School of Nursing, Midwifery and Paramedicine

The Epidemiology of Trauma Patients Attended by a Paramedic Staffed Emergency Medical Service in Perth, Western Australia

Elizabeth Emma Brown

This thesis is presented for the degree of
Doctor of Philosophy
of
Curtin University

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Ethics Approval

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014.

The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number HR 128/2013.

My name was added to the list of investigators for HR 128/2013: "Western Australian Prehospital Care Record Linkage Project" to enable data access and analysis on the 5th May 2015. A copy of this approval is provided in Thesis Appendix A.

Approval to access St John Western Australia Patient Care Records was gained from the St John Western Australia Research Advisory Group (now called the Research Governance Committee).

A separate approval (RGS0000000464) was obtained from the Royal Perth Hospital (RPH) Human Research Ethics Committee for the use of State Trauma Registry data. A copy of this approval is provided in Thesis Appendix B.

Elizabeth Emma Brown

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Abstract

Background: Injury is a significant cause of preventable mortality and morbidity in both developed and developing countries. As well as potentially imposing significant disabilities on individuals of all ages, both physically and psychologically, injuries can cause loss of potential years of life and the economic implications can be high. Gaining an understanding of the epidemiology of trauma and prehospital management of injuries may help inform clinical practice, enable better tailoring of paramedic education and improve patient outcomes.

Aim: To describe the epidemiology of trauma patients who are attended by a paramedic staffed emergency medical service (EMS), in the metropolitan area of Perth, Western Australia (WA) and examine prehospital factors associated with patient survival outcomes.

Methods: Firstly, a retrospective cohort study was undertaken of all adult (≥16 years) trauma patients (excluding drowning, hanging or poisoning) who were attended by St John Western Australia (SJ-WA) paramedics in greater metropolitan Perth, WA between the 1st January 2013 and 31st December 2016. The aim of this study was to describe the epidemiology of trauma from all causes and all acuity levels. The specific objectives of the study were to describe trauma incidence and mortality rates and their trends over time; to compare the characteristics of patients between those who survived 30-days and those who died and to report the interventions performed by paramedics. This study used data from the SJ-WA database and WA death data. Descriptive statistics were used to describe the cohort. Crude age-specific incidence and mortality rates (defined as death within 30-days) were derived for the study cohort and trends in these figures were compared across the calendar years 2013 to 2016 using the Cochran–Armitage test.

To gain a greater understanding of major trauma (Injury Severity Score >15) in the metropolitan area of Perth, WA, a retrospective cohort study was undertaken of adults who were transported to hospital by SJ-WA emergency ambulance in metropolitan Perth and were then retrospectively diagnosed with major trauma and featured in the WA State Trauma Registry (WA-STR). The aim of this study was to describe the demographics, injury characteristics and outcomes of major trauma patients transported to hospital by ambulance. This study involved analysing data from both the SJ-WA database and from the WA-STR using descriptive statistics to describe the cohort.

After examining the epidemiology and characteristics of trauma patients, prehospital factors that were associated with major trauma outcomes were investigated, in particular, prehospital time and hospital destination. Multivariate analyses with inverse probability of treatment weighting were performed to determine if prehospital time, specifically a time of more than one hour, was associated with outcome in major trauma patients transported to hospital in metropolitan Perth, WA. The primary outcome of interest was 30-day mortality and the secondary outcome was the length of hospital stay for 30-day survivors.

The characteristics and outcomes of major trauma patients who were transported directly or indirectly to the Trauma Centre and those who never received Trauma Centre care were then examined and compared. Further analysis was then undertaken to determine whether older age was associated with a reduced likelihood of transport (directly or indirectly) to the Trauma Centre. In addition, multivariate logistic regression with inverse probability of treatment weighting was used to determine if Trauma Centre transport was associated with in-hospital mortality in older adults.

Finally, a systematic review of the literature was carried out to identify if there was an association between age and the likelihood of Trauma Centre transport in major trauma patients. The following databases were searched: Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Scopus, Cochrane Library and grey literature until 7th of March 2019. To be included in the review studies had to meet the following criteria: 1) The study must be a comparative study, including randomised controlled trials, cohort studies, cross-sectional studies or case-control studies 2) study participants must be patients with major trauma 3) the patients must have been initially transported from the accident scene to hospital by EMS and 4) the study must report the association between major trauma patient, age and Trauma Centre transport.

Results: Overall there were 97,724 adult trauma patients who were attended by SJ-WA paramedics in greater metropolitan Perth between the 1st January 2013 and 31st December 2016. During this period, there was a statistically significant increase in the incidence rate (from 1,466 to 1,623 per 100,000 population-years, $p<0.001$) with the highest incidence rate in the ≥85-years age group. Of these patients, 1,625 were retrospectively diagnosed with major trauma and featured in the WA-STR. The median age of major trauma patients was 51 years (interquartile range [IQR] 30-75 years) and the most common mechanism of injury was falls from standing (n=460; 28%). Falls from standing were also responsible for most of the early (n=45/175, 26%) and late deaths (n=69/158, 44%). These findings were reported in two published papers.[1, 2]

With respect to prehospital factors and outcomes, no significant association was found between a prehospital time of one hour and 30-day mortality (adjusted odds ratio [AOR] 1.10, 95% confidence interval [CI] 0.71-1.69). No association between any individual prehospital time interval and 30-day mortality was found. However, in the 30-day survivors, one-minute increase of on-scene time was associated with 1.16 times (95% CI 1.03-1.31) longer length of stay. The results of these analyses were reported in a published paper.[3]

In relation to hospital destination, those major trauma patients who did not receive care at the Trauma Centre were of older age, with a high prevalence of major head injuries and falls from standing as their mechanism of injury. These findings were reported in a published paper.[4]

Compared to younger adults with major trauma, older adults (≥65 years) had lower odds (AOR 0.52, 95% CI 0.35-0.78) of Trauma Centre transport. Furthermore, not being transported to the Trauma Centre was associated with 1.7 times the likelihood of in-hospital mortality (95% CI 1.04-2.7) in older adults. These findings were reported in a published paper.[5] Further investigation of the literature in the systematic review revealed that older adults with major trauma have a reduced likelihood of EMS Trauma Centre transport when compared to younger adults. The findings were reported in a paper which has been submitted for publication.

Conclusions: The majority of trauma patients attended to by SJ-WA ambulance paramedics did not have immediate life threats. These findings suggest that focusing research, training and resources solely on critically injured trauma patients will not cater for the needs of the majority of trauma patients. However, prehospital factors such as prehospital time and choice of hospital destination have an influence on major trauma patient outcomes. Therefore, prehospital care should be delivered in a timely fashion and delivery of the patient to an appropriate hospital should occur reasonably promptly. Furthermore, trauma is not only a disease of the young, therefore, to ensure older adults with major trauma receive transport to an appropriate hospital, specific trauma triage for older patients, together with a focus on extended EMS training, may be required.

Manuscripts published

Brown E, Williams T, Tohira H, Bailey P, Finn J. Epidemiology of Trauma Patients Attended by Ambulance Paramedics in Perth, Western Australia. Emergency Medicine Australasia. 2018;30(6):827-833.

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Longer Prehospital Time Was Not Associated with Mortality in Major Trauma. A Retrospective Cohort Study. Prehospital Emergency Care. 2018;23(4):527-537.

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Older Age is Associated with a Reduced Likelihood of Ambulance Transport to a Trauma Centre after Major Trauma in Perth. Emergency Medicine Australasia. 2019;31:763-71.

Brown E, Tohira H, Bailey P, Fatovich D, Finn J. Major Trauma Patients Are Not Who You Might Think They Are. A Linked Data Study. Australasian Journal of Paramedicine. 2019. [In Press].

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. A Comparison of Major Trauma Patient Transport Destination in Metropolitan Perth, Western Australia. Australasian Emergency Care. 2019. [In Press].

Manuscript submitted for publication

Brown E, Tohira H, Bailey P, Finn J. Is Age Associated with Emergency Medical Service Transport to a Trauma Centre in Patients With Major Trauma? A Systematic Review. Under review – Australasian Journal of Paramedicine.

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List of Abbreviations

AED	Automated External Defibrillator
AIS	Abbreviated Injury Scale
AOR	Adjusted Odds Ratio
CAD	Computer Aided Dispatch
CI	Confidence Interval
CPR	Cardiopulmonary Resuscitation
EMS	Emergency Medical Service
ePCR	Electronic Patient Care Record
EtC02	End-Tidal Carbon Dioxide
GCS	Glasgow Coma Scale
HEMS	Helicopter Emergency Medical Service
ICD	International Classification of Diseases
IPTW	Inverse Probability of Treatment Weighting
IQR	Interquartile Range
ISS	Injury Severity Score
IV	Inverse Variance
KED	Kendrick Extrication Device
LOS	Length of Stay
LUCAS	Lund University Cardiac Arrest System
MBC	Motorbike Crash
M-H	Mantel-Haenszel
MPDS	Medical Priority Dispatch System
MVA	Motor Vehicle Accident
MVC	Motor Vehicle Crash
NEDS	National Emergency Department Sample
NHMRC	National Health and Medical Research Council
Non-TC	Non-Trauma Centre
NSW	New South Wales
OHCA	Out of Hospital Cardiac Arrest
OR	Odds Ratio
PCR	Patient Care Record
PRECRU	The Prehospital Resuscitation and Emergency Care Research Unit

PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analysis
PTTC	Prehospital Trauma Triage Criteria
RTS	Revised Trauma Score
SBP	Systolic Blood Pressure
SE	Standard Error
SJA-WA	St John Ambulance Western Australia
SJ-WA	St John Western Australia
SMD	Standardised Mean Difference
SPSS	Statistical Package for Social Sciences
TC	Trauma Centre
tRTS	Triage Revised Trauma Score
USA	United States of America
WA	Western Australia
WA-STR	Western Australian State Trauma Registry

Publications, Presentations and Scholarships

Publications

Brown E, Williams T, Tohira H, Bailey P, Finn J. Epidemiology of Trauma Patients Attended by Ambulance Paramedics in Perth, Western Australia. Emergency Medicine Australasia. 2018;30(6):827-833.

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Longer Prehospital Time Was Not Associated with Mortality in Major Trauma. A Retrospective Cohort Study. Prehospital Emergency Care. 2018;23(4):527-537.

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Older Age is Associated with a Reduced Likelihood of Ambulance Transport to a Trauma Centre after Major Trauma in Perth. Emergency Medicine Australasia. 2019;31:763-71.

Brown E, Tohira H, Bailey P, Fatovich D, Finn J. Major Trauma Patients Are Not Who You Might Think They Are. A Linked Data Study. Australasian Journal of Paramedicine. 2019. [In Press].

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. A Comparison of Major Trauma Patient Transport Destination in Metropolitan Perth, Western Australia. Australasian Emergency Care. 2019. [In Press].

Additional Publications

Beck B, Tohira H, Bray J, Straney L, **Brown E**, Inoue M, Williams T, McKenzie N, Celenza A, Bailey P, Finn J. Trends in Traumatic Out-of-Hospital Cardiac Arrest in Perth, Western Australia from 1997-2014. Resuscitation. 2016;98:79-84.

Manuscript Submitted for Publication

Brown E, Tohira H, Bailey P, Finn J. Is Age Associated with Emergency Medical Service Transport to a Trauma Centre in Patients with Major Trauma? A Systematic Review. Australasian Journal of Paramedicine. [Under review]

Conference Presentations

Poster presentation at 2018 St John Experience, Perth, Western Australia, 2018.

> **Brown E,** Tohira H, Bailey P, Finn J. Characteristics and outcomes of adult trauma patients attended by St John Ambulance paramedics in metropolitan Perth.

Poster presentation at 2018 St John Experience, Perth, Western Australia, 2018.

> **Brown E**, Tohira H, Bailey P, Finn J. Prehospital time and survival outcomes in major trauma patients transported by ambulance paramedics in Perth.

Poster presentation at Trauma 2018 conference, Perth, Western Australia, 2018.

> **Brown E,** Williams T, Tohira H, Bailey P, Finn J. Characteristics and outcomes of adult trauma patients attended by St John Ambulance paramedics in metropolitan Perth.

Poster presentation at EMS2019 conference, Madrid, Spain, 2019.

> **Brown E**, Buzzacott P, Tohira H, Bailey P, Fatovich D, Finn J. Major Trauma Patients: They Are Not Who You Think They Are.

Poster presentation at EMS2019 conference, Madrid, Spain, 2019.

> Buzzacott P, Tohira H, Bailey P, Arendts G, Fatovich D, Ball S, Brown E, Finn J. Ambulance attended major trauma from falls in Western Australia.

Poster presentation at EMS2019 conference, Madrid, Spain, 2019.

> Buzzacott P, Ball S, **Brown E**, Tohira H, Finn J. Epidemiology of population mortality related to falls in California 2000-2016: an increasing challenge for EMS.

Other Presentations

Presentation for Candidacy, School of Nursing Midwifery and Paramedicine, Curtin University, Perth, Australia, 2015.

> *The Epidemiology of Trauma Patients attended by a paramedic staffed Emergency Medical Service in Perth, Western Australia.*

Poster presentation at Mark Liveris Seminar, Faculty of Health Sciences, Curtin University, Perth, Australia 2017.

> *The Epidemiology of Trauma Patients attended by a paramedic staffed Emergency Medical Service in Perth, Western Australia.*

Poster presentation at Mark Liveris Seminar, Faculty of Health Sciences, Curtin University, Perth, Australia 2018.

> *Prehospital time and survival outcomes in major trauma patients transported by ambulance paramedics in Perth.*
>
> *(**First Prize** for the Best Poster Display Award. **Second Prize** for the Best Poster Presentation Award)*

Poster presentation at Research Rumble, Curtin University, Perth, Australia 2019.

> *Major Trauma Patients: They Are Not Who You Think They Are.*
>
> *(**Winner** Librarian's highly commended award)*

Oral Presentation at Prehospital and Emergency Care Australia and New Zealand Face to Face Steering Committee meeting. Melbourne, Australia 2019.

> *The Epidemiology of Trauma Patients attended by a paramedic staffed Emergency Medical Service in Perth, Western Australia.*

Oral Presentation Curtin University, Perth, Australia 2019.

> *Milestone Three. The Epidemiology of Trauma Patients attended by a paramedic staffed Emergency Medical Service in Perth, Western Australia.*

Abstract accepted for poster presentation at Grass Roots Conference, Fremantle, Australia 2019.

> Tohira H, Buzzacott P, Bailey P, Brink D, **Brown E**, Ball S, Finn J. Identifying falls in St John WA ambulance data.

Scholarships

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Statement of Author Contributions to Published Papers and Submitted Papers

Published Papers

1. **Brown E,** Williams T, Tohira H, Bailey P, Finn J. Epidemiology of Trauma Patients Attended by Ambulance Paramedics in Perth, Western Australia. Emergency Medicine Australasia. 2018;30(6):827-833.

