police report, toxicology data and the patient care records (PCRs) for each of the attending ambulance crews. For patients who survived to hospital but subsequently died early (<24 hours) in their hospital stay, data on all hospital interventions and timing of these interventions were provided. Prior to the expert panel review, each panellist made an independent assessment of preventability.

At the expert panel review meeting, each case was presented to the panellists. Detailed discussion on each of the components of the system (bystander response and actions, ambulance response, on-scene clinical management, transport and triage decisions, where applicable) was used to identify situations in which optimal response and care was not provided to the patient.

The review of the trauma deaths was conducted under the framework of clinical practice that was relevant at the time of the death.

To facilitate the identification of areas for improvement, the Joint Commission’s (formerly the Joint Commission on Accreditation of Healthcare Organisations) patient safety event taxonomy was utilised. This has been recommended by the WHO’s Guidelines for Trauma Quality Improvement Programs and is similar to that used by McDermott et al. This classification uses five interacting root nodes: 1) the impact; 2) the type; 3) the domain; 4) the cause; and 5) prevention and mitigation. The focus of this report is on the type of event or process that was suboptimal. Specific areas for improvement were identified a priori (prior to the commencement of the expert panel reviews) and are contained in the Supplementary Material. These areas for improvement focussed on those that related to the system (for example, response time), diagnosis (for example, whether the diagnosis of a specific injury was missed or delayed) and the treatment or management of the patient (for example, whether an incorrect procedure was performed or whether the on-scene time was deemed to be excessive). More than one area for improvement could be assigned to each case.

The determination of preventability is detailed below.

5.1.3 Preventability assessment

Using classifications of preventability from the World Health Organisation’s (WHO) Guidelines for Trauma Quality Improvement Programs, Shackford et al., McKenzie et al., Vioque et al. and Oliver & Walter as a guide, preventability was classified as follows:

**Not preventable**
- System provided appropriate and timely care
- Evaluation and management appropriate according to relevant clinical guidelines

**Potentially preventable**
- System generally provided appropriate and timely care, although potential for improvement
- Evaluation and management generally appropriate
- Some deviations from standard of care that may, directly or indirectly, have been implicated in patient’s death

**Preventable**
- Delivery of care was suboptimal
- Avoidable error is judged to have directly caused the final outcome

Where 100% agreement on preventability could not be achieved during the expert panel reviews, cases were taken to a larger panel review subsequent to the sub-panel reviews. This wider panel review included three MICA paramedics, five emergency physicians / trauma surgeons and one forensic pathologist.
5.1.4 Novel interventions

In addition to reviewing trauma deaths with respect to clinical practice that was relevant at the time of the death, expert panellists were also asked to consider the role of novel interventions. A list of novel interventions were defined a priori by a team of leading prehospital and in-hospital trauma clinicians (see Supplementary Material). These interventions, either unavailable at the time of the trauma death or not considered as part of the standard of care by the treating paramedic team, were interventions believed to be potentially beneficial in the care of severely injured patients. In addition to the a priori list of novel interventions, expert panellists were also asked to provide additional suggestions throughout the review process that may improve the system of care provided to these patients. More than one novel intervention could be assigned to each death.

5.2 Results

Of those cases that had a full autopsy and had attempted resuscitation from paramedics, 55 (33%) had anatomical injuries that were deemed to be ‘survivable’. These cases underwent expert panel review.

5.2.1 Potentially preventable road trauma deaths

Over the 7 year study period, there were 45 not preventable and 10 potentially preventable (n=8) or preventable (n=2) prehospital or early in-hospital road trauma deaths. Potentially preventable or preventable deaths represented 18% of those cases that had ‘survivable’ injuries (10 of 55 deaths), and 6% of all cases that had attempted resuscitation from paramedics (10 of 169 deaths). A breakdown of preventability by road user type is presented in Table 6.

Table 6

Summary of the expert panel review determination of preventability.

