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Factors associated with a positive shock index in the prehospital setting after major trauma

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Abstract

Background Bleeding and coagulopathy are the leading causes of potentially preventable death and multi-organ damage after injury. Trauma care in the prehospital setting focusses on three key tenets; identification, lifesaving interventions and transport. Existing prehospital trauma triage guidelines use a combination of physiological, and patterns of injury to identify potential major trauma, however these guidelines are not designed to identify potential shock.

Methods We conducted a registry-based cohort study using data from the Victorian State Trauma Registry (VSTR) on adult major trauma patients (≥ 16 years) transported by EMS between 2010 and 2020, including patients within 70 km of Melbourne's major trauma services. Data from VSTR were linked with the Victorian Ambulance Clinical Information System and operational records from Ambulance Victoria. The primary outcome was shock, defined by a shock index (SI) ≥ 0.9.Logistic regression models stratified by transport mode examined associations with shock. Descriptive statistics and tests of association were used, followed by multivariate logistic regression.

Results Over this 10-year study, 16,265 patients were identified within 70 km of the major trauma services. 26% of the patients had a shock index ≥ 0.9, and the majority of these patients (88%) were transported by road ambulance. The majority of the patients in this study (69%) were injured within 30 km of the MTS. Females had an increased adjusted odds of shock (aOR = 2.19), as did patients who were entrapped (aOR = 1.23).

Discussion This study identified that over a quarter of major trauma patients experienced shock during the prehospital phase, with most lacking access to advanced lifesaving interventions typically provided by MICA-flight paramedics. These findings underscore the importance of aligning prehospital care systems with patient needs to optimize trauma outcomes.

Conclusion Over 25% of major trauma patients developed a shock index ≥ 0.9 within the prehospital phase of their care. Furthermore, 88% of the shocked patients did not have access to the most advanced prehospital life-saving interventions available within the state.

Keywords Trauma, Prehospital, Shock, Lifesaving interventions

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Introduction

Bleeding and coagulopathy are the leading causes of potentially preventable death and multi-organ damage after injury [1, 2]. Haemorrhagic shock is associated with up to 50% of early preventable trauma deaths, and a requirement for blood transfusion to optimise resuscitation [3–6].

Trauma systems were introduced to reduce the time from injury to lifesaving and definitive interventions, and to coordinate patient care [7, 8]. Trauma systems in high income settings typically involve a network of hospitals, each designated a level corresponding to available clinical services [9–11]. Haemorrhage control and the reversal of shock is one of the key priorities of early care in major trauma centres. The centralisation of trauma care to specialist major trauma centres has resulted in a reduction in morbidity and mortality [8, 12].

In addition to specialist major trauma centres, an integrated prehospital system is a vital component of an inclusive trauma system. Trauma care in the prehospital setting focusses on three key tenets: the identification and triage of major trauma patients, the access and provision of life saving interventions, and the timely transport of patients to specialist trauma centres [13–16]. In urban areas, road-based paramedics provide patient care and transport [17, 18], whilst in non-urban areas, access to helicopter emergency medical services (HEMS) often provides more advanced clinical interventions and swift transport to specialist trauma services [19–21]. The use of HEMS in urban settings is not widespread in Australasia [22–24]. Prehospital trauma guidelines generally direct clinicians to bypass less well-resourced hospitals, and to prioritise primary transport to a higher level of trauma care [16].

Prehospital identification of major trauma is difficult, with existing trauma triage criteria often resulting in under triage of paediatric and older patients, and over triage of adult trauma patients [25]. Existing prehospital trauma triage guidelines are based on the ACS-COT guideline, and use a combination of physiological parameters, and patterns of injury to identify potential major trauma and risk of death, however these guidelines are not designed to identify potential shock [16, 26].

Research is needed to assist in identifying potential early warning signs of shock. Therefore the aim of this study was to identify any factors that were associated with shock following injury, including distance from a major trauma centre.

Methods

Study design

We performed a registry-based cohort study using the population-based Victorian State Trauma Registry (VSTR) in Australia. The VSTR includes data on patient demographics, injury event and diagnosis, as well as hospital treatment and in-patient outcomes. The provision of the data to the registry is mandatory for trauma-receiving hospitals [27]. Ethical approval for VSTR was received from the Victorian Department of Health and Department of Families, Fairness and Housing Human Research Ethics Committee (DHHREC 11/14) and the Monash University Human Research Ethics Committee (ID 8226). Ethics for this project was approved by the Monash University Human Research Ethics Committee (31741).

Setting

The Victorian State Trauma System has two designated adult major trauma services (MTS), both located in the centre of metropolitan Melbourne in the state of Victoria, Australia. This study focussed on patients who were injured within 70 km of both adult major trauma services in Melbourne, Australia. Major trauma patients were transported by both road and helicopter air ambulance to these services, from across metropolitan and regional Victoria. In addition to these two MTS, the Victorian state trauma system includes nine metropolitan trauma services (MeTS). This study setting additionally included one regional trauma service (RTS) and eight primary care centres (Fig. 1). The Victorian state trauma system is a tiered trauma system, with the major trauma service the highest level of trauma care, followed by the Metropolitan or Regional trauma services, and then the primary care centres. Each hospital designation has been previously defined [9]. Emergency medical service triage guidelines direct potential major trauma patients to the highest level of trauma care within 60 min of injury location[#].