Author	Contribution	Signature
Miss Elizabeth Brown	65%	
Dr Teresa Williams	10%	
Dr Hideo Tohira	10%	
Associate Professor Paul Bailey	5%	
Professor Judith Finn	10%	

I, Elizabeth Emma Brown, was the primary author of this published paper. My contribution was 65%. Data for the study was sourced from SJ-WA in consultation with Associate Professor Paul Bailey. Due to data privacy regulations, this extraction was undertaken by my supervisor at the time Dr Teresa Williams. The linking of the WA death data and the SJ-WA database was undertaken by my supervisor Dr Hideo Tohira. I then conducted the data cleaning with the assistance of Dr Teresa Williams. I undertook the analysis with the assistance of Dr Teresa Williams and Dr Hideo Tohira. I prepared the manuscript, which was reviewed by all the authors. All the authors were involved in the subsequent revision of the article and final approval of the submitted version.

2. **Brown E**, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Longer Prehospital Time Was Not Associated with Mortality in Major Trauma. A Retrospective Cohort Study. Prehospital Emergency Care. 2018;23(4):527-537.

Author	**Contribution**	**Signature**
Miss Elizabeth Brown	65%	
Dr Hideo Tohira	10%	
Associate Professor Paul Bailey	5%	
Professor Daniel Fatovich	5%	
Dr. Gavin Pereira	5%	
Professor Judith Finn	10%	

I, Elizabeth Emma Brown, was the primary author of this paper. The extent of my contribution 65%. Dr Hideo Tohira linked the data from SJ-WA with the data from the WA-STR. With the assistance of Dr Hideo Tohira and Dr Gavin Pereira I undertook the analysis and interpretation of the data. I then prepared the manuscript, which was reviewed by all the authors. All authors were involved in the subsequent revision and gave final approval of the submitted version.

3. **Brown E**, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Older Age Is Associated with a Reduced Likelihood of Ambulance Transport to a Trauma Centre after Major Trauma in Perth. Emergency Medicine Australasia. 2019;31:763-71.

Author	**Contribution**	**Signature**
Miss Elizabeth Brown	65%	
Dr Hideo Tohira	10%	
Associate Professor Paul Bailey	5%	
Professor Daniel Fatovich	5%	
Dr. Gavin Pereira	5%	
Professor Judith Finn	10%	

I, Elizabeth Emma Brown, was the primary author of this paper. The extent of my contribution 65%. I conceived and designed the study. With the assistance of Dr Hideo Tohira and Dr Gavin Pereira I undertook the analysis and interpretation of the data. I then prepared the manuscript, which was reviewed by all the authors. All authors were involved in the subsequent revision and gave final approval of the version to be submitted.

4. **Brown E**, Tohira H, Bailey P, Fatovich D, Finn J. Major Trauma Patients Are Not Who You Might Think They Are. A Linked Data Study. Australasian Journal of Paramedicine. 2019. [In Press].

Author	**Contribution**	**Signature**
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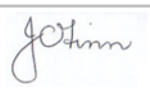
Dr Hideo Tohira	5%	
Associate Professor Paul Bailey	5%	
Professor Daniel Fatovich	5%	
Professor Judith Finn	5%	

I, Elizabeth Emma Brown, was the primary author of this paper. The extent of my contribution 80%. I conceived and designed the study. I undertook the analysis and interpretation of the data. I prepared the manuscript, which was reviewed by all the authors. All authors were involved in the subsequent revision and gave final approval of the version to be submitted.

5. **Brown E**, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. A Comparison of Major Trauma Patient Transport Destination in Metropolitan Perth, Western Australia. Australasian Emergency Care. 2019. [In Press].

Author	**Contribution**	**Signature**
Miss Elizabeth Brown	65%	
Dr Hideo Tohira	10%	
Associate Professor Paul Bailey	5%	
Professor Daniel Fatovich	5%	
Dr. Gavin Pereira	5%	
Professor Judith Finn	10%	

I, Elizabeth Emma Brown, was the primary author of this paper. The extent of my contribution 65%. I conceived and designed the study. I analysed and interpreted the data with the assistance of Dr Hideo Tohira and Dr Gavin Pereira. I then prepared the manuscript prior to review by all of the authors. All authors were involved in the subsequent revision and gave final approval of the version to be submitted

Manuscripts Submitted for Publication

1. **Brown E**, Tohira H, Bailey P, Finn J. Is Age Associated with Emergency Medical Service Transport to a Trauma Centre in Patients with Major Trauma? A Systematic Review.

Author	**Contribution**	**Signature**
Miss Elizabeth Brown	75%	
Dr Hideo Tohira	10%	
Associate Professor Paul Bailey	5%	
Professor Judith Finn	10%	

I, Elizabeth Emma Brown, was the primary author of this paper. The extent of my contribution was 75%. I conceived and designed the study. I undertook the search of the literature and selected potentially relevant papers. Dr Hideo Tohira, independently screened these papers to identify relevant articles for inclusion and both Dr Hideo Tohira and I independently performed the risk of bias assessments. I then performed the analyses and drafted the manuscript. All authors reviewed the manuscript prior to submission.

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Chapter 1 Introduction

1.1 Background and Rationale

Physical trauma (trauma) is defined as being 'a body wound produced by sudden physical injury from impact, violence or accident'.[6] It is recognised as a frequent cause of preventable mortality and morbidity in both the developed and developing world.[7] As well as imposing significant disabilities on individuals of all ages both physically and psychologically,[8] injuries cause loss of potential years of life and the economic burden is high.[7] Over 5 million people die as a result of trauma each year, accounting for 9% of global mortality [9] and these deaths frequently occur in young and economically productive individuals.[10] However, for those who survive their injury, many are left with temporary or permanent disabilities and it is estimated that for every death there are dozens of hospitalisations, hundreds of emergency department attendances and thousands of doctors' appointments.[9]

There are many different mechanisms that can cause trauma, from non-intentional injuries to intentional inter-personal violence. Each type of traumatic mechanism has its own characteristics and the severity of the injury can range from requiring minimal intervention through to multisystem trauma which requires definitive management from multidisciplinary teams.[11]

To improve trauma patient outcomes and reduce the burden on society, trauma systems have been developed.[12] These systems provide a multidisciplinary care strategy for seriously injured patients.[13] It is the responsibility of these trauma systems to provide clinical practice based on the best available evidence. Within these systems, EMS providers (otherwise referred to as 'ambulance services') are often the first point of access. The prevention of further injury, initiation of resuscitation and timely transport to an appropriate hospital facility are key objectives of the prehospital phase.[13] This initial management is likely to influence the trauma patient's outcome.

To enable the development of appropriate policies and practices, it is paramount that there is an understanding of the epidemiology of trauma and the prehospital factors that influence trauma patient outcome. Gaining this understanding enables better tailoring of EMS provider education, and in turn, improved patient outcomes. Without having a true understanding of the epidemiology of trauma there will be suboptimal development and implementation of trauma management policies and practices. This, in turn, will result in deleterious trauma patient outcomes.

1.2 Aim

The aim of this research was to describe the epidemiology of adult (≥16 years) trauma patients who were attended by a paramedic staffed EMS (ambulance service), in the metropolitan area of Perth, Western Australia (WA) and examine prehospital factors associated with patient survival outcomes. As the outcomes of trauma are different between patients injured in rural areas and those injured in metropolitan areas,[14] the focus of this research is on the care received by patients in a metropolitan area. Furthermore, approximately 70% of the state's major trauma cases occur in the metropolitan area, with 94% of all major trauma occurring in those aged ≥14 years.[15]

Summary of Broad Research Aims

1. Describe the characteristics of all adult patients with trauma, attended by EMS, including prehospital deaths.
2. Determine the association between prehospital time and survival outcomes in major trauma patients.
3. Examine and compare the characteristics and outcomes of major trauma patients between transport destinations (Trauma Centre versus non-Trauma Centre).
4. Examine older adults with major trauma transported by EMS as a specific interest group of patients.
5. To provide recommendations to EMS to ensure the optimisation of trauma patient outcomes.

Specific Research Objectives

The following research objectives were defined to address the specific research aims above.

1. Describe the characteristics of adult patients with trauma, attended by EMS, including prehospital deaths.

    a) To undertake a retrospective cohort study of all adult trauma patients attended by EMS.
    b) To describe trauma incidence and mortality rates and their trends.
    c) To compare the characteristics of patients between those who survived 30-days and those who died.
    d) To report the interventions performed by ambulance paramedics.
    e) To describe the characteristics of major trauma patients transported to hospital by EMS.
    f) To describe the outcomes of major trauma patients transported to hospital by EMS.

2. Determine the association between prehospital factors and survival outcomes in major trauma patients.

    a) To estimate the association between prehospital time of more than one hour and major trauma patient 30-day mortality.
    b) To estimate the association between prehospital time of more than one hour and major trauma patient length of hospital stay (in those who survived more than 30-days).
    c) To estimate the association between any individual prehospital time (response, on-scene, travel or total prehospital time) and major trauma patient 30-day mortality.
    d) To estimate the association between individual prehospital time (response, on-scene, travel or total prehospital time) and major trauma patient length of hospital stay (in those who survived more than 30-days).

3. Examine and compare the characteristics and outcomes of major trauma patients between transport destinations (Trauma Centre versus non-Trauma Centre).

    a) To describe and compare the characteristics of major trauma patients between transport destinations.
    b) To describe and compare the outcomes of major trauma patients between transport destinations.

4. Examine older adults with major trauma transported by EMS as a specific interest group of patients.

    a) To describe the demographics and injury characteristics of major trauma patients transported to hospital by EMS.
    b) To estimate the association between older age and EMS transport to a Trauma Centre.
    c) To estimate the association between Trauma Centre transport and in-hospital mortality in older adults with major trauma.
    d) To conduct a systematic review of the existing literature to determine the association between older age and EMS transport to a Trauma Centre.

5. To provide recommendations to EMS to ensure the optimisation of trauma patient outcomes.

    a) Using the findings from the analyses to develop recommendations for the development of EMS clinical practice guidelines and paramedic education.

1.3 Thesis Approach

This thesis is based on a 'hybrid model' which incorporates both published research papers together with a written description of the work undertaken. An overview of each chapter is provided in Table 1.

Table 1 Overview of thesis chapters.

Chapter	Description	Aim	Objective
1	***Introduction***		
2	***Contextual Overview*** A contextual overview of EMS and trauma systems. This includes detailed descriptions of the population and setting of this study, with an overview of the EMS system in WA.		
3	***Epidemiology of Trauma - Methodology*** A detailed description of the methods used for the chapters of this thesis that describe the epidemiology and the characteristics of patients with trauma including a description of the data sources and statistical analysis used.		
4	***Epidemiology of Trauma*** Paper Published: ***Brown E****, Williams T, Tohira H, Bailey P, Finn J Epidemiology of Trauma Patients Attended by Ambulance Paramedics in Perth, Western Australia. Emergency Medicine Australasia. 2018;30(6):827-833.* This manuscript describes the epidemiology of trauma cases from all causes and all acuity levels attended by emergency ambulance in Perth, WA from 1st January 2013 to 31st December 2016. The manuscript also describes incidence and mortality rates and their trends; compares the characteristics of patients between those who survived 30-days and those who died, and reports the interventions performed by paramedics. This chapter contains a summary of the findings from a paper, of which I was a co-author, describing the epidemiology of traumatic aetiology out of hospital cardiac arrest.	(1)	a,b,c,d
5	***Demographics, Injury Characteristics and Outcomes of Major Trauma Patients - Methodology*** This chapter describes how the data from the WA-STR was used for the studies pertaining to major trauma patients.		

Chapter	Description	Aim	Objective
6	***Demographics, Injury Characteristics and Outcomes of Major Trauma Patients*** Paper Published: ***Brown E****, Tohira H, Bailey P, Fatovich D, Finn J. Major Trauma Patients Are Not Who You Might Think They Are. A Linked Data Study. Australasian Journal of Paramedicine. 2019. [In Press].* This chapter describes the demographics, injury characteristics and outcomes of major trauma patients transported to hospital by EMS in Perth, WA from 1st January 2013 to 31st December 2016.	(1)	b,e,f
7	***Prehospital Time and Outcomes - Methodology*** This chapter describes the methods used for the following analysis of the association between prehospital time and major trauma patient outcomes.		
8	***Prehospital Time and Outcomes*** Paper Published*:* ***Brown E****, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Longer Prehospital Time Was Not Associated with Mortality in Major Trauma. A Retrospective Cohort Study. Prehospital Emergency Care. 2018;23(4):527-537.* This retrospective cohort study investigated the influence of prehospital time on major trauma patient outcomes.	(2)	a,b,c,d
9	***Transport Destination for Major Trauma Patients - Methodology*** This chapter describes the methods used for the following analysis of the characteristics and outcomes of major trauma patients between transport destinations.		
10	***Transport Destination for Major Trauma Patients*** Paper Published: ***Brown E****, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. A Comparison of Major Trauma Patient Transport Destination in Metropolitan Perth, Western Australia. Australasian Emergency Care. 2019. [In Press].* This retrospective cohort study examines and compares the characteristics and outcomes of major trauma patients between transport destinations.	(3)	a,b
11	***Older Adults and Trauma Centre Transport - Methodology*** This chapter describes the methods used for the following analysis of the association between older age and transport to the Trauma Centre.		

Chapter	Description	Aim	Objective
12	***Older Adults and Trauma Centre Transport*** Paper Published: ***Brown E**, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Older Age is Associated with a Reduced Likelihood of Ambulance Transport to a Trauma Centre after Major Trauma in Perth. Emergency Medicine Australasia. 2019;31:763-71.* This retrospective cohort study describes the characteristics and outcomes of older adult (≥65 years) major trauma patients. The study also determines whether older age is associated with a reduced likelihood of transport (directly or indirectly) to a major Trauma Centre and whether this is associated with in-hospital mortality.	(4)	a,b,c
13	***Systematic Review - Older Age and Trauma Centre Transport*** This chapter reports the results of a systematic review of the literature to identify if there was an association between age and the likelihood of Trauma Centre transport in major trauma patients.	(4)	d
14	***Discussion, Recommendations and Concluding Remarks*** This chapter contains a detailed discussion of my findings, the limitations of my work and suggestions for future research. It also contains a final set of recommendations based on the research findings and concluding remarks.	(5)	a

Chapter 2 Contextual Overview

2.1 Introduction

The intent of this chapter is to provide background information relating to trauma, trauma systems the components of these systems and the trauma systems specific to the setting of this study. The following discussion sets the scene for the subsequent description of the epidemiology of trauma attended by EMS in Chapter 3.