<table>
<thead>
<tr>
<th>Overall</th>
<th>Vehicle occupants</th>
<th>Motor cyclists</th>
<th>Pedestrians</th>
<th>Pedal Cyclists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not preventable</td>
<td>45 (81.8%)</td>
<td>22 (78.6%)</td>
<td>16 (88.9%)</td>
<td>6 (75.0%)</td>
</tr>
<tr>
<td>Potentially preventable</td>
<td>8 (14.6%)</td>
<td>5 (17.9%)</td>
<td>1 (5.6%)</td>
<td>2 (25.0%)</td>
</tr>
<tr>
<td>Preventable</td>
<td>2 (3.6%)</td>
<td>1 (3.6%)</td>
<td>1 (5.6%)</td>
<td>0</td>
</tr>
</tbody>
</table>

5.2.2 Areas for improvement

Potentially preventable or preventable road trauma deaths

For all potentially preventable or preventable trauma deaths, there were 2 cases that had areas for improvement in the response of the system. These issues related to one case of delayed dispatch and one case with a long response time and challenges with the availability of helicopter emergency medical services (HEMS).

There were 3 cases that had areas for improvement in diagnosis. There was one case in which the paramedics did not recognise that the patient was hypothermic, one case where the degree of shock was underdiagnosed and one case in which a significant pelvic fracture was missed.

There were 8 cases that had areas for improvement in the treatment or management of the patient. There were 3 cases in which a necessary procedure was not performed (2 cases with an absence of adequate haemorrhage control and 1 case in which pelvic splinting and lower limb splinting was not performed). There were 2 cases in which it was deemed that the amount of time spent on-scene was excessive and that expedited transport may have improved outcomes. There was one case with the correct procedure, but with a complication, which related to an ineffective Pneumocath insertion. There was one case with the correct procedure, but incorrectly performed, which related to insufficient fluid resuscitation. There were two cases that had areas for improvement classified as ‘other’: one case had a prolonged extrication time that was deemed to have been excessive and potentially contributed to the death, and one case in which the clinical judgement to intubate a haemorrhaging patient was questioned.

Not preventable road trauma deaths

The 45 not preventable road trauma deaths were also reviewed with respect to areas for improvement. There were 2 cases that had areas for improvement in the response of the system. Both of these cases related to longer response times than would be expected for the event locations.

There were no cases with areas for improvement in diagnosis.
There were 6 cases that had areas for improvement in the treatment or management of the patient. There were 2 cases in which it was determined that resuscitation efforts were terminated earlier than would have been expected. There were 2 cases in which a procedure was not performed: one case in which chest decompression was not performed, and one case in which pelvic and lower limb splinting was not performed. There was one case with delayed treatment, which related to the need for earlier advanced airway management. There was one case in which the correct procedure was performed, but with complication, which related to challenges with intubating the patient. There was one case where the correct procedure was utilised, but it was incorrectly performed, which related to chest decompression, in which the Pneumocaths were not in the pleural cavity.

5.2.3 Novel interventions

The role of novel interventions in potentially improving outcomes for critically injured road trauma patients was evaluated for all cases that underwent expert panel review. There were 2 cases in which an early notification system (for example, when an in-vehicle crash detection system automatically notifies EMS) was determined to be of potential benefit. There were 7 cases in which the use of ultrasound in the prehospital setting was determined to be of potential benefit in diagnosing internal injuries, such as a haemothorax. There were 13 cases in which it was determined that blood products (currently only in use by MICA flight paramedics in Victoria) could have improved outcomes. There were 13 cases in which it was determined that finger thoracostomy (also currently only in use by MICA flight paramedics in Victoria) may have improved outcomes. There were 2 cases in which it was suggested that arterial tourniquets could have assisted haemorrhage control. There were no cases in which resuscitative endovascular balloon occlusion of the aorta (REBOA), on-scene thoracotomy, ultrasound-guided needle pericardiocentesis or prehospital decompressive burr hole drainage were thought to have potentially improved outcomes.

In addition to those novel interventions defined a priori, expert panellists were asked to consider any other novel interventions that may improve outcomes. There were 23 cases in which other novel interventions were identified (noting that a single case could have more than one suggested novel intervention).

There were 4 cases in which it was suggested that providing on-scene paramedics with remote decision making support (telemedicine) would assist in providing appropriate clinical management. This was suggested to occur through a video link from the scene to either the receiving hospital, or to a central communication centre.