Ambulance Victoria (AV) is the sole emergency medical services (EMS) provider for the state of Victoria and operates a two-tiered road response system in both metropolitan and regional Victoria. Advanced life support (ALS) paramedics account for the majority of the clinical response capacity of AV, and have authority to provide fundamental lifesaving interventions, including basic airway procedures, external haemorrhage control, and needle pleural decompression, however only in clinical extremis [28] (appendix 1). In addition to ALS, mobile intensive care ambulance (MICA) paramedics have an increased scope of practice, including prehospital emergency anaesthesia and a broader scope for pleural wall decompression (needle thoracostomy). In addition to road response capacity, AV operates five helicopter emergency medical services (HEMS), located at four bases throughout the state. MICA flight paramedics, work solely on the HEMS platform, and have a further increased clinical scope of practice, including finger thoracostomy, the use of blood products and increased diagnostics with point of care ultrasound (POCUS). Unlike

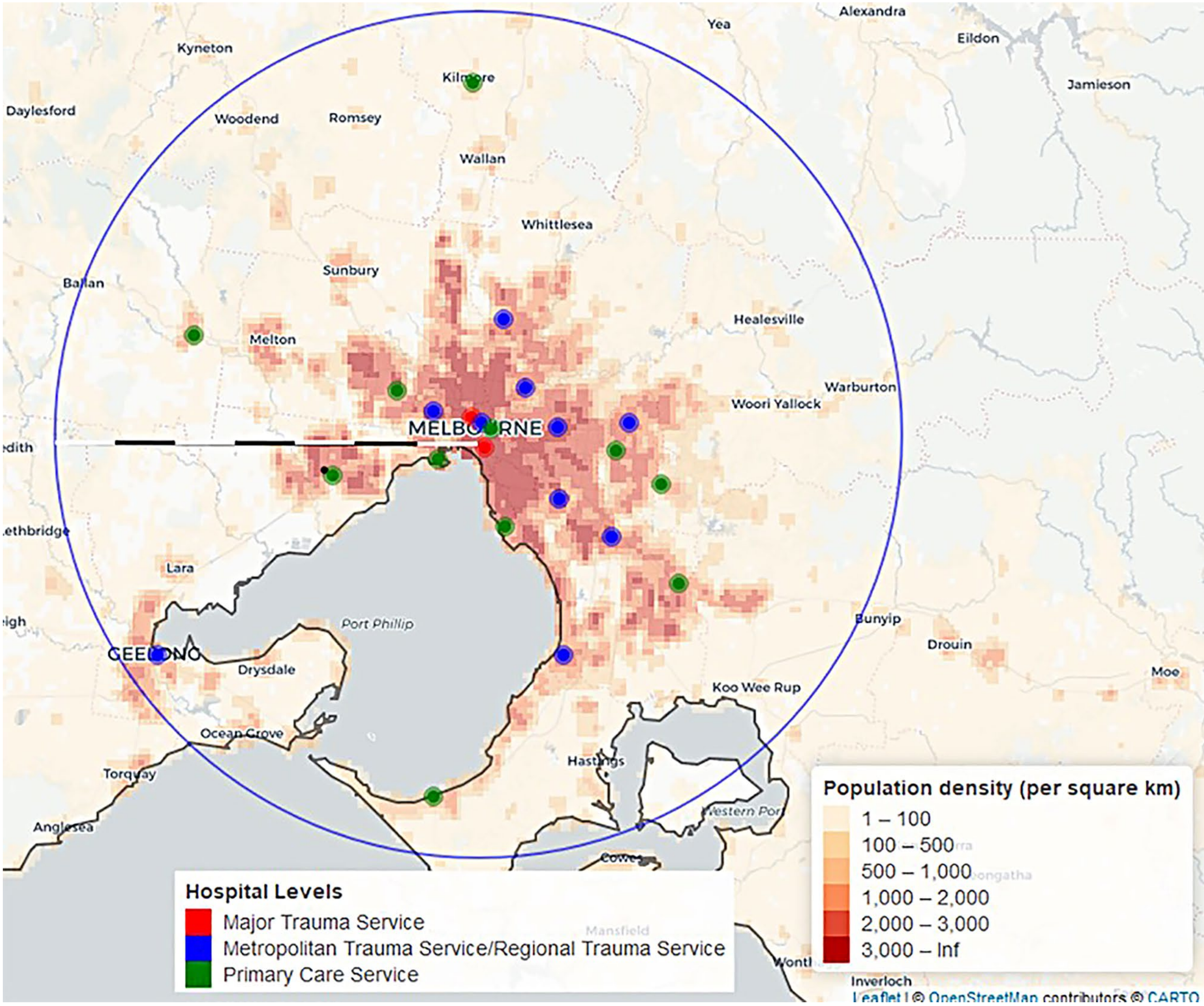


Fig. 1 70km Study area of Metropolitan Melbourne, with overlaid population density and locations of all trauma services

European aeromedical services which may deliver a medical team via helicopter to the patient, for subsequent road transport, in Melbourne the dispatch of HEMS to patients within 40 km to an MTS is not normal procedure, and seldom occurs [24]. However, potential major trauma patients may have access to MICA paramedic scope of practice in the metropolitan setting.