2.2 Mechanism of Injury

An injury or injuries can be caused by blunt, penetrating or thermal mechanisms. All of these mechanisms have the ability to cause injury both externally and to internal organs.[11] Blunt injuries result from the acceleration, deceleration, compression and shearing forces when the body, or parts of the body, impact with another object. Blunt force trauma is likely to result from high kinetic energy events such as motor vehicle crashes and falls from height and can result in potentially devastating damage to organs and vascular structures.[16] Penetrating trauma results when an object pierces through the skin and enters the body often resulting from interpersonal violence such as gunshot wounds and knife crime.[17] Thermal trauma can result from extremes of heat, cold or chemical exposure. For example, in relation to injuries from extremes of heat, burns can result from exposure to fire or hot liquids.[18] In extremes of cold, the body can be damaged by being subjected to temperatures below freezing or when there is continuous exposure to low temperatures for several hours or days.[19] Exposure to chemicals can also cause burns when a corrosive agent comes into contact with the skin or eyes, or when a chemical is inhaled or ingested.[20]

2.3 Trauma Systems

Components of contemporary trauma systems include injury prevention, prehospital care, services at Trauma Centres and post-hospital care.[21] If injury prevention strategies fail and injuries occur, then the ultimate aim of caring for trauma patients will be to optimise their outcomes by preventing the death and disability associated with these injuries.[22]

Appropriate use of trauma systems provides systematic approaches to the care of trauma patients.[23] Regionalised trauma systems are designed to reduce morbidity and mortality that occur from severe injury.[21] Furthermore, they also improve preparedness for manmade and natural major incidents involving multiple patients.[21] This system of care involves trauma patients being transported to a small number of specialised Trauma Centres, staffed and equipped to provide multidisciplinary care to severely injured patients, as opposed to the closest hospital facility.[21-24]

The development of regionalised trauma systems to cater for severely injured trauma patients is a widely recognised model of care [25] and these trauma systems have been shown to reduce mortality.[21, 26-28] It has also been shown that the absence of an organised trauma system is associated with increased risk-adjusted mortality when compared with an inclusive trauma system.[29]

2.4 Prehospital Care

The first step in the trauma system is prehospital care.[13] EMS respond to calls for help from people who are believed to require urgent medical assessment, treatment and/or transportation to a hospital for further care.[30] Prehospital care aims to prevent further injury and improve recovery by initiating advanced life support as appropriate and providing appropriate patient transport.[13] It is the responsibility of the EMS providers to ensure that patients receive both prompt emergency care at the scene and appropriate transportation for further evaluation and treatment.[31] Prehospital care is provided by a variety of different agencies.[32] In some countries/states this will be through the local fire department, whereas other countries/states will have separate EMS agencies.[32] There is commonly, local variation in regards to the staffing and the configuration of staffing, which is often subject to local EMS system medical direction.[33] Examples of staffing arrangements include paramedics, firefighter/paramedics, emergency medical technicians, nurses and physicians or a combination of these. The levels of care provided by a particular EMS system may also vary between basic, intermediate, and advanced life support, as well as critical care.[32, 33] Furthermore, depending on the population and demand for EMS in specific areas, staff may be paid or volunteers or a mixture of both.[32]

2.5 Prehospital Triage

The word triage is derived from the French word "trier" which means separating, categorising or classifying.[34] In relation to the prehospital environment, triage relates to the categorisation, classification, and prioritisation of patients based on the urgency of their requirement for treatment.[34] The aim of this is to categorise the severity of the patients' injuries to ensure the appropriate allocation of resources to effectively treat multiple patients. However, the triage of patients following trauma is complex and influences patient outcomes.[35]

Prehospital triage is often used in three different ways: (1) during the initial dispatch of the most appropriate resources on receipt of an emergency call, (e.g. basic life support or critical care response) (2) whilst on the scene of an incident when the number of patients outweigh the EMS providers (3) to determine the patients' hospital destination, mode of transport (e.g. air or road) and/or driving conditions (e.g. lights and sirens) under which they will be transported.

Dispatch

EMS prioritise emergency calls to ensure that patients with time-critical conditions who require urgent medical attention take precedence over patients with non-critical injuries or illnesses.[36] Prioritisation of the emergency response is based on the information provided during the emergency telephone call. This often occurs by the utilisation of structured call taking based on codes and scripted questions.[37] In addition to medical dispatching, triage will also be used to determine the EMS response. The EMS organisation may dispatch basic or advanced life support ambulances or prehospital emergency physicians and helicopter EMS (HEMS) depending on the information gained from the emergency call.[37]

On Scene

Upon arrival at an injury scene, EMS providers must determine the severity of patients' injuries and initiate medical management, through a process called 'prehospital triage' or 'field triage'.[12] When the number of patients exceeds the EMS providers and when there are not enough resources to treat everyone, triage is used to prioritise care. This ensures that care is provided to the greatest number of injured people [34] and triage is a key principle in the effective management of major incidents.[38] There are many types of triage systems in existence and there is no consensus on how triage should be performed. Triage systems may be based on criteria such as vital signs, injuries, or the resources required to respond to the patients' needs.[39]

Interventions

The procedures undertaken and medications administered prehospital by EMS, differ between jurisdictions and the level of training of the EMS provider. However, there is generally a distinction made between what constitutes basic and advanced life support interventions. Basic life support often consists of non-invasive interventions, which can be performed easily and undertaken by EMS providers with a minimal amount of training, such as basic airway manoeuvres, chest compression, haemorrhage control and splinting.[32, 40] Conversely, providing advanced life support requires more extensive training and includes interventions such as endotracheal intubation, 12-lead electrocardiogram interpretation, manual defibrillation, needle thoracentesis (thoracocentesis) and intravenous medication administration.[41]

Transport Destination

As part of an optimal trauma system, prehospital triage ensures the transport of the right patient to the right hospital [42] and this is key to the effectiveness of a trauma system.[28] To improve the chances of patient survival and to prevent disabilities, the treatment of a severely injured trauma patient should be provided at a high-level Trauma Centre which has the most appropriate trauma care facilities to best manage the patient's condition.[8, 26, 43, 44] The triage of trauma patients is a critical process in a trauma system and often relies on decision tools consisting of physiological, anatomical, mechanism of injury and special considerations criteria.[32, 45, 46] Patients who meet the physiological or anatomical criteria of the trauma triage tools should be transported to a high-level Trauma Centre, where those who meet mechanism of injury criteria may be taken to lower-level hospitals.[32] It is essential that a prehospital trauma triage criteria is able to balance sensitivity, the identification of severely injured patients, with specificity, the identification of minor injuries.[47] Inaccurate triage results in a patient, who has a specific care requirement, not being transported to a high-level Trauma Centre and this is termed undertriage.[12] The result of undertriage is that a patient does not receive the specialised trauma care required, in a timely fashion. Conversely, overtriage occurs when a patient is transported to a higher-level Trauma Centre who is not in need of specialised care.[12] Both under and overtriage have consequences. Undertriage can result in preventable mortality due to delays in definitive care,[48] delays in diagnosis and treatment and decreased functional outcome.[26, 44] Overtriage can result in scarce resources being unnecessarily consumed.[12] Furthermore, overtriage can overburden Trauma Centres and decrease cost-effectiveness.[12]

2.6 Descriptors of Levels of Trauma Services

The hospital component of the trauma system is made up of different levels of care capabilities. The need for a systematic approach to trauma was first recognised in the United States of America (USA) [21] and regional trauma services have since been developed in other countries such as the United Kingdom [49] and Australia.[22, 50] Although there are worldwide variations, the following pertains to the American College of

Surgeons criteria for categorising hospitals, based on the availability of resources, volume of trauma patients seen and the hospital's educational and research commitment.[48]

Trauma Centres

Trauma Centres are classified as being one of four levels. A Level I centre has the greatest number of immediately available staff and resources for the care of the trauma patients. A Level I centre is also required to treat a pre-specified number of seriously injured patients per year.[48] In addition to this, the Level I centre provides education, research, and prevention programmes.[48] Level II Trauma Centres provide care to trauma patients either in addition to the Level I Trauma Centre, or solely in rural or sparsely populated areas. It is expected that a Level II Trauma Centre can provide definitive trauma care and be clinically equivalent to the Level I Trauma Centre.[48] However, depending on geographic location, the volume of patients, staffing, and resources, the Level II Trauma Centre may not be able to provide the same care as a Level I Trauma Centre. Therefore, patients with more complex injuries may require transfer to a Level I Trauma Centre. A Level III Trauma Centre has the ability to assess, resuscitate and perform emergency surgery prior to the severely injured trauma patient being transferred to a Level I or II Trauma Centre in areas where there is no immediate access to a higher level Trauma Centre. Similarly, a Level IV Trauma Centre is capable of assessment, resuscitation and stabilisation prior to transfer to a Level I or II Trauma Centre.[48]

Trauma Registries

Disease and illness registries provide an evidence base for many of the treatments and interventions in acute care situations. Furthermore, they provide information to assist epidemiological research, the programming of public health, and patient care improvement.[51] Similar to disease and illness registries, trauma registries provide comprehensive data regarding injured patients and provide important information to assess the management of trauma patient care.[51, 52] In the USA, trauma registries have previously been used to change legislation, promote prevention and the evaluation of the effectiveness of trauma systems.[51]

Regional trauma registries include multiple hospitals from a state or province.[52] The benefit of regional trauma registries is that they include a wider geographical area and therefore, are able to provide epidemiological data pertaining to a wider area than an individual hospital registry.[52]

2.7 Abbreviated Injury Scale

The first comprehensive injury severity scoring system to describe injuries and to measure injury severity was The Abbreviated Injury Scale (AIS).[53] The scale was developed by The Association for the Advancement of Automotive Medicine in conjunction with the American Medical Association, to provide researchers with an accurate method for rating and comparing injuries received in motor vehicle crashes whilst also standardising the language used to describe the injuries.[53]

The AIS is a consensus derived, anatomically based system that classifies individual injuries by body region on a 6-point ordinal severity scale. The scale ranges from AIS 1 which is a minor injury to AIS 6 which is a fatal, untreatable injury. Additionally, each injury description carries a unique, five-digit code.[54] The scale is calculated after scoring each of the nine anatomical divisions listed below.

The injured areas are as follows;[54]

1. Head.
2. Face.
3. Neck.
4. Thorax.
5. Abdomen and pelvic contents.
6. Spine and vertebrae.
7. Upper extremity.
8. Bony pelvis and lower extremity.
9. External including burns.

2.8 Injury Severity Score (ISS)

The AIS cannot measure the overall injury severity of a patient with multiple injuries, therefore, tools that can measure the overall severity of multiple injuries have been developed using the AIS.[55] The ISS provides a numerical description of the overall severity of injury in persons who have sustained an injury to more than one region of the body.[56] The original nine AIS subgroups are placed into six body regions. The ISS is then calculated from the sum of the squares from the highest AIS grade in each of the three most severely injured areas, resulting in a score from 1-75.[56]

The injured areas are as follows;[56]

1. Head or neck (includes cervical-spine).
2. Face (includes eyes, mouth, nose and facial bones).
3. Chest (includes thoracic spine and diaphragm).
4. Abdominal or pelvic contents (includes lumbar spine).
5. Extremities or pelvic girdle (including sprains and fractures).
6. External (including lacerations, abrasions and burns).

2.9 Triage Revised Trauma Score

The Revised Trauma Score (RTS) is a physiological injury severity score that numerically summarises assessments of the circulation, respiratory and central nervous system. There are two versions of the scoring system. One version is used for triage, using physiological variables and the other is used in outcome evaluation and controls for the ISS. As the ISS is based on injury diagnoses, which are not known prehospital, the ISS cannot be calculated prehospital. Thus the triage RTS (tRTS) is often used to assess the level of severity of trauma patients.[57] The intervals are coded with values ranging from 0 to 4, with 0 being the worst score and 4 being the best. For EMS providers, the tRTS may indicate whether a trauma patient should be transported to a Trauma Centre or not.[58] Table 1 depicts the variable breakpoints of the tRTS.

Table 1 Triage Revised Trauma Score.[59]

Glasgow Coma Scale	Systolic Blood Pressure	Respiratory Rate	Code Value
13-15	>89	10-29	4
9-12	76-89	>29	3
6-8	50-75	6-9	2
4-5	1-49	1-5	1
3	0	0	0

2.10 Major Trauma

Patients with major trauma are known to have higher rates of mortality, have longer stays in hospital and greater need for rehabilitation.[60] An ISS of more than 15 has been historically used to define major trauma.[56] However, other definitions have been used such as: ISS >15 or death within 24 hours,[61] at least one injury AIS ≥3,[62] ISS >15 or death following trauma; an intensive care unit stay of longer than 24 hours requiring mechanical ventilation or urgent surgery.[63]

2.11 Trauma Systems and Western Australia

The following discussion of the characteristics of Western Australia, the trauma systems and the components of these systems specific to the setting of this study, set the scene for the subsequent description of the epidemiology of trauma attended by EMS in Chapter 3.

Geography and Demography of Western Australia

Western Australia (WA) is the largest state in Australia [64] with a land mass of 2,529,875km^2 and with more than 12,500 kilometres of coastline.[65, 66] During the study period WA had a population of more than 2.5 million.[64] The median age for the state was 36.1 years with females having a higher median age of 36.8 years than males at 35.4 years.[64] Persons over the age of 65 made up 13% of the state's population.[67]

Geography and Demography of Metropolitan Perth

The metropolitan area of Perth, the capital of WA, spans more than 6000km^2, the boundaries of which are defined by the Australian Bureau of Statistics.[68, 69] During the study period, the metropolitan area of Perth had a population of over two million which was 78% of the state's population.[64] The median age of persons living in the metropolitan area was 35.7 years [64] and of WA residents over 65 years of age, 79% were living in the Perth metropolitan area.[67]

St John Western Australia (SJ-WA)

SJ-WA, previously known as St John Ambulance Western Australia (SJA-WA), is a charitable, non-profit, humanitarian organisation and is contracted by the WA Department of Health to be the sole provider of emergency ambulance services within the state of WA.[70] WA is the world's largest area covered by a sole ambulance service provider.[71] In 2013/2014 SJ-WA responded to more than 255,000 ambulance cases across the state, increasing to more than 289,000 in 2015/2016.[70, 72] SJ-WA is also the leading provider of first aid training in WA. In addition to this SJ-WA also provides event health services and medical services, primary health services, patient transfer services, the community first responder system and first aid training to school students.[70]

SJ-WA Prehospital Care - Clinical Practice Guidelines

The extent and standard of the clinical care practised by staff within SJ-WA is established through the provision of the clinical practice guidelines. The delivery of patient care in accordance with these guidelines is covered by the organisation's 'Professional Indemnity' insurance policy.[73] These clinical practice guidelines represent a multidisciplinary consensus view of what is deemed to be the most appropriate management of a particular condition or clinical situation.[74] Clinical staff are only permitted to use those clinical practice guidelines for which they have been trained and authorised by SJ-WA unless approved by an Ambulance Service Medical Advisor.[73]

SJ-WA Prehospital Care

Prehospital care is undertaken within SJ-WA by a variety of health care professionals in many differing roles and locations, with varying responsibilities, guided by the aforementioned clinical practice guidelines.[73] In some regional areas, ambulances are staffed by volunteer ambulance officers. These staff members are authorised to undertake specific skills and equipment usage. These include, but are not limited to, administration of aspirin, glyceryl trinitrate, salbutamol and ondansetron and use of an automated external defibrillator (AED). Volunteer ambulance officers are authorised to practise under the specific volunteer ambulance officers clinical practice guidelines as published by SJ-WA to the level appropriate to their level of clinical training.[75]

During the study period, paramedics employed by SJ-WA were authorised to perform advanced-life support skills including, but not limited to, endotracheal intubation, cricothyroidotomy, needle thoracentesis/thoracocentesis (in cardiac arrest only) manual defibrillation and administration of medications such as adrenaline, fentanyl, midazolam and ketamine. Paramedics were not permitted to perform rapid sequence induction (drug-assisted endotracheal intubation).[73] Until 2004 paramedics were trained 'in house' by SJ-WA. Since then, it has been a requirement to undertake a three-year undergraduate degree in paramedical studies prior to gaining employment or during supervised employment with SJ-WA. However, experienced paramedics without undergraduate academic degrees from other Australian states or overseas are sporadically employed. Staff undertaking their paramedic training with SJ-WA are referred to as ambulance officers and are authorised to practise within the role-specific clinical practice guidelines and skills as published by SJ-WA under the supervision of a senior paramedic.[73]

In December 2018 paramedicine became a registered profession and the titles 'paramedic' and 'paramedicine' became protected by law and only those registered with the Australian Health Practitioner Regulation Agency are now permitted to refer to themselves as a paramedic.[76]

SJ-WA Prehospital Care – Specialist Roles

Within SJ-WA, paramedics may undertake specialist roles such as critical care paramedic, industrial paramedic, special operations, community or clinical support and these roles are defined within the role-specific clinical practice guidelines and skills as published by SJ-WA. Such authority to practise applies only when directly engaged in undertaking these specialist paramedic roles as designated by SJ-WA.[73]

Critical Care Paramedics

SJ-WA is contracted to provide critical care paramedics to the HEMS, owned by the Department of Fire and Emergency Services.