There were 5 cases in which it was suggested that an improved protocol around trapped patients (especially those who are critically ill) may have improved outcomes. Specifically, it was suggested that a ‘fast extrication’ protocol needs to be developed that would apply in situations where the trapped patient is extremely sick and is in need of immediate extrication.

There were 5 cases in which it was suggested that providing the SAM pelvic binder to all Ambulance Victoria crews would be of benefit. This has already been addressed by Ambulance Victoria.

There were 2 cases in which the Military Anti-Shock Trousers (MAST) suit (or other novel methods of lower limb splinting) was suggested to be of potential benefit.

There were 2 cases in which expert panellists queried the benefit of intubating a haemorrhagic patient.

There were 2 cases in which it was noted that improved communication between Ambulance Victoria and Adult Retrieval Victoria (ARV) would be beneficial. In one case, it was suggested that a standard protocol should be introduced where ARV are notified by AV that they are taking a critically injured patient to a non-major trauma service (MTS) that may need a subsequent transfer to a MTS. In another case, it was suggested that the need to consult ARV to obtain approval to use blood products be removed from standard protocol. This has already been removed from standard protocol by Ambulance Victoria. There were 2 cases in which the timeliness of the launch of HEMS was queried.

There were 3 cases in which response times and the availability of multiple crews in rural areas were suboptimal. There was one case in which a video 000 call (as opposed to an audio-only phone call) was suggested to enable greater information on the scene and the need for additional resources (such as MFB, CFA or SES to assist with extrication).

There were 2 cases that expert panellists suspected may have resulted from a phenomenon known as impact brain apnoea. Impact brain apnoea is the cessation of breathing after traumatic brain injury, in which it has been suggested that early ventilation (either by bystanders or paramedics) may significantly increase the chance of survival. Greater education of both the public and paramedics on this phenomenon may be required.
5.3 Summary

In a detailed review of prehospital and early in-hospital road trauma deaths, a small proportion (18%) of cases that had ‘survivable’ anatomical injuries and had attempted resuscitation from paramedics were deemed to be potentially preventable or preventable. Upon identifying areas for improvement in these cases, there were no identified systematic problems. Rather, we identified a number of specific circumstances in which the system of care provided to the patient was suboptimal. The identification of these areas for improvement provide opportunities to make incremental improvements that may reduce road trauma mortality.

A number of novel interventions were identified that may improve outcomes for critically injured trauma patients. Further work is required to explore the feasibility of these interventions in the system of care provided to these patients.
1. Continued efforts in the primary prevention of road trauma deaths are required.
   Given the low rate of prehospital and early in-hospital potentially preventable and preventable road trauma deaths, it is likely that the most effective method to reduce road trauma mortality is through primary prevention efforts. However, continued efforts to improve the system of care provided to road trauma patients are warranted.

2. Continued education is provided to paramedics on protocols for critically injured trauma patients.
   It is known that paramedics have low exposure to these critically injured trauma patients. Continued efforts to ensure that paramedics adhere to up to date clinical practice guidelines are warranted.

3. In patients with ongoing haemorrhage, time to definitive treatment at hospital is critical.
   Therefore, ensuring short on-scene times is critical. Additionally, a review of intubation in shocked trauma patients is required. Through the expert panel review process, two potentially preventable or preventable deaths were identified as having excessive on-scene times. Furthermore, the role/benefit of intubating a haemorrhagic/shocked patient was queried in a number of cases.

4. Consideration be given to enabling the administration of blood products by MICA road paramedics in areas with longer transport times.
   MICA flight paramedics currently carry blood products and this review has identified that patients managed by MICA road paramedics with longer transport times may benefit from blood products. Further evidence on the benefits of providing blood products in the prehospital setting is warranted. The logistical challenges of providing all MICA road paramedics with blood products is acknowledged.

5. Consideration be given to providing MICA road paramedics with the capability to perform finger thoracostomies (drainage of the pleural cavity through a small incision in the chest wall with intrapleural palpation to confirm access to the pleural space).
   MICA flight paramedics currently have the capability to perform finger thoracostomies. Current clinical practice for MICA road paramedics is the use of needle thoracostomies, which may not definitively decompress the chest. This review has identified that patients managed by MICA road paramedics may benefit from finger thoracostomies.