Study population

This study included all adult (≥ 16 years) major trauma patients registered on the VSTR with a date of injury from January 1, 2010, to December 31, 2020, who were transported to an emergency department by EMS. All patents were included if they met the VSTR criteria for major trauma (see appendix 2).

Data sources

The VSTR data are routinely linked to the Victorian Ambulance Clinical Information System (VACIS) using probabilistic linkage of patient identifiers. VACIS is an infield electronic medical records system and linked database, which includes all clinical patient data and paramedic interventions. In addition to VACIS data, operational data were sourced and linked, to identify the location of injury. Ambulance Victoria uses a Computer Aided Dispatch (CAD) system, operated by Triple Zero Victoria*[1]. Emergency call takers identify the location of the patient and use this information to dispatch the closest available ambulance resource. The CAD system records all patient location data, as well as logistic management data, including time of ambulance dispatch,

[1] * during the period of this study, this role was previously performed by the emergency services telecommunication authority (ESTA).

arrival at scene, departure from scene, hospital destination and time of arrival at hospital (see appendix 3).

Outcome variable

The shock index is calculated by dividing the heart rate by the systolic blood pressure, and has been shown to be associated with ongoing resuscitation requirements, multi-organ damage and a fourfold increase in mortality [4, 29–32]. The shock index was calculated from all clinical data from both AV and primary destination hospitals. A patient was considered to have shock if they had a shock index ≥ 0.9 during any period from ambulance arrival to arrival at ED. A shock index ≥ 0.9 has been previously shown to be associated with increased requirement for transfusion [4], increased mortality [29] and poorer functional outcomes [32].

Covariates

Demographics included a patient's age and sex (*Male, Female)*. Patient age was grouped into eight categories (*16–25, 26–35, 36–45, 46–55, 56–65, 66–75, 76–85 and > 85 years*). Injury variables included injury severity score (ISS), Abbreviated Injury Scale (AIS), in-hospital mortality, injury type (*blunt, penetrating, thermal, other*) and injury cause. Injury cause was categorised into the nine most prevalent groups, with all other causes categorised into an 'other' group. Low fall was defined as a fall on the same level or less than or equal to 1 m, and a high fall was > 1 m, based on the Victorian Emergency Minimum Dataset. Patient entrapment was binary (*yes/no*). Prehospital lifesaving interventions were categorised into fundamental and advanced. Fundamental interventions included:

- *Fundamental airway procedures, including oropharyngeal/nasopharyngeal airway, bag-valve mask ventilation, supraglottic airway.*
- *Pelvic binder and fracture splinting,*
- *Haemorrhage control (tourniquet, wound dressing).*
- *Intravenous access and fluid administration (0.9% NaCl), however specific volumes were not reported.*

Advanced interventions and diagnostics included:

- *Endotracheal intubation,*
- *Cricothyroidotomy,*
- *Pleural wall decompression (needle or finger thoracostomy),*
- *Blood product administration, (4 units of red cell concentrate are available, administered via a portable blood warming system where appropriate, however specific volumes were not reported)*
- *Ultrasound.*

Injury location was determined using coordinates from CAD, and straight-line distances were calculated to a point equidistant between both adult major trauma services in Melbourne, using ArcGIS (ArcGIS Online, ESRI). Distance calculations were cross referenced using VACIS injury suburb to validate injury location. Distance isochrones were categorised into seven, 10-kilometre groupings, from 0 to 70 km.

Transport mode was categorised into road or air, and the primary hospital destination was categorised into three groups; major trauma service, metropolitan or regional trauma service, or metropolitan primary care clinic. Primary hospital was defined as the first hospital transport destination for the patient. All time periods were calculated from AV data including response time (triple zero (000) call time to arrival at scene), scene time (first ambulance arrival on scene to departure from scene), transport time (departure from scene to arrival at primary hospital) and total prehospital time (triple zero (000) call time to arrival at primary hospital).

Data analysis

Data were summarised using frequencies and percentages for categorical variables, and median and interquartile range (IQR) for continuous variables due to the skewed distribution of these variables. Associations between covariates of interest and shock were examined using Chi-square tests for categorical variables and Wilcoxon rank-sum test for continuous variables. Due to the variation in the use of air transport across isochrones, separate logistic regression models for road transport and air (HEMS) transport, with robust standard errors, were performed to investigate the key variables associated with shock. The logistic regression models produced odds ratios, with 95% confidence intervals. Background research and univariate analyses were initially performed to guide the development of a comprehensive multivariate model. After initial investigation of unadjusted associations, the study's multivariable logistic regression models for shock included age group, sex, ISS, AIS, cause, entrapment, distance isochrones, primary hospital destination, time periods, and prehospital interventions. For the categorical variables, the first category was used as the reference group, except for injury cause, where low falls was used, due to having the largest proportion. An interaction was then included in the road transport model to better understand the moderating effect between age and sex [33]. Post estimation diagnostics were performed which included the Pearson Goodness of fit and an ROC analysis (appendix 5) [34]. Probabilities of shock and 95% confidence intervals across sex and age were predicted and graphed to explain the moderating effects.