One or more of the following must be confirmed for helicopter attendance:[77]

- High mechanism of injury.
- Where access or extrication of a patient is required from difficult terrain which could delay patient treatment or transfer.
- Confirmation of entrapment.
- Obvious fractures or significant polytrauma.
- Loss of consciousness.
- Airway compromise.
- Breathing difficulties/issues evident.
- Circulatory compromise.
- Severe burns.
- Probable spinal injury
- Paediatric patient requiring advanced care.

In accordance with the specific clinical practice guidelines, critical care paramedics, whilst operating in a HEMS role, can provide skills and medications other than those permitted for paramedic usage. Some of these include: non-invasive pacing, rapid sequence induction, naso/orogastric tube insertion, finger thoracostomy and administration of packed red cells. Critical care paramedics are not permitted to undertake rapid sequence induction whilst working on road ambulances.[73]

In the metropolitan area HEMS use is restricted to:[78]

- Rescue requirements – where the access or extrication of a patient is required from difficult terrain which could possibly delay patient treatment or transfer.
- Beacon search is required.
- Requested by Department of Fire and Emergency Services.

Clinical Support Paramedic

Clinical support paramedics provide clinical leadership, support and mentoring for ambulance personnel as well as performing clinical audits, undertaking the development and review of clinical practice guidelines, skills and clinical equipment. Clinical support paramedics also respond to emergency calls to provide additional clinical support or as a first responder.[79] They are also required to work in the State Operations Centre as the senior clinician. Although clinical support paramedics adhere to the same clinical practice guidelines as paramedics, they also carry specialised equipment such as the Lund University Cardiac Arrest System (LUCAS) mechanical chest compression device, Kendrick Extrication Device (KED) and specialised lifting equipment.[79]

Area Manager

Area managers operate within specific areas of the metropolitan region. Their role is to provide the necessary leadership for on-road staff to ensure the delivery of a high-quality ambulance service to patients.[79] There is no requirement for area managers to be practising paramedics, however, they are required to provide additional support or as a first responder.[79] Area managers also carry the LUCAS mechanical chest compression device, the KED and specialised lifting equipment.[79]

SJ-WA Delivery of Prehospital Care

In the 2015/2016 financial year, there were 173 ambulance stations and 533 ambulance vehicles across the state of WA.[72] In the non-metropolitan area there were 144 regional ambulance stations, many of these solely staffed by volunteer ambulance officers, while others were a mix of volunteer ambulance officers and career paramedics.[72] Ambulance crews, which were comprised of at least one paramedic, were responsible for attending 93 percent of ambulance calls outside of the Perth metropolitan area in the 2015/2016 financial year.[72] In the same financial year, the helicopter, staffed by critical care paramedics, undertook more than 600 retrievals.[72]

Ambulance depots (stations) are located throughout the metropolitan area of Perth and in 2015/2016 there were 29 of these and 141 ambulance vehicles.[72] At the time of the study, each ambulance in the metropolitan area was staffed with at least one paramedic and a second crew member who was either a paramedic or an ambulance officer. All metropolitan ambulance crews had the capacity to provide advanced life-support, excluding rapid sequence induction.[73] In addition to ambulances, SJ-WA had sole responders in emergency vehicles which do not have the ability to transport patients. These vehicles were generally staffed with area managers or clinical support paramedics.

Prehospital Triage in Western Australia - Dispatch

EMS dispatch for all of WA, including the metropolitan area of Perth, is managed from the State Operations Centre located in Belmont, Perth. The Medical Priority Dispatch System (MPDS) is used by SJ-WA to categorise (and subsequently prioritise) emergency calls (000 calls) for dispatch.[36] The SJ-WA State Operations Centre assigns an ambulance response priority from one to three [70] and these priorities differ in target response times and response driving conditions.

A Priority 1 is assigned to the highest acuity cases which are perceived to be the most time-critical. In the metropolitan area, a Priority 1 should have an emergency vehicle arriving on scene within 15 minutes of receiving the dispatch instruction from the State Operations Centre.[72] In both rural and metropolitan areas the responding vehicle is permitted to drive under emergency conditions using ‘lights and sirens’.[70] Priority 2 is assigned to urgent but non-emergency conditions and an emergency vehicle should arrive on scene within 25 minutes of the call being received in the metropolitan area.[72] A Priority 3 response is assigned to non-urgent, low acuity cases and these should be attended within 60 minutes in the metropolitan area.[72] Priority 2 and below are responded to at normal road speeds in both rural and metropolitan areas. In the 2015/2016 financial year, in the metropolitan area, 93 percent of Priority 1 cases were responded to within the 15-minute target. For Priority 2 cases, 90.1 percent of callouts were within 25 minutes and Priority 3 callouts achieved a 94.3 percent attendance rate within 60 minutes.[72]

On receipt of an emergency call, if it is suspected that the patient has suffered a cardiac arrest (the cessation of cardiac mechanical activity as confirmed by the absence of signs of circulation)[80] the State Operations Centre dispatches two ambulance vehicles. The ambulance that arrives first on the scene is termed the ‘primary’ crew and the ambulance that arrives second is referred to as the ‘backup’.[81] In addition to this, in the metropolitan area, a clinical support paramedic or area manager is also dispatched to provide additional support and the LUCAS device. In the circumstance where a patient is thought to have severe injuries or where there is thought to be multiple patients with serious injuries, the State Operations Centre may dispatch more than one ambulance and/or additional support provided by a clinical support paramedic or area manager in an emergency vehicle. Similarly, 'backup' ambulance crews can be requested by the 'primary' attending crew on arrival at the scene for assistance with patient treatment, extrication or in situations where there are multiple patients requiring treatment. Multiple ambulance responses are also routinely sent to declared aircraft emergencies.[81] The dispatch of more than one ambulance response in rural areas is dependent on the availability of resources within that rural area.[81]

When an ambulance or emergency vehicle is dispatched to an emergency call, all the information gathered relating to the emergency call (000 call) are sent to the responding vehicle(s) and appear on a screen called an AMBICAD. The AMBICAD also provides satellite navigation, a global positioning system and a duress alarm.

Emergency Driving

There are four situations in which appropriately trained SJ-WA staff are permitted to drive under emergency conditions ('lights and sirens'). These are: (1) responding to a Priority 1 call as directed by the State Operations Centre (as discussed above), (2) conveying a patient requiring immediate care to a hospital (discussed in the *transport* section below), (3) transporting special equipment or personnel and (4) responding to an incident to provide logistical or managerial support (e.g. clinical support paramedic or area manager).[82]

When driving under emergency conditions the warning lights fitted to the vehicle are required to be switched on, in addition, the audible warning device (siren) is required to have been activated.[82] However, the siren could be turned off if the vehicle driver deemed it safe and appropriate to do so.[82] When driving under emergency conditions, appropriately trained staff are permitted to travel above the gazetted speed limit. However, this is required to be undertaken in a safe manner, and SJ-WA vehicles are not permitted to travel at greater than 40km/h above the gazetted speed limit.[82] An exception to this is when travelling during times of operation of a school zone. In this situation, the maximum permitted speed is 40km/h.[82]

When at a controlled intersection and the red light is displayed, or at an intersection controlled by a stop sign, the visual warning devices are required to be operating.[82] On approach to the intersection, the maximum permitted speed is 5km/h. Once the intersection is deemed safe, it is permitted to cross at the maximum speed of 40km/h.[82] SJ-WA vehicles driving under emergency conditions are not permitted to traverse a level crossing until the boom gates are vertical and the lights have stopped flashing, unless under the direction of an employee of the railway authority.[82]

Patient Care Records

SJ-WA paramedics, ambulance officers and volunteer ambulance officers are required to complete a patient care record (PCR) for every patient who is attended to by SJ-WA.[73, 83] These records are completed electronically via an iOS 'app' (an operating system created by Apple Inc.) using an iPad. These electronic PCRs are known as ePCRs. In the circumstance where there is an electronic failure, a paper PCR is completed.[73, 83] The PCR and ePCR are confidential, legal documents that can be used in a court of law to provide evidence of care provided to a patient. The document should be completed whilst the patient is being attended to, or shortly afterwards. A copy should then be provided to the receiving hospital after handover, either in electronic or paper format.[73, 83]

The PCR and ePCR reflect all relevant information pertaining to the treatment of an individual patient.[73, 83] The PCR or ePCR is completed by the paramedic or ambulance officer who is attending to the patient and providing the majority of the care.[73, 83] The attending 'backup' ambulance crew(s) are also required to complete a PCR/ePCR for each patient they attend, however, the majority of pertinent information should be contained in the 'primary' attending ambulance crew's documentation. Similarly, the area manager or clinical support paramedic are also required to complete documentation whether they are the first response or attending as additional support.

For the 'primary' attending crew, there is a minimum requirement to document the following vital signs: Glasgow Coma Scale scores, respiration rate, pulse and blood pressure and where appropriate, pain scores, blood glucose levels, end-tidal carbon dioxide ($EtC0_2$), and oxygen saturation.[73, 83] Information pertaining to interventions, medications and skills performed is captured by using specific tick boxes which, when entered on the ePCR, create unique numerical codes. Relevant information that could not be recorded by the tick boxes is entered in the free text section.[73, 83] This section could include background of events preceding the emergency call and other pertinent information.

When completing the PCR or ePCR, a 'problem code' that describes the patient's condition or mechanism of injury must be entered. This code should reflect the condition that required the majority of treatment and that had the most severe consequences for the patient.[73, 83] A list of ‘problem codes’ can be found in Thesis Appendix C.

Patients who are transported to hospital are also required to have an appropriate ‘problem urgency’ allocated on their ePCR. This refers to the acuity level of their presenting condition, as determined by the attending paramedics. Assessment of the patient’s condition acuity level is undertaken using a five-point ordinal scale based on the Australian Triage Scale and this refers to both the time that treatment is required to start on arrival at the hospital and the driving conditions that the patient is to be transported under (discussed further in the following section). The ‘problem urgencies’ are as follows: 1 (immediate or imminent life-threat), 2 (to be treated at hospital within 10 minutes), 3 (to be treated within 30 minutes), 4 (to be treated within 60 minutes) and 5 (to be treated within 120 minutes).[73, 84]

For each PCR or ePCR a ‘transport destination’ is entered, either written or by completing a tick box. For a patient who is transported to hospital, the hospital name is recorded. For those patients treated but not transported, a code is entered. In cases where multiple crews attend one patient, or a clinical support paramedic or area manager is in attendance, the ‘transport destination’, for those who are not transporting the patient, is recorded as ‘back up’.

Transport

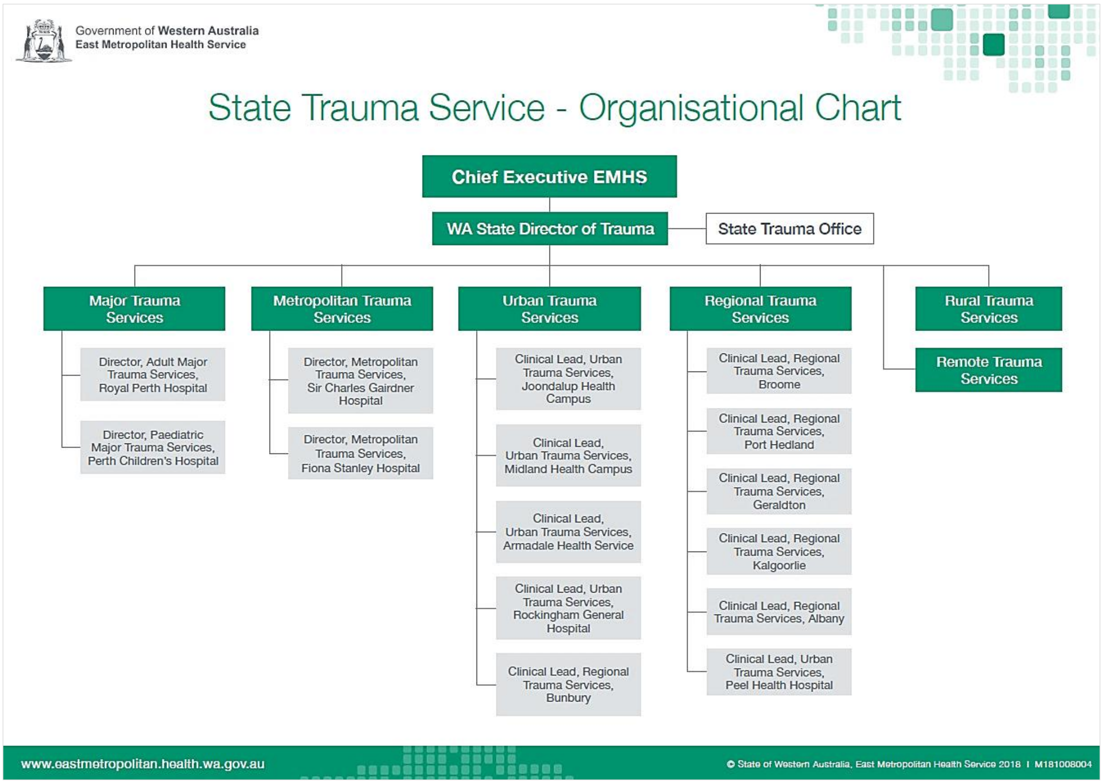
When transporting a patient to hospital, if the patient’s condition is deemed time-critical by the attending paramedics or ambulance officer, the patient is allocated a ‘problem urgency’ 1 or Priority 1. This means that the patient will be transported to hospital using ‘lights and sirens’. Patients allocated a ‘problem urgency’ other than Priority 1, are conveyed to hospital at normal road speed.[36, 82] Priority 1 transport to hospital is the only level of patient transfer that allows the use of lights and sirens and is only used for immediately life-threatening emergencies.[36, 82]

Hospital Destination

The WA State Trauma Service is made up of six streams which are comprised of major trauma services, metropolitan trauma services, urban trauma services, regional trauma services, rural trauma services and remote trauma services. The State Trauma Office governs the WA State Trauma Service and is comprised of the State Director for Trauma Services, State Trauma Programme Manager and a Senior Project Officer. The State

Trauma Office reports to the Chief Executive East Metropolitan Health Service, Executive Sponsor for State Trauma.[85]

Figure 1 State Trauma Service organisational chart.[86]



EMHS – East Metropolitan Health Service.