6. Consideration be given to the role of telemedicine (and other forms of remote decision support) in providing paramedics (particularly advanced life support paramedics) with clinical support for critically injured trauma patients, where necessary.
   Telemedicine was identified as a novel intervention that may improve clinical management of these critically injured trauma patients, particularly in remote places or in cases in which the paramedics request clinical support. Consideration should be given to other forms of remote decision support and technology to support paramedics at the scene.

7. Consideration be given to a novel ‘fast extrication’ protocol for critically ill trauma patients who are trapped.
   In a number of cases, it was noted that the delayed extrication of the patient contributed to the death. The development of a novel ‘fast extrication’ protocol is warranted in specific cases.
8. The Victorian Institute of Forensic Medicine (and the National Coronial Information System) to routinely collect Ambulance Victoria patient/case numbers.
Ambulance Victoria patient/case numbers are not currently collected by the Victorian Institute of Forensic Medicine (VIFM) or the National Coronial Information System (NCIS). Collecting this information would facilitate future data linkage projects that would be of benefit to multiple patient populations.

9. The Victorian Institute of Forensic Medicine consider utilising a standard methodology for the recording of injuries.
It is suggested that VIFM use the Abbreviated Injury Scale (AIS) injury descriptors as a standard method for reporting injuries in autopsy reports. This would improve the consistency of injury reporting and would ensure that the reporting meets an internationally-recognised standard.

10. It is recommended that a greater number of deaths undergo full autopsy.
In this study, only 45% of road trauma deaths underwent full autopsy, thereby limiting the potential to identify opportunities to improve the system of care provided to trauma patients. In the absence of full autopsy, there is a need to explore the use of post-mortem computed tomography (CT) in identifying injuries and causes of death.

11. It is recommended that the methodology employed in this study become the routine approach to reviewing prehospital trauma deaths and that this becomes an on-going clinical quality improvement process as part of the Victorian State Trauma System.
To continue to evaluate the system of care provided to all trauma patients, not only those that are transported to hospital, there is a need to continuously monitor prehospital trauma deaths. As part of this, employing the methodology used in this study will enable rigorous evaluation of opportunities to improve the whole trauma system.
Acknowledgements

We would like to acknowledge the contributions of Ms Josine Siedenburg and Dr Eric Mercier. Ambulance Victoria are thanked for the provision of the data and their support of this project. We also thank the Victorian State Trauma Outcome Registry and Monitoring (VSTORM) group for providing VSTR data. We also thank the National Coronial Information System and the Victorian Institute of Forensic Medicine for their assistance.

We would like to particularly thank all of the expert panellists and wider study team for their contributions:

Ambulance Victoria
• Prof Karen Smith
• Prof Stephen Bernard
• Mr Colin Jones
• Prof Paul Jennings
• Mr Ben Meadley
• Mr Toby St Clair
• Dr Ziad Nehme

Emergency Physicians / Surgeons
• Prof Peter Cameron
• Prof Mark Fitzgerald
• Prof Rodney Judson
• Dr Joseph Mathew
• A/Prof Biswadev Mitra
• Dr Eric Mercier
• Dr Andrew Buck
• A/Prof Warwick Teague
• A/Prof Dinesh Varma

Victorian Institute of Forensic Medicine
• A/Prof Richard Bassed
• Dr Michael Burke

Other
• Prof Belinda Gabbe
• Dr Janet Bray
• Ms Susan McLeian
• Ms Jane Ford
• Ms Rashmi Ramanath
• Ms Erin Magee
• Ms Josine Siedenburg


Supplementary material

9.1 Classification of medical causes of death

Head injury
- As noted by the pathologist’s cause of death
- An AIS 5 or 6 head injury in the absence of spinal cord injury (as noted by the pathologist’s cause of death) or a significant vascular injury

Cervical spine injury
- As noted by the pathologist’s cause of death
- An AIS 4+ cervical spine injury in the absence of a head injury, vascular injury, thoracic or abdominal organ injury or pelvic ring fracture