All statistical analysis were performed using Stata Version 17.0 (Stata Corp, College Station, TX). Statistical significance was set at the $p < 0.05$ level. This work is supported by Monash University through the Monash eResearch Centre and Helix, utilising the University hosted Secure eResearch Platform (Monash SeRP) on the Nectar Research Cloud. The Nectar Research Cloud is supported by the Australian National Collaborative Research Infrastructure Strategy.

Results

Over the 10-year period, 16,265 major trauma patients were transported by ambulance to a hospital Emergency Department (Table 1). Males represented 69% of all patients, and the median age was 55 years. A low fall was the predominant injury cause followed by transport (motor vehicle, motorcycle, bicycle and pedestrian) incidents. Transport was the predominate cause for patients 55 and younger, whilst low fall was the predominate cause for patients over 55 (appendix 4). The median injury severity score was 17 and 87.8% of the patient group had an ISS > 12. Over 90% of the total patient cohort were transported by road ambulance, and 74% of patients were transported to a major trauma service as their primary destination. A total of 4,325 (26%) patients were shocked.

Shocked patients

Of the 16,265 patients in this study, 26% had a positive shock index, however there was no difference in shock status between sexes (Table 1). Patients with shock were younger compared to patients without shock, and nearly one quarter of all shocked patients were aged 16–25 years. Overall mortality for patients with shock was higher, with the greatest difference in mortality seen in the first 24 h. Patients with penetrating injuries represented over 11% of all shocked patients, whilst only representing 5.1% of the total patient cohort. Transport injuries collectively (motor vehicle, motorbike, bicycle and pedestrians) represented the greatest proportion of all shocked patients. Comparatively, low falls were the most common cause of injury in the group without shock.

88% ($n = 3{,}819$) of patients with shock were transported to hospital by road ambulance, and 12% were transported by HEMS (Table 1). Patients with shock spent longer on scene with EMS, however transport times were quicker. The percentage of patients who received advanced lifesaving intervention was higher in the shock group (14.9%) compared to no shock (5.2%.) More shocked patients (83%) were transported to an MTS compared to patients without shock (73%).

Distance isochrones

The majority of the patients in this study (69%) were injured within the first three distance isochrones (0–30 km), with all of these patients transported by road ambulance. Median prehospital times increased with increasing distance, except for the 61–70 km isochrone (Graph 1). A gradual decrease in overall patient incidence was seen as distance from the MTS increased, with the exception of the 61–70 km isochrone, which saw a slight increase (Table 1).

Patients transported by road ambulance

After adjusting for all other variables in the model, females had increased odds of shock compared to males (Table 2). There were reduced odds of shock as age increased and this association differed by patient's sex. The interaction between age and sex in patients with and without shock is highlighted in graph 2. The predicted average probability of shock in females aged 16–25 and 26–35 was higher than males in the same age groups, but there was no difference in the predicted average probability of shock between the two sexes from 36 years of age onwards.

The adjusted odds of developing shock for patients with penetrating injuries was 2.7 times the odds of patient having low falls (Table 2). Whilst transport causes including motor vehicle collision, motorcycle and bicycle all showed reduced adjusted odds of shock. Comparatively, the adjusted odds of shock patients who were entrapped was 23% greater than patients who were not entrapped.

The odds of adjusted shock for patients within the 11–30 km isochrones was between 18 and 20% higher than patients within 10 km. Comparatively, patients between 41 and 50 km had a 22% reduced adjusted odds of shock compared those within 0–10 km. Patients with shock had quicker transport times, however there was a 2% reduction in shock for every 1-minute increase in transport time.

Patients receiving advanced lifesaving interventions had twice the adjusted odds of shock compared to patients not receiving this intervention. Conversely, the adjusted odds of shock were 1.4 times higher for patients who received fundamental LSI compared to patients who received no fundamental LSI.

Patients transported by air (HEMS) ambulance

There were few variables associated with shock in the HEMS unadjusted models. After adjusting for all variables, the odds of a female being shocked was 2.7 times higher than males. (Table 2). Additionally, for patients transported by HEMS, the odds of shock increased by 1% with every minute of scene time increase. Similarly, the odds of shock increased 5% with every increase in ISS.