Trauma patients who were transported to hospital in the metropolitan area of Perth, during the study period, were transported to one of ten hospitals: four tertiary and six secondary hospitals. There are only two tertiary hospitals in the state with the staff and resources for managing major trauma. For patients 14 years and older, this is Royal Perth Hospital and for those under 14 years, the paediatric tertiary hospital, Princess Margaret Hospital which was replaced in 2018 by the Perth Children's Hospital.[87, 88] In 2009 Royal Perth Hospital was designated the State Adult Major Trauma Centre with the Royal Australasian College of Surgeons Level I Major Trauma Verification Status.[87, 88] During the study period Royal Perth Hospital admitted approximately 5,000 trauma patients annually, with 700 of those being major trauma patients, approximately 80% of the state's major trauma.[88] The other two tertiary hospitals are Level II Trauma Centres which can provide services and inpatient management for a limited number of adult major trauma patients, upon agreement with the State Adult Major Trauma Centre if the patient's injuries are not considered severe enough to warrant transfer to the State Adult Major Trauma Centre.[87]

These are Sir Charles Gairdner Hospital and Fremantle Hospital which was replaced by Fiona Stanley Hospital in 2013. The five secondary hospitals and one private hospital can provide definitive care for non-major trauma.[87]

These are:

- Joondalup Health Campus.
- Swan District Hospital (replaced by St John of God Midland in 2015).
- Peel Health Campus.
- Rockingham General Hospital.
- Armadale-Kelmscott Memorial Hospital.
- St John of God Murdoch (private).

During the study period the only hospitals with neurosurgery capabilities were Royal Perth Hospital, Sir Charles Gairdner Hospital and Princess Margaret Hospital.[89] Royal Perth Hospital was the only tertiary hospital that undertook neurosurgery on adult patients with trauma and Sir Charles Gairdner Hospital was the only tertiary hospital that undertook neurosurgery on adult patients with conditions of non-traumatic aetiology. For paediatric patients the paediatric tertiary hospital, Princess Margaret Hospital (replaced in 2018 by the Perth Children's Hospital) provided neurosurgery for both conditions of a traumatic and non-traumatic aetiology.[89] All hospitals had the capacity to care for older adults without major trauma or requirement for specific medical specialities.[90]

During the study period, it was recommended by the WA Department of Health, that major trauma patients (defined as any injury that has the potential to cause prolonged disability or death), be transported directly to Royal Perth Hospital for those ≥14 years and Princess Margaret Hospital for those <14 years.[73, 87] As an ISS >15 is a retrospective diagnosis of major trauma, made using information that is not available prehospital, for example, results from imaging, the SJ-WA clinical practice guideline – (1.1E major trauma guideline implemented in 2012 -Thesis Appendix D) lists situations when direct transport should be considered.[73] These situations include mechanism of injuries and anatomical criteria, however, no physiological criteria are included in the guideline. These situations are:

Mechanism of Injury:

- Motorbike crash >30km/h with injuries.
- Motor vehicle crash >60km/h with injuries.
- Fall >3m.
- Pedestrian or cyclist with speed impact >25km/h.
- Ejection from vehicle.
- Fatality on scene whereby the patient was in the same vehicle.

or…Anatomical:

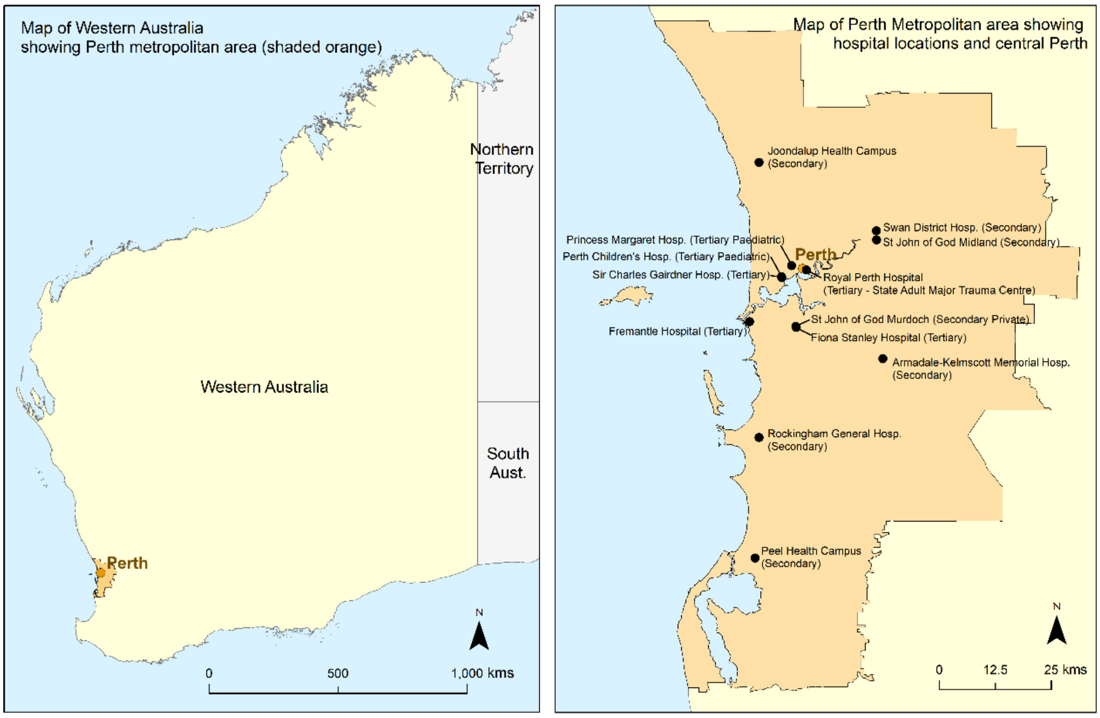
- Penetrating injury to head, neck, torso or proximal extremities.
- Flail chest.
- Pelvic fractures.
- Amputation/crush injury proximal to hand and foot.
- Two or more long bone fractures.
- Suspected spinal injury.
- Polytrauma.
- Open or depressed skull fractures.
- De-gloving or mangled extremity proximal to hand and foot.

In the situation where there was an immediate or imminent life-threat, paramedics and ambulance officers were permitted to divert to the nearest emergency department for patient stabilisation.[73, 87] It was then recommended that the patient should be prepared for rapid and early inter-hospital transfer to Royal Perth Hospital or Princess Margaret Hospital depending on age.[91]

Trauma patients who were deemed to be low-acuity were also transported to a surge capacity unit that was available for low-acuity patients at peak periods of emergency department utilisation.[73] Patients would then be either discharged, admitted directly to a hospital ward or transported to an emergency department when activity levels were lower.[73] This unit is no longer in operation.

Hospital Locations

Figure 2 Map of Western Australia – Including Perth metropolitan area and hospital locations.



Source: Aust Bureau of Statistics 2016 shapefile for Great Capital City Statistical Areas

Referral Pathways

Silver Chain provides in-home health and aged care in WA. When attending patients with low acuity injuries in the metropolitan area, paramedics and ambulance officers can refer these patients to Silver Chain, for acute wound assessments. The purpose of the referral system is to facilitate patient treatment in their home (or residential care facility) in preference to being treated in an emergency department.[73] If accepted, the patient is seen by a nurse with advanced assessment skills within 4 hours of being contacted by SJ-WA paramedics.[73] When referring patients to this service it is required that this is documented on the PCR or ePCR.

During the study period, in some situations, where the paramedic or ambulance officers deemed the presenting condition to be suitable for management by a general practitioner in the patient's home, the patient could be referred to a service called 'Dial-a-Doctor'.[92] Hours of operation were between 18.00-24.00 Monday to Friday, Saturday 12.00-24.00 and Sunday 07.00-24.00.[92] This service was only available within certain suburbs of the metropolitan area. When referring patients to this service, it was required that this was documented on the PCR or ePCR. This referral service is no longer available.

Assessed and Discharged on Scene

In some circumstances, a patient may refuse transport to further care or the patient is provided with treatment at the scene and transport is not indicated or needed. Patients of adult age have the ability to choose if they wished to receive medical treatment provided by SJ-WA, except in cases of emergency or necessity.[83] In the situation where the patient refuses either treatment, transportation for further care or referral to other services, a specific section of the PCR or ePCR is completed.

The decision to refuse further care must be (1) voluntary - made by the patient in the absence of influence or coercion, (2) informed, the patient must be aware of the consequences and potential risks involved, (3) relevant to the treatment that has been recommended, (4) the patient must demonstrate that they have the capacity to understand the consequence(s) of the decision to refuse and (5) the patient must be provided with advice or recommendations to promote comfort and safety.[83] It is a requirement for paramedics and ambulance officers to record the patient's destination on the PCR or ePCR by either using the 'transport destination' tick box or manually recording the destination. Destination options include all hospitals, the referral pathways, assessed and discharged on the scene or that the attendance to the patient / scene was as a 'back up' resource.

Prehospital Times

The date and time of each emergency call (000 call) are recorded by the State Operations Centre. The time that the call is dispatched to the responding ambulance or emergency vehicle is also recorded. On arrival at the scene of an incident, all ambulance or emergency vehicles are required to acknowledge that they have arrived by pressing a button on the AMBICAD known as a '79'. This time is then automatically recorded at the State Operations Centre. When the ambulance departs the scene of the incident another button, '80' is pushed and on arrival at hospital the '81' button indicates that the ambulance has arrived at its destination. All of these times are recorded by the State Operations Centre.

2.12 Summary

By providing an overview of trauma, trauma systems the components of these systems and the trauma systems specific to the setting of this study this chapter has set the scene for the subsequent description of the epidemiology of trauma attended by a paramedic staffed EMS. The mechanisms of injury and the coding of injury severity have been discussed and how these codes are used to define major trauma explained. Details of the levels and capabilities of trauma systems have been provided and discussed specifically in relation to the context of this study. Furthermore, an overview of WA and the trauma system specific to this region have been provided and explored.

Chapter 3 Epidemiology of Trauma – Methodology

This chapter describes the methodology used to undertake the first study of this PhD research.

3.1 Rationale

The key aim of this PhD research is to describe the epidemiology of trauma attended by a paramedic staffed EMS in a metropolitan area and to determine the association between prehospital factors and survival outcomes. Prior to investigating the specific prehospital factors that influence trauma patient outcomes, it was important to gain an understanding of the population-based incidence and mortality trends and characteristics of these patients.

Evaluating the mortality and morbidity resulting only from major cases will underestimate the total burden of injury on resources.[93] Furthermore, including all trauma patients, without limiting to only those severely injured, allows for the investigation of workload and complexity of patients attended by EMS. This, in turn, will have implications for current and future development of EMS specific to the region studied.

The research aim was:

> To describe the characteristics of adult patients with trauma, attended EMS, including prehospital deaths.

The specific objectives were:

- To undertake a retrospective cohort study of all adult trauma patients attended by EMS.
- To describe trauma incidence and mortality rates and their trends.
- To compare the characteristics of patients between those who survived 30-days and those who died.
- To report the interventions performed by ambulance paramedics.

3.2 Study Design

To achieve the aim of describing the epidemiology of trauma attended by paramedics, a retrospective cohort study was undertaken. The study included all trauma patients aged ≥16 years attended by SJ-WA in greater metropolitan Perth, WA between 1 January 2013 and 31 December 2016. This study has been published and is presented in Chapter 4. The details below are an extension of the methodology used to undertake the study.

3.3 Study Setting

The study setting was fully described in Chapter 2, Section 2.11.

3.4 Inclusion Criteria

All trauma patients aged ≥16 years who were attended by SJ-WA paramedics in greater metropolitan Perth, WA between 1 January 2013 and 31 December 2016 were included in the retrospective cohort study. These patients were either transported to hospital, referred to other medical services (dial a doctor and Silver Chain), discharged alive on scene or recognised as deceased prehospital. Only the initial episode of care was included and not any subsequent inter-hospital transfer. In the case of multiple emergency vehicle attendance to the same patient for the same incident, the data from the 'primary' attending ambulance crew was included.

3.5 Exclusion Criteria

Similar to studies conducted elsewhere,[94-96] cases involving drowning, hanging or poisoning were excluded, which is consistent with the definition of physical trauma 'as a body wound produced by sudden physical injury from impact, violence or accident'.[6] Also excluded were cases that were missing key demographic and clinical data on the ePCR. Patients injured in rural areas were not included in the study. As the helicopter does not routinely operate in the metropolitan area, patients attended to by critical care paramedics working on the helicopter were not included.

3.6 Data Sources

Two data sources were used for this study: the SJ-WA database and the WA death data.

Computer-Aided Dispatch (CAD) System Database

The computer-aided dispatch (CAD) system database contains geographical and operational information collected by the State Operations Centre for each emergency call that was received.[97] This information included: the date, the location of the incidence and important times.[97]

Times recorded in the database included:

- When the emergency call was received.
- When the ambulance or emergency vehicle was dispatched.
- When the ambulance or emergency vehicle arrived on-scene.
- When the ambulance departed the scene when transporting a patient to hospital.
- When the ambulance arrived at the hospital destination.

For each ambulance or emergency vehicle dispatched to an emergency call, the CAD system database creates a unique 'case number'. To link multiple ambulances or emergency vehicles attending the same patient or multiple patients at the same scene, the system creates an 'incident number'.

SJ-WA Database

The SJ-WA database contains data from the ePCR together with data from the CAD system database, which forms a single record for each unique 'case number'.

WA Death Data

The WA Registry of Births, Deaths and Marriages has an agreement with The Prehospital Resuscitation and Emergency Care Research Unit (PRECRU), Faculty of Health Sciences Curtin University to supply confidential death information for the purpose of data cleaning, public health and medical research purposes. These data were used to identify patient deaths. If there was no record of the patient in the WA Death Registry then the patient was assumed to be alive.