Haemorrhage
- Any cause of death that notes blood loss
- Any cause of death that notes stab wounds, piercing, incisions, etc
- Any vascular injury or chest/abdominal organ laceration injury, in the absence of:
  - Head injury (as noted by the pathologist’s cause of death)
  - Cervical spine injury (as noted by the pathologist’s cause of death)

Threat to breathing
- Asphyxia (as noted by the pathologist’s cause of death)
- Trachea/Esophagus/Larynx/Pharynx/Bronchus injury in the absence of head or cervical spine injury

Head and trunk injuries
- Head and thoracic/abdominal injuries in the absence of ‘threat to breathing’ or vascular injuries

Head and vascular injuries
- Head and vascular injuries in the absence of ‘threat to breathing’, ‘head and trunk injuries’ or pelvic ring fracture.

Multiple trunk injuries
- Where the pathologist’s cause of death is ‘blunt chest trauma’ or where coded as ‘multiple injuries’ but the injuries are localised to the trunk.

Multiple injuries
- As noted by the pathologist’s cause of death

Other
- Including burns, smoke inhalation, poisoning, self-immolation

9.2 Injury classification

Note: all injuries were classified using the Abbreviated Injury Scale (AIS) 2005 – 2008 Update.

Vascular injuries

Neck
- Carotid artery
- Vertebral artery
- Jugular vein

Thorax – arteries
- Aorta, thoracic
• Brachioccephalic artery
• Coronary artery
• Pulmonary artery
• Subclavian artery
• Other named arteries

Thorax – veins
• Brachioccephalic vein
• Pulmonary vein
• Subclavian vein
• Vena Cava
• Other named veins

Abdomen – arteries
• Aorta, abdominal
• Celiac artery
• Iliac artery
• Superior mesenteric artery
• Other named arteries

Abdomen – veins
• Iliac vein
• Vena Cava
• Other named veins

Upper extremity
• Axillary artery
• Axillary vein
• Brachial artery
• Brachial vein
• Other named arteries
• Other named veins

Lower extremity
• Femoral artery
• Femoral vein
• Popliteal artery
• Popliteal vein
• Other named arteries
• Other named veins

Chest/abdominal organ injuries

Thoracic organ lacerations
• Heart
• Lung
• Haemothorax

Abdominal organ lacerations
• Adrenal gland
• Anus
• Colon
• Duodenum
• Gallbladder
• Jejunum-ileum
• Kidney
• Liver
• Mesentary
• Pancreas
• Prostate
• Rectum
• Spleen
• Stomach
Threat to breathing injuries
- Haemo/pneumothorax
- Esophagus laceration
- Larynx laceration
- Pharynx laceration
- Trachea laceration
- Bronchus laceration

9.3 Specific areas for improvement

System factors
- Long response time

Diagnostic factors
- Missed/incorrect diagnosis
- Delayed diagnosis
- Examples:
  - Tension pneumo/haemothorax
  - Hypovolaemic shock
  - Severe hypoxia
  - Underestimation of the severity of the injury

Treatment/management factors
- Delayed treatment
- Incorrect procedure
- Correct procedure, but with complication
- Correct procedure, incorrectly performed
- Equipment failure
- Inaccurate prognosis
- Excessive on-scene time
- Triage error
- Examples:
  - Management of chest injuries
  - Haemorrhage control
  - Airway management
  - Fluid resuscitation
  - Spinal immobilisation

9.4 Novel interventions

Novel interventions to be considered as part of the review include:
- Early notification systems (such as crash detection systems or smartphones to alert EMS)
- Ultrasound
- Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)
- On-scene thoracotomy
- Ultrasound-guided needle pericardiocentesis
- Prehospital Decompressive Burr Hole Drainage
- Novel methods of haemorrhage control at scene
  - Pelvic packing
  - Abdominal packing
  - Abdominal Junctional Tourniquet
- Tranexamic acid (TXA)
- Freeze-dried plasma
- Decision support

Interventions implemented during or after the study period to be considered:
- Red cell concentrate/packed red blood cells
- Arterial tourniquets
- Finger thoracostomy