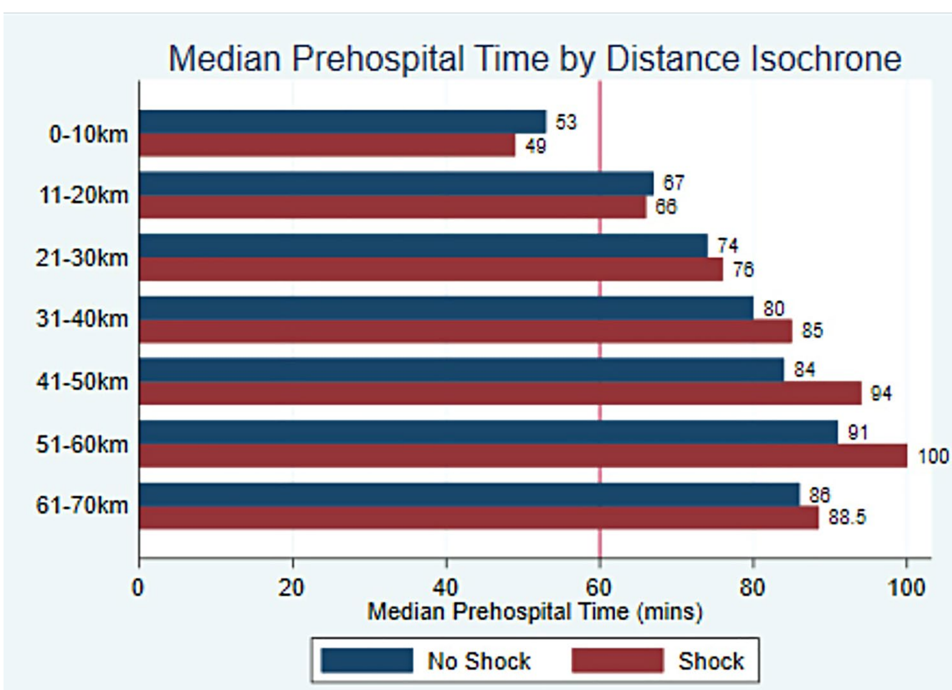
Table 1 Shock demographics

Base	All 16,265	Shock (≥ 0.9) 4,325 (26.6%)	No Shock (< 0.9) 11,940 (73.4%)	*p*-value
Male	11,334 (69.6%)	3,043 (70.3%)	8,291 (69.4%)	0.26
Age, years (median, IQR)	55 (34–76)	41 (26–61)	60 (40–78)	< 0.001
Age Categories (years)				< 0.001
16–25	2,226 (13.6%)	1,007 (23.2%)	1,219 (10.2%)	
26–35	2,093 (12.8%)	818 (18.9%)	1275 (10.6%)	
36–45	1,956 (12.0%)	668 (15.4%)	1288 (10.7%)	
46–55	2,000 (12.3%)	534 (12.3%)	1466 (12.2%)	
56–65	1,996 (12.2%)	400 (9.2%)	1596 (13.3%)	
66–75	1,921 (11.8%)	329 (7.6%)	1592 (13.3%)	
76–85	2,355 (14.4%)	345 (7.9%)	2010 (16.8%)	
> 85	1,718 (10.5%)	224 (5.1%)	1494 (12.5%)	
In Hospital Mortality				< 0.001
Yes	3,542 (21.7%)	1,042 (24.0%)	2,500 (20.9%)	
No	12, 723 (78.2%)	3,283 (75.9%)	9,440 (79.0%)	
24 h Mortality				< 0.001
Yes	598 (3.68)	328 (7.5%)	270 (2.2%)	
No	15,667 (96.3%)	3,997 (92.4%)	11,670 (97.7%)	
7 Day Mortality				0.03
Yes	1,026 (6.3%)	303 (7.0%)	723 (6.0%)	
No	15,239 (93.9%)	4,022 (92.9%)	11,217 (93.9%)	
ISS (median, IQR)	17 (14–25)	19 (14–29)	17 (14–22)	< 0.001
Injury Type				< 0.001
Blunt	14,934 (91.8%)	3,595 (83.1%)	11,339 (94.9%)	
Penetrating	838 (5.15%)	495 (11.4%)	343 (2.87%)	
Thermal	295 (1.81%)	108 (2.50%)	187 (1.57%)	
Other	198 (1.22%)	127 (2.94%)	71 (0.59%)	
Cause				< 0.001
Low Fall	4,614 (28.3%)	722 (16.6%)	3,892 (32.6%)	
Motor vehicle	2,972 (18.2%)	1,004 (23.2%)	1,968 (16.4%)	
High Fall	2,177 (13.3%)	426 (9.85%)	1,751 (14.6%)	
Motorcycle	1,370 (8.4%)	447 (10.3%)	923 (7.73%)	
Pedestrian	1,317 (8.10)	469 (10.8%)	848 (7.10%)	
Bicycle	1,012 (6.2%)	137 (3.17%)	875 (7.33%)	
Struck (person or object)	1,012 (6.2%)	280 (6.47%)	732 (6.13%)	
Cutting/Piercing/Gunshot	803 (4.94%)	483 (11.1%)	320 (2.68%)	
Other	708 (4.35%)	256 (5.92%)	452 (3.79%)	
Thermal	280 (1.72%)	101 (2.34%)	179 (1.50%)	
Entrapment				
Yes		580 (13.6%)	759 (6.43%)	< 0.001
No		3,675 (86.3%)	11,031 (93.5%)	
Distance Isochrone (km)				0.001
0–10	3,961 (24.3%)	1,043 (24.1%)	2,918 (24.4%)	
11–20	4,705 (28.9%)	1,247 (28.8%)	3,458 (28.9%)	
21–30	2,708 (16.6)	756 (17.4%)	1,952 (16.3%)	
31–40	1,752 (10.7)	506 (11.7%)	1,246 (10.4%)	
41–50	1,258 (7.73%)	289 (6.68%)	969 (8.12%)	
51–60	853 (5.24%)	241 (5.57%)	612 (5.13%)	
61–70	1,028 (6.32%)	243 (5.62%)	785 (6.57%)	
Transport Mode				< 0.001
Road Transport	15,111 (92.91%)	3,819 (88.30%)	11,292 (94.57%)	
HEMS	1,154 (7.09%)	506 (11.70%)	648 (5.43%)	
Primary Hospital Level				< 0.001