Identification of Patients Meeting Inclusion Criteria

Trauma patients were identified in the SJ-WA data as those who had received a paramedic-allocated 'problem code' that indicated a mechanism of injury i.e. injuries in the home, motor vehicle crashes (MVCs – referred to as a motor vehicle accident [MVA] 'problem code'), violence (assaults, shootings, stabbings), sexual assault, burns/electric shock/industrial and other/unspecified on their ePCR (Thesis Appendix C). These codes indicated that the patient's main presenting complaint was that of a traumatic origin. These cases were then limited to the metropolitan area by use of postcodes to depict the boundaries defined by the Australian Bureau of Statistics.[68, 69] Due to data privacy regulations this extraction was undertaken by Dr Teresa Williams (PhD Supervisor).

Data Linkage

Probabilistic or deterministic linkage was used to combine the WA death data and the SJ-WA database to identify the same individuals. Date of birth, first and last names and residential address were used as key identifiers [98] to create a likelihood score indicating a correct link between the databases (FRIL ver.2.1.5, Emory University and Centers for Disease Control and Prevention, Atlanta, Georgia, U.S.). Links were manually checked if the score was close to a predetermined cut-off value. Linkage failure occurred if the information was missing in the SJ-WA database (e.g., name, date of birth). This method has previously been reported to be 96.3% successful in correctly linking records.[30]

The linking of the WA death data and the SJ-WA database was undertaken by Dr Hideo Tohira (PhD Supervisor), due to data privacy regulations. If a date of death was recorded for a patient who had more than one ambulance attendance during the study period, a unique number was allocated to each patient to prevent these deaths from being counted more than once. De-identified data were then provided, including the removal of the patient's name, residential address and other contact details from the ePCR data. Further to this, the personal identification numbers for the attending ambulance crews were also removed from the data.

Data Cleansing

Using the 'incident' number recorded in the SJ-WA database, cases were grouped together that pertained to the same patient or multiple patients at the same scene. Using the 'transport destination' code enabled the identification of which 'case number' referred to 'backup' ambulances and which 'case numbers' pertained to the 'primary' attending/transporting crew. It was then possible to ascertain which 'case numbers' pertained to each individual patient.

Patient characteristics including age, sex and interventions undertaken using the unique numerical codes created by the tick boxes, were extracted from the 'primary' attending crews' record. Syntax was created to examine the free text fields for further interventions not recorded in the tick boxes. Using the same method, 'backup' ambulance ePCR data were examined to ascertain if there was any additional information not noted in the 'primary' attending crews' record. Any additional information identified was then added to the 'primary' attending crew record and other records were then excluded to ensure that the patient was not inadvertently double-counted. As there were fewer than five patients in some groups confidentiality was maintained by merging of the groups. The groups that were merged were as follows; 'sporting and recreational' incidents were merged into trauma 'other/unspecified' and 'sexual assaults' were combined with 'assault'.

The paramedic allocated 'problem urgency' was used as a measure of patient acuity. Low-acuity patients were defined as those with acuity level /'problem urgency' levels 3 to 5 [99, 100] and the highest level was acuity level /'problem urgency' level 1 or Priority 1. If a date of death was recorded for a patient who had more than one incident resulting in an ambulance(s) attendance during the study period, the last date of ambulance attendance was used to calculate if the death occurred within 30-days.

3.7 Statistical Analysis

The primary outcome of interest was death within 30-days post-injury (30-day mortality). Univariate descriptive statistics were used to describe the cohort, including medians with IQR for continuous variables and counts and percentages for categorical variables. Crude age-specific incidence rates, mortality rates (defined as death within 30-days) were derived for the study cohort. Trends in these figures across the calendar years 2013 to 2016 were compared using the Cochran-Armitage test. Crude incidence rates per 100,000 population were calculated, using the 2014-16 Australian Bureau of Statistics census data for Perth, WA.[67] As the study excluded cases with age <16 years, the population data for those aged 15 to 19 years was adjusted by multiplying the data by 0.8 to reflect a 16 to 19 years age group, assuming an equal distribution of age.

Patient age, sex, mechanism of injury and acuity level were compared between those who died prehospital (immediate deaths), the day of injury (early deaths), within 30-days (late deaths) and those who survived longer than 30-days (survivors), using Kruskal-Wallis tests or Pearson chi-square tests. Interventions provided to patients, except those discharged alive on the scene were reported. Data analysis was performed with IBM Statistical Package for Social Sciences (SPSS) Version 24.0 (IBM, Armonk, NY, USA). A p-value <0.05 was considered statistically significant.

Chapter 4 Epidemiology of Trauma

4.1 Overview

To achieve the aim of describing the epidemiology of trauma, a retrospective cohort study was undertaken of all trauma patients aged ≥16 years attended by SJ-WA paramedics in greater metropolitan Perth, WA between 1 January 2013 and 31 December 2016. The specific objectives of this study were: (1) to describe the trauma incidence and mortality rates and their trends across calendar years, (2) to compare the characteristics of patients between those who died at the scene, those who died on the day of injury, those who died within 30-days of the event and those who survived 30-days and (3) to report the interventions performed by paramedics.

The findings of this study are reported in the following manuscript.

Brown E, Williams T, Tohira H, Bailey P, Finn J. Epidemiology of Trauma Patients Attended by Ambulance Paramedics in Perth, Western Australia. Emergency Medicine Australasia. 2018;30(6):827-833.

Permission to include the manuscript in this thesis has been obtained from John Wiley and Sons and a copy of the License Agreement is included in Thesis Appendix E.

EMA Emergency Medicine Australasia

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PREHOSPITAL AND RETRIEVAL MEDICINE

Epidemiology of trauma patients attended by ambulance paramedics in Perth, Western Australia

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Abstract

Objective: The aim of the study was to describe the epidemiology of trauma in adult patients attended by ambulance paramedics in Perth, Western Australia.

Methods: A retrospective cohort study of trauma patients aged ≥16 years attended by St John Ambulance Western Australia (SJA-WA) paramedics in greater metropolitan Perth between 2013 and 2016 using the SJA-WA database and WA death data. Incidence and 30 day mortality rates were calculated. Patients who died prehospital (immediate deaths), on the day of injury (early deaths), within 30 days (late deaths) and those who survived longer than 30 days (survivors) were compared for age, sex, mechanism of injury and acuity level. Prehospital interventions were also reported.

Results: Overall, 97 724 cases were included. A statistically significant increase in the incidence rate occurred over the study period (from 1466 to 1623 per 100 000 population year $P \leq 0.001$). There were 2183 deaths within 30 days (n = 2183/97 724, 2.2%). Motor vehicle accidents were responsible for most immediate and early deaths (n = 98/203, 48.3% and n = 72/156, 46.2%, respectively). The majority of transported patients were low acuity (acuity levels 3 to 5, n = 60 594/79 887, 75.8%) and high-acuity patients accounted for 2.7% (n = 2176/79 997). Analgesia administration was the most frequently performed intervention (n = 32 333/80 643, 40.1%), followed by insertion of intravenous catheters (n = 25 060/80 643, 31.1%). Advanced life support interventions such as endotracheal intubation were performed in <1% of patients.

Conclusion: The trauma incidence rate increased over time and the majority of patients had low-acuity injuries. Focusing research, training and resources solely on high-acuity patients will not cater for the needs of the majority of patients.

Key words: *ambulance, epidemiology, incidence, paramedics, trauma.*

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Key findings

- The trauma incidence rate increased over time, with the highest incidence in the ≥85 years age group.
- The majority of transported patients (75.8%) had low-acuity injuries.
- High-acuity patients accounted for <3% of trauma cases with advanced life support performed on <1% of patients.

Introduction

Injury is a significant cause of preventable mortality and morbidity in both developed and developing countries.[1,2] As well as potentially imposing significant disabilities on individuals of all ages both physically and psychologically, injuries can cause loss of potential years of life and the economic implications can be high.[1,3,4] Trauma systems have been developed to improve patient outcomes and reduce the burden on society.[5] These systems provide a multidisciplinary care strategy for seriously injured patients.[6] The first step in the trauma system is prehospital care, which in metropolitan Australia is commonly delivered by paramedics. The prevention of further injury, initiation of resuscitation and timely transport to an appropriate hospital facility are key objectives of the prehospital phase.[6]

Epidemiological trauma studies often exclude patients who died prehospital or are dead on arrival at hospital and are often restricted to major trauma.[2,7,8] Gaining an understanding of the epidemiology of trauma and paramedic management of injuries, may help inform clinical practice, enable better tailoring of paramedic education and improve patient outcomes.

The aim of this study was to describe the epidemiology of trauma attended by paramedics in greater metropolitan Perth, Western Australia (WA). The specific objectives were to describe the trauma incidence and mortality rates and their trends, to compare the characteristics of patients between those who died at the scene, those who died on the day of injury, those who died within 30 days of the event and those who survived 30 days and to report the interventions performed by paramedics.

Methods

Design, setting and population

A retrospective cohort study of all trauma patients aged ≥16 years attended by St John Ambulance WA (SJA-WA) paramedics was undertaken in greater metropolitan Perth, WA between 1 January 2013 and 31 December 2016. Perth is the capital city of WA and has a population of over 2 million, 78% of the state's population.[9] SJA-WA is a single tier ambulance service and the sole provider of emergency road ambulances in Perth. Within the metropolitan area, ambulances are staffed by paramedics who provide prehospital care (including advanced life support), guided by Clinical Practice Guidelines.[10] Advanced life support skills include, but are not limited to: endotracheal intubation (non-rapid sequence), medication administration through vascular access and manual defibrillation.[10]

All patients ≥16 years with trauma who were either transported to hospital, referred to other medical services (general practitioner or nursing services), discharged alive on scene or recognised as deceased prehospital were included in the study. Only the initial episode of care (and not any transfer) was included. In the case of multiple emergency vehicle attendance to the same patient for the same incident, we included the data from the primary attending ambulance. Similar to studies conducted elsewhere,[11–13] cases involving drowning, hanging or poisoning were excluded, which is consistent with the definition of physical trauma 'as a body wound produced by sudden physical injury from impact, violence or accident'.[14] Cases that were missing key demographic and clinical data on the electronic patient care record (ePCR) were excluded.

Patients who were transported were taken to one of nine EDs that accepted adult patients with trauma: three tertiary and six secondary hospitals. One of the tertiary hospitals housed the State Major Trauma Centre and had 24/7 trauma facilities.[15] The other two tertiary hospitals provided services for inpatient management of major trauma. The five secondary facilities and one private ED provided definitive care for non-major trauma.[15] A surge capacity unit was available for low-acuity patients at peak periods of ED utilisation.[10]

Data sources

We used two data sources: the SJA-WA database and WA death data. The SJA-WA database contained data from the ePCR, completed for each case by paramedics, which together with data from computer-aided dispatch formed a single record for each episode of care. We defined trauma patients as those who had received a paramedic-allocated mechanism of injury code, that is, injuries in the home, motor vehicle accidents (MVAs), violence (assaults, shootings, stabbings), burns/electric shock/industrial and other/unspecified. These codes indicate that the patient's main presenting complaint was that of a traumatic origin. We used the SJA-WA database to identify these trauma patients. We then extracted patient characteristics including: age, sex, interventions undertaken and acuity level. Free text fields in the ePCR were also examined for these data. Acuity level assessment was undertaken by paramedics using a five-point ordinal scale based on the Australian Triage Scale: 1 (immediate life threat), 2 (to be treated at hospital within 10 min), 3 (to be treated within 30 min), 4 (to be treated within 60 min) and 5 (to be treated within 120 min).[10,16] Low-acuity patients were defined as those with acuity levels 3 to 5.[17,18]

The WA death data, from the Western Australian Registry of Births, Deaths and Marriages was then used to identify patient deaths. Patients were assumed to be alive if they were not recorded in the WA Death Registry. The two data sources were probabilistically or deterministically linked to identify the same individuals. Date of birth, first and last names and residential address were used as key identifiers[19] to create a likelihood score indicating a correct link between the databases (FRIL ver.2.1.5, Emory University and Centers for Disease Control and Prevention, Atlanta, GA, USA). Links were manually checked if the score was close to a predetermined cut-off value. Linkage failure occurred if information was missing in the SJA-WA database (e.g. name, date of birth). This method has previously been reported to be 96.3% successful in correctly linking records.[20]

Data analysis

Descriptive statistics were used to describe the cohort, including medians with interquartile range (IQR) for continuous variables and counts and percentages for categorical variables. We derived crude age-specific incidence rates, mortality rates (defined as death within 30 days) for the study cohort; and trends in these figures were compared across the calendar years 2013 to 2016 using the Cochran–Armitage test. Crude incidence rates were calculated per 100 000 population, using the 2014–2016 Australian Bureau of Statistics (ABS) census data for Perth, WA.[21]

We compared patient age, sex, mechanism of injury and acuity level

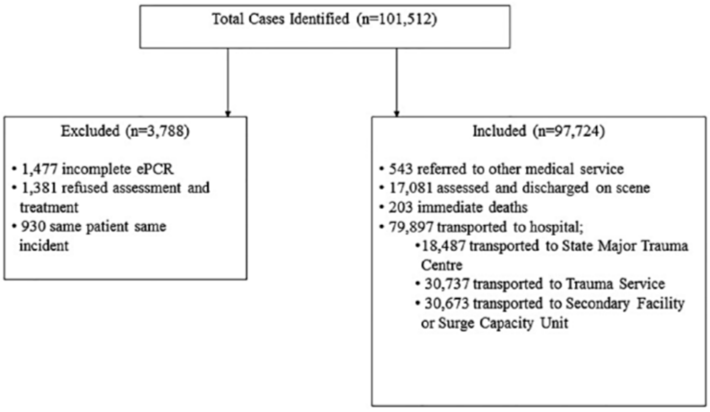

Figure 1. *Flowchart of study cohort.*

between those who died prehospital (immediate deaths), the day of injury (early deaths), within 30 days (late deaths) and those who survived longer than 30 days (survivors) using Kruskal–Wallis tests or Pearson's chi-squared tests. Interventions were reported for patients except those discharged alive on scene. Data analysis was performed with IBM Statistical Package for Social Sciences (SPSS) Version 24.0 (IBM, Armonk, NY, USA). A P-value < 0.05 was considered to be statistically significant.

Ethical approval was obtained for this study as a sub-study of the overarching study, Western Australian Prehospital Record Linkage Project, by the Curtin University Human Research Ethics Committee (HR 128/2013) and approval obtained from the St John Ambulance Research Advisory Group.

Results

During the study period, 97 724 cases met the inclusion criteria, of which 79 897 (81.7%) were transported to a hospital by paramedics (Fig. 1). The median age was 60 years (IQR 34–83 years) and 47 582 (48.7%) patients were male (Table 2).

Incidence of trauma

The number of patients with trauma attended by SJA-WA increased from 23 116 in 2013 to 26 601 in 2016 (Table 1). There was a statistically significant increase in the incidence rate from 1466 to 1623 per 100 000 population-year ($P \leq 0.001$) over the study period, with an increasing trend in incidence rate in patients aged 45 years and over. The highest incidence rate was in the ≥85 years age group with an increase of more than 2300 per 100 000 population-year ($P \leq 0.001$) over the study period.

Patient outcomes

There were 2183 deaths in 30 days (n = 2183/97 724, 2.2%) with mortality in 30 days increasing from 1.8% to 2.7% ($P \leq 0.001$) over the study period (Table 1). MVAs were responsible for the highest proportion of immediate (n = 98/203, 48.3%) and early deaths (n = 72/156, 46.2%) (Table 2). There was a statistically significant difference in median age between the immediate, early and late deaths and the survivors ($P \leq 0.001$) with immediate deaths being the youngest at 38 years (IQR 28–53 years). There were no signs of life detected in the first assessment of 198 (n = 198/203, 97.5%) patients in the immediate death cohort. In the early death cohort, 74 (n = 74/156, 47.4%) had no signs of life on the initial assessment and 70 (n = 70/74, 94.6%) of these still had no signs present on arrival at the ED. Ninety of the early deaths (n = 90/156, 57.7%) arrived at the ED with no life signs.

The majority of transported patients were low acuity (acuity levels 3 to 5, n = 60 594/79 887, 75.8%) with a 30 day mortality of 2.0% (n = 1226/60 594) (Table 2). Patients transported with the highest acuity level accounted for 2.7% (n = 2176/79 997) of the workload with a 30 day mortality rate of 9.5% (n = 206/2176). As shown in Table 2, there were more early and late deaths (n = 20/153, 13.1% and n = 1178/1565, 75.3%) in the acuity level 3 cohort than the acuity level 2 group (n = 11/153, 7.2% and n = 275/1565, 17.6%). Of the 20 early deaths in the acuity level 3 group, the median age was 88.5 years (IQR 79–92 years) and 17 (n = 17/20, 85.0%) patients had a fall from ground level as a cause of their injury described in the free text fields.

Interventions undertaken

The administration of analgesic drugs was the most common intervention performed by paramedics, with 40.1% (n = 32 333/80 643) of patients receiving at least one analgesic agent, most frequently intravenous fentanyl (n = 19 889/80 643, 24.7%) followed by the inhaled anaesthetic methoxyflurane (n = 12 192/80 643, 15.1%) (Table 3). Almost a third of patients had an intravenous catheter inserted (n = 25 060/80 643, 31.1%). Advanced life support such as endotracheal intubation, surgical cricothyrotomy or needle thoracentesis was performed in less than 1% of patients.

Discussion

This is the first study to describe the epidemiology of trauma in adults attended by paramedics in the metropolitan region of Perth. The trauma incidence rate increased over the study period, with a significant increase in the incidence rate in patients 45 years and over and the highest rate seen in the 85 years and over cohort. MVAs were identified as being responsible for the most immediate and early deaths, with the immediate deaths having the lowest median age. The majority of patients

TABLE 1. *Incidence of trauma for all patients ≥16 years per 100 000 population in WA 2013–2016*

	2013	2014	2015	2016	P-value†
Greater Perth population ≥16 years	1 576 311	1 615 895	1 627 314	1 638 734	–
Patients ≥16 years attended by SJA-WA	23 116	22 701	25 306	26 601	–
Incidence per 100 000	1466	1405	1555	1623	<0.001*
Incidence of trauma per 100 000 population per age group					–
16–24	1301	1166	1229	1209	0.171
25–34	958	926	968	968	0.596
35–44	901	833	869	901	0.785
45–54	807	783	870	953	<0.001*
55–64	885	871	977	967	0.009*
65–74	1486	1472	1626	1742	<0.001*
75–84	4714	4368	5090	5256	<0.001*
85+	14 424	14 305	15 877	16 737	<0.001*
30 day mortality	412	455	597	719	–
30 day mortality rate %	1.8	2.0	2.3	2.7	<0.001*

*Significant. †Cochrane-Armitage test for trend.

were low acuity with fewer than 3% being high acuity and advanced life support interventions were performed infrequently.

Incidence

Similar rises in ambulance attendances for patients over 85 years of age have been reported in Melbourne, Victoria, Australia.[22] This study investigated all requests for ambulances and found the predominant reason in the older age groups was falls from ground level.[22] More recently a study in New South Wales (NSW), Australia, of injury presentations to EDs, identified comparable rises in presentations of over 85 year olds.[7] It is apparent that as the population ages there will be an increasing burden placed on the ambulance service. This highlights a need for service planning, injury prevention and injury management.[7,22]

Patient outcomes

Similar to previous studies we found MVAs to be the most frequent cause of untimely deaths.[4,8,23] We also reported a mortality rate for those with the highest acuity level of 9.5%, which is considerably higher than the 3% reported in a similar Australian study.[7] This disparity may be explained by our inclusion of patients transported with no vital signs who are subsequently deemed deceased on arrival at hospital.

It is important to note the patients who died prehospital were the youngest of the mortality groups. Prehospital deaths are often not included in trauma studies and therefore, untimely deaths are often underestimated. It has previously been highlighted that the prevention of trauma is the biggest opportunity for improvement in outcomes.[24] More recently it has been suggested that the majority of preventable deaths are those that occur in the prehospital environment.[25] Beck *et al.* emphasised a critical limitation of evaluating trauma care is the exclusion of those who were not transported to hospital.[25] Beck *et al.* recommended that prehospital deaths should be reviewed to provide evidence to direct innovative trauma management and in turn reduce mortality.[25]

Falls trauma

Under the current SJA-WA mechanism of injury classification system, there is no specific code for falls from ground level. It is likely that most of these would be captured under the trauma in the home code. However, the limited specificity of the coding means the utilisation of ambulances for injuries from this mechanism cannot be fully evaluated. It is already known that elderly trauma patients have the ability to appear deceptively uninjured due to their lack of obvious physiological derangement.[26] Furthermore, it has been suggested that paramedics do not take into account the effect of age especially after falls and this may account for the number of early deaths in the lower acuity group.[26] In consideration of this, the addition of a specific prehospital trauma code for these patients may help with the early identification and further analysis of this high-risk group.

Acuity

Only a small percentage of patients in our study were high acuity, the

TABLE 2. *Comparison of characteristics of those trauma patients who survived and those who died*

	Total patients	Immediate	Early	Late	Survivors	*P*-value
Number of patients	97 724	203	156	1824	95 541	–
Age median (IQR)†	60 (34–83)	38 (28–53)	55.5 (34–80)	86 (80–91)	59 (34–82)	<0.001*
Male (%)‡§	47 582 (48.7)	160 (78.8)	103 (66.0)	954 (52.3)	46 365 (48.5)	<0.001*
Mechanism of injury‡						<0.001*
Trauma in the home (%)	42 509 (43.5)	0 (0)	33 (21.2)	1348 (73.9)	41 128 (43.0)	–
Motor vehicle accident	17 612 (18.0)	98 (48.3)	72 (46.2)	36 (2.0)	17 406 (18.2)	–
Violence (assaults, shootings, stabbings)	9116 (9.3)	50 (24.6)	17 (10.9)	14 (0.8)	9035 (9.5)	–
Other/unspecified	25 799 (26.4)	45 (22.2)	27 (17.3)	410 (22.5)	25 317 (26.5)	–
Burns/electric shock and industrial	2688 (2.8)	10 (4.9)	7 (4.5)	16 (0.9)	2655 (2.8)	–
Acuity level‡¶††						<0.001*
Number of patients	79 897	–	153	1565	78 179	–
Level 1 (%)	2176 (2.7)	–	122 (79.7)	84 (5.4)	1970 (2.5)	–
Level 2 (%)	17 117 (21.4)	–	11 (7.2)	275 (17.6)	16 831 (21.5)	–
Level 3 (%)	59 223 (74.1)	–	20 (13.1)	1178 (75.3)	58 025 (74.2)	–
Levels 4 and 5 (%)	1371 (1.7)	–	0 (0.0)	28 (1.8)	1343 (1.7)	–

*Significant. †Kruskal–Wallis. ‡χ^2. §Twelve patients had an unknown gender. ¶Patients who were referred, deceased or discharged on scene did not have an acuity level. ††Ten missing acuity level.

majority being low acuity. This is demonstrated by the small percentage of advanced life support interventions undertaken.[27] A comparable distribution was reported in NSW where hospital triage level was used to define acuity level.[7] The lack of paramedic exposure to high-acuity patients and the resulting skill decay and decreasing job satisfaction has previously been reported.[22] More concerning is the impact the increase in low-acuity patients has on response times to high-acuity patients.[27] However, although low-acuity patients may not require immediate advanced life support it is important that they are included when considering the total burden of injury. These patients will often require prehospital interventions such as analgesia and go on to require hospital admission, surgery and rehabilitation.[2] By focusing research, training and resources only on high-acuity patients, the true burden of injury will be underestimated and in turn, not adequately managed.[2] It is imperative that emergency medical services cater for both high and low-acuity patients, without comprising either cohort; however, how this occurs is beyond the scope of our discussion.

Strengths and limitations

A strength of this study is the inclusion of all trauma cases including prehospital deaths. Studies often focus on major trauma, which, as we have highlighted, is not a common presentation in metropolitan Perth and often exclude prehospital deaths.[2,7,8] Gaining an understanding of the epidemiology of trauma specific to this region provides evidence to assist in the planning for future prehospital service delivery.

This study had several limitations. First, the mechanism of injury codes used to identify trauma patients are broad, subjective and do not identify key subpopulations such as falls. The trauma in the home code is also generic and ambiguous. Similarly, there are no defined codes for specific road trauma subpopulations such as pedestrians and cyclists. Using mortality as an outcome is a crude method and does not fully reflect the burden of injury.[2] Information such as morbidity or length of stay in hospital was not available for this study, therefore, the long-term injury burden is not discussed.

TABLE 3. *Interventions administered by paramedics to 80 643 patients (excluding those who were discharged on scene)*†

Intervention	Number of patients	Percentage of patients
Analgesia	32 333	40.1
Fentanyl (all routes)	22 846	28.3
Fentanyl (intravenous)	19 889	24.7
Fentanyl (intranasal)	2957	3.7
Ketamine (all routes)	1300	1.6
Ketamine (intravenous)	1253	1.5
Ketamine (intramuscular)	47	0.06
Methoxyflurane (inhalational)	12 192	15.1
Paracetamol (oral)	4004	5.0
Multiple analgesics	7436	9.2
Airway intervention	659	0.8
Oropharyngeal airway	319	0.4
Nasopharyngeal airway	131	0.2
Endotracheal tube intubations§	115	0.1
Supraglottic airway device insertions¶	88	0.1
Surgical cricothyrotomy	6	0.01
Vascular access	25 217	31.3
Intravenous cannulation	25 060	31.1
Intraosseous cannulation	148	0.2
External jugular cannulation	9	0.01
Other		
Fluid administration (normal saline 0.9%)	11 286	14.0
Combat application tourniquet	70	0.09
Pelvic stabilising device	414	0.5
Splinting	10 762	13.3
Cervical collar	10 400	12.9
Needle thoracentesis	44	0.05

†Patients may have received multiple interventions. §Limited to cardiac arrest in 85 patients. ¶Limited to cardiac arrest in 62 patients.

Conclusion

The incidence rate of trauma is increasing especially in the elderly and this is consistent with findings from previous studies. Our results found the majority of patients attended by paramedics are low-acuity and high-acuity patients are seen infrequently. Furthermore, we have suggested that focusing research, training and resources solely on high-acuity patients will underestimate the true burden of injury and not cater for the needs of the majority of patients.

Acknowledgements

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Competing interests

PB is the Clinical Services Director for SJA-WA. JF receives partial salary support from SJA-WA. EB is a SJA-WA paramedic and PhD candidate and the recipient of a National Health and Medical Research Council (NHMRC) Centre for Research Excellence – Prehospital Emergency Care scholarship under grant APP1116453.

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4.2 Extension of Discussion

The death rate of 9.5% reported in this study for those who received critical injuries (acuity level 1) is considerably higher than previously reported in a similar Australian study (three percent mortality reported in NSW [New South Wales]).[101] The inclusion of patients transported in traumatic cardiac arrest and pronounced dead on arrival may account for this disparity. In relation to the cause of mortality, this study found that MVCs were the most frequent cause of immediate and early deaths. This supports earlier research undertaken in metropolitan Perth which found almost 70% of patients, who were transported to hospital in traumatic aetiology cardiac arrest, had received their injuries in MVCs.[102] Similarly, a 33.7% in-hospital mortality rate resulting from MVCs in patients with major trauma (ISS>15) was reported in NSW; this was the second most frequent cause of in-hospital mortality after falls.[24] Previously, also in NSW, MVCs were found to be the most frequent mechanism of major trauma (ISS>15).[8] It is important to consider that these studies did not include patients who were found to be deceased prehospital and therefore, underestimate the true impact of injuries resulting from MVCs.

The use of analgesic agents was identified as the most frequently performed prehospital intervention. Traumatic origin pain has been recognised as a common reason for the usage of EMS.[103] Effective management of pain is especially important in patients with pain of a traumatic origin.[104] Presentations of traumatic origin pain in patients requiring an ambulance have been reported at 40.1% in Melbourne.[105] Thus, 40% of patients receiving an analgesic agent prehospital is not unexpected. The application of cervical collars is currently a controversial topic, and it has been suggested that there is a lack of high-level evidence on the effect of prehospital cervical spinal immobilisation on patient outcomes.[106] The need for a large prospective study to determine clinical benefit and to identify subgroups of patients most likely to benefit from the application of these devices, has recently been emphasised.[106] It will be interesting to investigate whether the rate of application of cervical collars in this study is comparable to future studies.

4.3 Summary

Incidence

Over the study period, there was a significant increase in the trauma incidence rate in patients 45-years and over, the highest being in those 85-years and over. This age group had an increase of more than 2,300 per 100,000 population-year ($p<0.001$) over the study period. An increase in EMS attendances for patients over 85-years of age has also been reported in Melbourne, Victoria, Australia.[107] Similarly, an increase in emergency departments presentations in those aged over 85-years has also been reported in NSW, Australia.[101] As the population ages, it is likely that there will be an increasing burden placed on EMS. Therefore, it is important that this is considered during EMS planning, injury prevention and injury management.

Prehospital and Early Deaths

MVCs were identified as being responsible for most immediate and early deaths. A statistically significant difference was found in median age between the immediate, early and late deaths and the survivors ($p<0.001$) with immediate deaths being the youngest at 38-years (IQR 28-53 years). The finding of MVCs being the most frequent cause of untimely deaths is similar to previous studies.[24,108] The consequences of the underestimation of these untimely deaths when prehospital deaths are not included in trauma studies was highlighted. It was concluded that the prevention of trauma offers the biggest opportunity for improvement in outcomes in this patient population.