Table 1 (continued)

Base	All 16,265	Shock (≥ 0.9) 4,325 (26.6%)	No Shock (< 0.9) 11,940 (73.4%)	*p*-value
MTS (Level 1)	11,718 (74.1%)	3,550 (83.8%)	8,168 (70.5%)	
MeTS/RTS (Level 2)	3,722 (23.5%)	646 (15.2%)	3,076 (26.5%)	
MCPS/USS (Level 3)	372 (2.35%)	40 (0.9%)	332 (2.8%)	
Time Periods, minutes (Median, IQR)				
Response Time	14 (9–22)	13 (9–20)	14 (10–23)	< 0.001
Scene Time	23 (15–34)	25 (16–38)	23 (15–33)	< 0.001
Transport Time	24 (16–34)	23 (14–32)	25 (16–35)	< 0.001
LSI Fundamental[1]				< 0.001
Yes	14,545 (89.4%)	4,090 (94.5%)	10,455 (87.5%)	
No	1,720 (10.5%	235 (5.43%)	1,485 (12.4%)	
LSI Advanced[2]				< 0.001
Yes	1,278 (7.86%)	648 (14.9%)	630 (5.2%)	
No	14,987 (92.1%)	3,677 (85.0%)	11,310 (94.7%)	
Severe Injury (AIS severity scale score ≥ 3)				
Chest				< 0.001
Yes	6,137 (37.7%)	1,944 (44.9%)	4,193 (35.1%)	
No	10,128 (62.2%)	2,381(55.0%)	7,747 (64.8%)	
Abdomen/Pelvis				< 0.001
Yes	1,389 (8.54%)	754 (17.4%)	635 (5.32%)	
No	14,876 (91.4%)	3,571 (82.5%)	11,305 (94.6%)	
Head				< 0.001
Yes	6,481 (39.8%)	1,430 (33.0%)	5,051 (42.3%)	
No	9,784 (60.1%)	2,895 (66.9%)	6,889 (57.7%)	
Missing Data				
Entrapment		70 (1.61%)	150 (1.25%)	

Low fall: fall onsame level or less than or equal to 1 m. High fall: > 1 m



Graph. 1 Median total prehospital time for shock and no shock, by distance isochrone

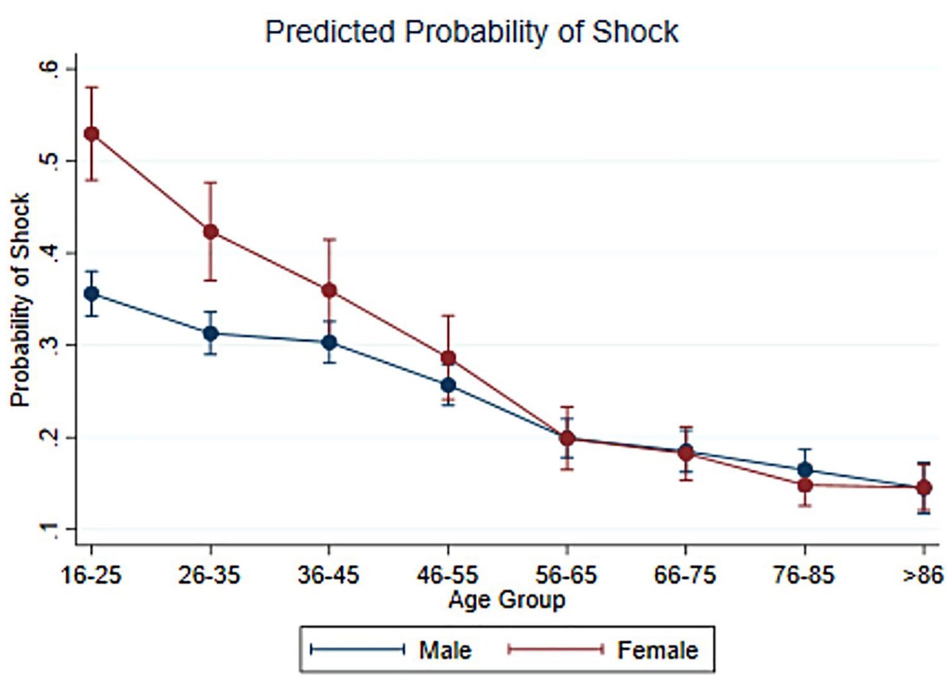
Table 2 Major trauma patients, by mode of transport

	Road Transport *n* = 14,315		**HEMS Transport *n* = 1,154**	
	Adj. Odds Ratio (95% CI)	***p*-value**	**Adj. Odds Ratio (95% CI)**	***p*-value**
Sex				
Male	ref.	-	ref.	-
Female	2.19 (1.72–2.80)	< 0.001	2.723 (1.40–5.28)	0.003
Age Categories (years)				
16–25	ref.	-	ref.	-
26–35	0.80 (0.68–0.94)	0.009	1.07 (0.62–1.87)	0.78
36–45	0.76 (0.64–0.89)	0.001	0.76 (0.45–1.28)	0.30
46–55	0.58 (0.49–0.7)	< 0.001	0.74 (0.44–1.25)	0.27
56–65	0.40 (0.33–0.48)	< 0.001	0.97 (0.51–1.83)	0.93
66–75	0.36 (0.29–0.48)	< 0.001	0.79 (0.34–1.86)	0.60
76–85	0.31 (0.25–0.38)	< 0.001	0.76 (0.32–1.75)	0.52
> 85	0.26 (0.19–0.34)	< 0.001	1.19 (0.35–3.97)	0.77
Interaction: Sex x Age (years)				
Male	ref	-		
Female x 16–25	ref.	-		
Female x 26–35	0.78 (0.54–1.11)	0.17	-	
Female x 36–45	0.61 (0.42–0.89)	0.010	-	
Female x 46–55	0.55 (0.38–0.79)	0.001	-	
Female x 56–65	0.47 (0.33–0.68)	< 0.001	-	
Female x 66–75	0.46 (0.32–0.67)	< 0.001	-	
Female x 76–85	0.42 (0.32–0.67)	< 0.001	-	
Female x > 85	0.48 (0.32–0.72)	< 0.001	-	
ISS	1.03 (1.03–1.04)	< 0.001	1.05 (1.04–1.07)	< 0.001
Cause				
Low Fall	ref.	-	ref.	
Motor vehicle	0.70 (0.58–0.83)	< 0.001	1.14 (0.34–3.78)	0.81
High Fall	0.54 (0.46–0.64)	< 0.001	0.50 (0.13–1.89)	0.31
Motorcycle	0.69 (0.56–0.84)	< 0.001	1.37 (0.4–4.6)	0.61
Pedestrian	0.97 (0.81–1.16)	0.77	1.55 (0.44–5.35)	0.48
Bicycle	0.36 (0.28–0.46)	< 0.001	0.46 (0.1–2.07)	0.31
Struck (person or object)	0.92 (0.75–1.12)	0.42	1.09 (0.27–4.34)	0.89
Cutting/Piercing/Gunshot	2.71 (2.17–3.38)	< 0.001	3.64 (0.97–13.6)	0.05
Other	0.78 (0.62–0.99)	0.043	1.44 (0.41–5.08)	0.56
Thermal	0.97 (0.61–1.23)	0.45	1.81 (0.44–7.32)	0.40
Entrapment				
No	ref	-	ref	-
Yes	1.23 (1.03–1.45)	0.019	1.39 (0.91–2.12)	0.12
Distance Isochrone (km)				
0–10	ref.	-	-	
11–20	1.20 (1.07–1.36)	0.002	-	
21–30	1.18 (1.02–1.37)	0.022	-	
31–40	1.16 (0.97–1.39)	0.09	ref.	
41–50	0.78 (0.62–0.99)	0.046	0.81 (0.54–1.22)	0.33
51–60	1.01 (0.75–1.36)	0.92	0.98 (0.65–1.49)	0.95
61–70	1.17 (0.91–1.51)	0.20	0.62 (0.38-1.0)	0.05
Primary Hospital Level				
MTS (Level 1)	ref.	-	-	
MeTS/RTS (Level 2)	0.82 (0.71–0.94)	0.007	-	
MCPS/USS (Level 3)	0.56 (0.39–0.82)	0.003	-	
Time Periods (minutes)				
Response Time	0.99 (0.99-1.00)	0.44	1.00 (0.99-1.00)	0.62

Table 2 (continued)

	Road Transport *n* = 14,315		HEMS Transport *n* = 1,154	
	Adj. Odds Ratio (95% CI)	***p*-value**	**Adj. Odds Ratio (95% CI)**	***p*-value**
Scene Time	1.00 (1.00-1.01)	< 0.001	1.01 (1.00-1.01)	0.001
Transport Time	0.98 (0.98–0.99)	< 0.001	1.00 (0.98–1.01)	0.76
LSI Fundamental[1]				
No	ref.	-	ref.	
Yes	1.42 (1.2–1.68)	< 0.001	1.47 (0.42–5.11)	0.54
LSI Advanced[2]				
No	ref.	-	ref.	
Yes	2.01 (1.69–2.39)	< 0.001	0.94 (0.66–1.35)	0.77
Severe Injury				
Chest				
No	ref.	-	ref.	
Yes	1.10 (1.00-1.22)	0.044	1.10 (0.78–1.56)	0.56
Abdomen/Pelvis				
No	ref.	-	ref.	
Yes	1.66 (1.43–1.93)	< 0.001	0.74 (0.50–1.09)	0.12
Head				
No	ref.	-	ref.	
Yes	0.59 (0.53–0.67)	< 0.001	0.66 (0.44–0.98)	0.043

(n.b. only 18 patients were transported by HEMS between 0–30 km, which have been excluded from the analysis)



Graph. 2 Predicted probability of shock index ≥ 0.9 by age categories

Discussion

This study found that 88% of shocked patients in this study, who may have benefited from more advanced pre-hospital LSI did not have access to this resource. Despite being closer to definitive care, patients 10–30 km from a major trauma service were at increased odds of shock during the early phases of care. Over the 10-year period of this study, shock was present in 26% of major trauma patients, and nearly 90% were transported by road ambulance. Whilst low falls accounted for 32% of major trauma, transport causes were more prevalent in patients with shock, and the adjusted odds of shock was higher in younger females than younger males.

In this study, approximately 70% of patients were located within 30 km of the major trauma centres. Whilst this is reflective of the increased population density in inner urban Melbourne [35], patients between 20 and 30 km still had a median prehospital time of 76 min. Previous literature has explored the benefits of advanced LSI in the prehospital setting [36] and have shown decreased mortality when physician led care and more advanced paramedic interventions are provided in the prehospital setting, in both urban and rural locations. The majority of trauma patients in this study had no access to more advanced LSI provided by HEMS paramedics, despite long prehospital times.

Scene times were slightly longer for patients with shock, and scene time had a positive association with shock. This may be a consequence of a greater need for on scene clinical stabilisation and resuscitation prior to transportation. Whilst some studies have found no association between scene time or total prehospital time, and patient outcome [37–39], there does remain a cohort of major trauma patients who may benefit from swifter prehospital times, including neurotrauma [40], shock [41] and thoracic trauma [42]. There are multiple factors which can lead to increased scene times, including mechanical entrapment [43], as well as physiological entrapment; whereby a patient is physiologically unstable and requires urgent lifesaving interventions to make them safer for transport. In addition, the transport of patients from outer urban areas to a central MTS, can result in increased prehospital times, as reflected in this study.

This study showed a linear reduction in both the proportion, and odds of shock with increasing age. This has been shown in previous research which highlights the different mechanisms of injury between younger persons and older persons [44]. Additionally this may highlight the challenges in identifying major trauma in the older population with contributing comorbidities and medications impacting their baseline cardiovascular system. Regardless, the shock index remains a valid and important tool in predicting mortality in older trauma patients [45, 46].

Whilst 70% of all shocked major trauma patients were male, young females (< 35 years) had an increased predictive probability of shock. This sex dimorphism has been highlighted by previous studies [47] and is likely because females normally have lower blood pressures and higher heart rates than men [33, 48] and may highlight a limitation of the shock index without age and sex based modifications [3]. Further investigation may be required to develop age and sex specific shock indices, to better represent the cohorts. The increased association of shock in females, has not been associated with an increased mortality [49, 50], further emphasising the need for age and sex specific shock indices.

This study showed that high energy transport injury accounted for over 50% of all patients under 55, whilst low energy, low falls accounted for 51% of all patients over 55, which is consistent with broader, bi-national reporting on age and injury demographics [51]. Mortality rates from trauma increase with patient age, however this is often due to the impact of comorbidities and concurrent medical conditions [52, 53]. Future examination of trauma systems may require exploring the different patient clinical needs, based on age and injury cause. Patients with injuries from low energy falls may not necessarily require advanced lifesaving interventions.

With provision of advanced trauma interventions only available via HEMS, patients in this study who were further away from a MTS could have had access to advanced LSI (blood, ultrasound, finger thoracostomy) more quickly than patients within 30 km who were transported by road with no access to advanced LSI. It was not the intention of this study to determine if this dichotomy in the system impacted on patient outcomes, and further data on prehospital deaths and clinical review will be beneficial to analyse the potential impact of advanced LSI on outcomes. A system which facilitates access to appropriate LSI for all patients, in a timely manner, should be the goal of prehospital trauma care.

Strengths and limitations

This study used matched data from two organisations to better understand and describe the prehospital phase of trauma patients, and integrated geospatial data to map where the patient injury occurred. Data on prehospital deaths were not included. Additionally, the use of shock index as a measure of clinical significance, does not account for the variation in normal vital signs seen across sex and age, however the shock index remains a widely used measure [30–32]. Furthermore, a positive shock index was calculated as the lowest variable at a single timepoint, rather than being representative of a clinical trend. As this was an observational study, causation cannot be determined.

Conclusion

This research identified key factors associated with shock in a metropolitan prehospital setting. Over a quarter of major trauma patients developed a shock index ≥ 0.9 within the prehospital phase of their care. This paper highlighted that the majority of patients with shock were within 30 km of the major trauma services. Additionally, females and patients who were trapped had positive associations with shock. Furthermore, 88% of the shocked patients were transported by road, and therefore did not have access to the most advanced prehospital LSI available within the state. The prehospital clinical interventions required at each isochrone from an MTS to optimise survival and functional outcomes in shocked patients following major trauma is unclear.

Supplementary Information

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Supplementary Material 1

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Author contributions

TA; Data curation, formal analysis, visualisation, Writing – original draft. JD; Formal Analysis, Methodology, Supervision, Visualisation, Writing – review & editing. BG; Conceptualisation, Methodology, Supervision, Writing – review & editing. BB; Conceptualisation, Methodology, Supervision, Writing – review & editing. SC; Data curation. PC; Conceptualisation, Methodology, Supervision, Writing – review & editing.

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Data availability

Data for this project were obtained from the Victorian State Trauma Registry. Access to this dataset can be obtained with data custodian approval and the relevant ethics approvals. The data access policy is available at the project website https://www.monash.edu/medicine/sphpm/vstorm.

Declarations

Ethical approvel

Ethics for this project was approved by the Monash University Human Research Ethics Committee (Application number: 31741).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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