Falls

Falls have previously been found to be the most common reason for requesting an ambulance in the older age groups.[107] Unfortunately, under the current SJ-WA mechanism of injury classification system, there is no specific code for falls from ground level. This limited specificity of the coding meant that it was not possible to fully evaluate the utilisation of EMS for injuries from this mechanism. A recommendation was made that the addition of a specific prehospital trauma code for these patients may help with the early identification and further analysis of this group of trauma patients.

Acuity

It was found that the majority of patients were deemed to have low acuity injuries (paramedic allocated acuity level 3 to 5), with fewer than three percent of the cohort reported as being high-acuity (paramedic allocated acuity level 1). These findings were consistent with those reported in a study undertaken in NSW where hospital triage levels were used to determine patient acuity.[101] Further to this, it was noted that advanced life support interventions such as endotracheal intubation, surgical cricothyroidotomy and needle thoracentesis/thoracocentesis were undertaken infrequently. It was argued that focusing training and resources only on high-acuity patients, will not adequately manage the true burden of injury. Furthermore, it was highlighted that EMS must ensure that care caters for the needs of both low and high acuity patients.

4.4 Traumatic Out of Hospital Cardiac Arrest.

An important subgroup of trauma patients is those who suffer an out of hospital cardiac arrest (OHCA) due to traumatic injuries. Traumatic aetiology OHCA is one of the largest causes of cardiac arrest in Australia, second only to that of presumed cardiac aetiology.[109] The overall mean survival for all adult OHCA from any aetiology is 7%.[110] With traumatic aetiology OHCA, survival with a good neurological outcome as low as 2%.[111] The epidemiology of traumatic aetiology OHCA was compared to OHCA of presumed cardiac origin in a retrospective cohort study undertaken in Melbourne, Australia and found to have quite a different epidemiology.[109] Those with traumatic origin tended to be younger, more likely to be male and have fewer occurrences of shockable cardiac rhythms.[109] In addition, traumatic aetiology OHCAs were more likely to be witnessed by bystanders or EMS providers but were less likely to have had bystander cardiopulmonary resuscitation (CPR) than those of presumed cardiac aetiology.[109] The differences in epidemiology and lower survival rates, tragically, contribute to CPR being perceived as futile and an inappropriate use of resources in this patient group.[109]

Whilst undertaking my PhD research I was involved in a study of the trends in traumatic out-of-hospital cardiac arrest in Perth from 1997 to 2014.[112] The aim of this study was to describe and compare traumatic and medical aetiology OHCA, specifically to investigate temporal trends in incidence, characteristics and outcomes.

The findings of this study are fully reported in the following manuscript (Thesis Appendix F) and a brief summary of the findings follows.

Beck B, Tohira H, Bray J, Straney L, **Brown E**, Inoue M, Williams T, McKenzie N, Celenza A, Bailey P, Finn J. Trends in Traumatic Out-of-Hospital Cardiac Arrest in Perth, Western Australia from 1997-2014. Resuscitation. 2016;98.79-84.

Permission to include the manuscript in this thesis has been obtained from Elsevier and a copy of the License Agreement is also included in Thesis Appendix G.

4.5 Summary of Discussion

We did not observe a trend in the incidence or mechanism of injury for traumatic OHCA between 1997 and 2014. However, there was an increase in rates of bystander CPR and resuscitation efforts commenced by paramedics. Survival was rare with just nine patients surviving to hospital discharge in the 18-year study period.

Consistent with a retrospective cohort study undertaken in Melbourne, Australia, it was found that traumatic aetiology OHCA occurred in younger males with rare occurrences of shockable cardiac rhythms (ventricular fibrillation or pulseless ventricular tachycardia).[109] Furthermore, as also reported in the Melbourne study, many were witnessed by bystanders, though few had CPR commenced by bystanders.[109]

Similar to previous studies undertaken in Europe, we found that MVCs were the most common cause of traumatic aetiology OHCA.[113, 114] However, there were no trends in the mechanism of injury observed. Despite the increases in bystander CPR and paramedic resuscitation efforts, survival was poor, with only nine survivors between 1997 and 2014. Interestingly, no survivors received bystander CPR. This is likely to be due to chest compressions being ineffective in situations of hypovolaemia as there is incomplete cardiac filling and thus low cardiac output.[115]

It was concluded that further studies are needed to enable the identification of patients with traumatic aetiology OHCA who would be most likely to benefit from resuscitation efforts commenced by paramedics.

Chapter 5 Demographics, Injury Characteristics and Outcomes of Major Trauma Patients – Methodology

The previous chapters discussed the findings from the retrospective cohort study of all adult (≥16 years) patients with trauma and traumatic aetiology OHCA attended by EMS in the metropolitan area of Perth. The next objective of this PhD study was to describe the characteristics and outcomes of major trauma patients transported to hospital by EMS in the metropolitan area.

5.1 Rationale

Major trauma is associated with high rates of mortality, lengthy hospital stays and greater requirements for rehabilitation.[60] To enable further examination of the prehospital factors that may influence these outcomes, it was important to gain an understanding of the true demographics of major trauma managed by a paramedic staffed EMS in the metropolitan area of Perth.

The aim of this study was:

> To describe the characteristics of adult patients with trauma, attended by EMS.

The specific research objectives were:

- To describe the characteristics of major trauma patients transported to hospital by EMS.
- To describe the outcomes of major trauma patients transported to hospital by EMS.

5.2 Study Design

To achieve the aforementioned objectives, a retrospective cohort study of adult (≥16 years) patients with major trauma who were transported by SJ-WA emergency ambulances in metropolitan Perth between 1st January 2013 and 31st December 2016 was undertaken. This study has been accepted for publication and is presented in Chapter 6. The following is an extension of the methodology used to undertake the study.

5.3 Study Setting

The setting for this study was the metropolitan area of Perth, WA, as fully described in Chapter 2, Section 2.11.

5.4 Inclusions

Adult (≥16 years) patients with an ISS >15 resulting from a blunt, penetrating or thermal mechanism of injury who were transported to hospital by SJ-WA emergency ambulances in the metropolitan area of Perth, WA.

5.5 Exclusions

Consistent with previous trauma studies, trauma resulting from drowning, hanging or poisoning was excluded.[94-96] Patients who were not initially transported by SJ-WA from the incident scene and those not transported by road ambulance were also excluded, as were patients with late effects of injury (more than 24-hours post-trauma). Patients who were injured in hospital whilst in-patients and those who refused initial hospital transport at the time of injury but later presented to hospital by ambulance or other modes of transport were also excluded. In the situation where there was no ePCR available, these patients were also excluded, as access to paper PCR was not available.

5.6 Data Sources

The SJ-WA database (fully described in Chapter 3, Section 3.6) does not contain important trauma variables that may be associated with patient outcomes such as ISS, AIS or occurrence of serious complications. Ethical approval to access to the WA-STR data (Thesis Appendix B) was gained from the Royal Perth Hospital (RPH) Human Research Ethics Committee. For the purpose of this study, specific variables were requested from the WA-STR.

Western Australian State Trauma Registry (WA-STR)

The purpose of the WA-STR is to monitor the function and effectiveness of the WA trauma system.[116] Since August 1994 the WA-STR has been collecting data on trauma patients.[116] Data is collected by research nurses/officers with clinical backgrounds in intensive care, emergency department, trauma, clinical trials or health science.[116]

The WA-STR defines trauma as 'an injury or wound resulting from an external force'.[116] Included in the registry are all patients with major and minor trauma who present to a definitive hospital for treatment within 7 days of their date of trauma. These patients must have been hospitalised for greater than 24 hours at the definitive hospital and or suffered a trauma-related death at the definitive hospital regardless of hospital length of stay. Patients are divided into minor and major trauma admissions, depending on the severity of their injury. The registry collects extensive data on major trauma patients (defined as an ISS >15). For patients with minor trauma (ISS <16), a limited dataset is collected.[116] Patients who die prehospital and are subsequently not transported to hospital are not included in the WA-STR.

There are five hospitals in the metropolitan area that contribute data to the WA-STR and use identical databases and data definitions. These include the designated State Adult Major Trauma Centre with the Royal Australasian College of Surgeons Level I Major Trauma Verification Status (from here on referred to as the Trauma Centre), the paediatric tertiary hospital, the two other tertiary hospitals and one of the secondary facilities.[116] The registry also includes records for patients who are initially treated at a hospital (both rural or metropolitan) which does not provide data to the registry but are subsequently transferred to a hospital that does provide data.[116]

Data Linkage

Patients were identified in the WA-STR if they had an ISS >15, their mode of arrival was recorded as 'ambulance' and the location of injury occurrence was described as 'metropolitan'. Patient data were then linked with all ePCR 'case numbers' that pertained to that patient from the SJ-WA database using either deterministic or probabilistic matching (FRIL ver.2.1.5, Emory University and Centers for Disease Control and Prevention, Atlanta, Georgia, U.S.). Date of birth, first and last names and residential address were used as key identifiers to link between the databases. Linkage was undertaken by Dr Hideo Tohira, due to data privacy regulations. Dr Tohira then assigned a unique Prehospital Resuscitation and Emergency Care Research Unit (PRECRU) identification number to each individual patient identified in the WA-STR, as case numbers in the SJ-WA database are deemed potentially identifiable. To make it possible to retrieve the original data using the PRECRU identification number, a link table between the case numbers in SJ-WA database and PRECRU identification numbers was created and kept in the encrypted folder in a network drive which is accessible by only authorised staff within PRECRU. Dr Tohira also checked that there were no deaths in the WA death data that had not been recorded in the WA-STR prior to de-identifying the data. The data remained potentially re-identifiable by Dr Tohira or Professor Judith Finn after the linkage process was completed.

Data Cleaning

Linkage of the records in the WA-STR with the SJ-WA data could create multiple records ('case numbers') for each PRECRU identification number. These pertained to all the ambulances or emergency vehicles involved in the care of the individual patient. Using the 'transport destination' code identified which 'case number' related to the 'primary' attending and which were 'backups' and subsequent inter-hospital transfers. For the purpose of this study, only the 'primary' attending crews' record was used in the statistical analysis.

The WA-STR includes thirty-nine codes for different mechanisms of injury, some of which met the exclusion criteria (i.e. hangings, drownings and poisonings). The remaining were then re-coded into eight specific codes. These being: MVC, motorbike crash (MBC), pedestrian, pedal cyclist, fall from height (height higher than standing level), fall from standing (including falls from the toilet or chair), violence and other (fire, sport-related, other). The WA-STR also provides a severity level for each injury according to the AIS ranging from 6 (fatal) to 1 (minor). The nine original anatomical divisions (head, face, neck, thorax, abdomen and pelvic contents, spine and vertebrae, upper extremity, bony pelvis and lower extremity, external, including burns) were regrouped into six body regions (head or neck - including cervical-spine; face - including eyes, mouth, nose and facial bones; chest - including thoracic spine and diaphragm; abdominal or pelvic contents - including lumbar spine; extremities or pelvic girdle - including sprains and fractures; and external - including lacerations, abrasions and burns) and the highest score was calculated for each one of those. AIS codes were used to identify whether a patient sustained a major injury in the six ISS body regions (head/neck, face, chest, abdomen, extremities and external). AIS≥3 was used to define major injury.

Demographic details, injury mechanism, injury characteristics, length of hospital stay and if death occurred, the date and location of the death were extracted from the WA-STR. Time to death was calculated as the number of days and hours from the time and date of the emergency call and the time and date of death in the WA-STR. These deaths were categorised as being either early; patients who were declared deceased in hospital within 24 hours of the emergency call being received, or late deaths; those who died within 30-days (excluding those declared deceased within 24 hours).

Serious complications were extracted from the WA-STR and defined as: acute kidney injury, acute myocardial infarction, acute respiratory distress syndrome, cardiac arrest, cardiac failure, deep vein thrombosis, pulmonary embolism, pneumonia, sepsis, stroke and unplanned return to the operating room. These complications have been previously shown to increase the length of hospital stay or require substantial additional treatment.[117]

5.7 Data Analysis

Counts and percentages were used to describe the cohort of major trauma patients for categorical variables, and median and inter-quartile ranges (IQR) for continuous variables. Trends in demographics, injury characteristics and outcomes across the calendar years 2013 to 2016 for dichotomous variables were described using the Cochran–Armitage test. The Kruskal-Wallis test was used to compare continuous data and the Pearson chi-square for categorical variables. Patient demographics and mortality were compared between the mechanism of injury groups using counts and percentages and the Kruskal-Wallis test for continuous variables. A p-value <0.05 was considered statistically significant. Data analysis was performed with IBM Statistical Package for Social Sciences (SPSS) Version 24.0 (IBM, Armonk, NY, USA).

Chapter 6 Demographics, Injury Characteristics and Outcomes of Major Trauma Patients

6.1 Overview

To achieve the aim of describing the characteristics of all major trauma patients, attended by a paramedic staffed EMS, a retrospective cohort study was undertaken consisting of adult (≥16 years) patients who were transported by SJ-WA emergency ambulances in metropolitan Perth with an ISS >15 resulting from a blunt, penetrating or thermal mechanism of injury between 1st January 2013 and 31st December 2016. The specific objectives of this study were to describe the characteristics and the outcomes of major trauma patients transported to hospital by EMS.

Data from the WA-STR were used to identify patients with major trauma who had been transported to hospital by ambulance. These records were then linked with the SJ-WA database. Median age, injury characteristics, mechanism of injury, transport destination and patient outcomes, (death within 24 hours or within 30-days) were described.

The findings of this study are reported in the following manuscript.

Brown E, Tohira H, Bailey P, Fatovich D, Finn J. Major Trauma Patients Are Not Who You Might Think They Are. A Linked Data Study. Australasian Journal of Paramedicine. 2019. [In Press].

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Research

Major trauma patients are not who you might think they are: a linked data study

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Abstract

Introduction
Major trauma patients are often perceived as being young males injured by high energy transfer mechanisms. The aim of this study was to describe the demographics of major trauma patients who were transported to hospital by ambulance.

Methods
This is a retrospective cohort study of adult major trauma (injury severity score >15) patients transported to hospital by St John Western Australia emergency ambulance in metropolitan Perth, between 1 January 2013 and 31 December 2016. To describe the cohort, median and interquartile range (IQR) were used for continuous variables and counts and percentages for categorical variables. Differences between mechanism of injury groups were assessed using the Kruskal-Wallis test. Trauma deaths were defined as early (declared deceased within 24 hours) or late (declared deceased within 30 days).

Results
A total of 1625 patients were included. The median age was 51 years (IQR 30-75) and 1158 (71%) were male. Falls from standing were the most common mechanism of injury (n=460, 28%) followed by motor vehicle crashes (n=259, 16%). Falls from standing were responsible for the majority of early (n=45/175, 26%) and late deaths (n=69/158, 44%). A large number of early deaths also resulted from motorbike crashes (n=32/175, 18%) with a median age of 34 years (IQR 21-46, $p<0.001$).

Conclusion
Major trauma is not only a disease of the young. More than half of the cohort was more than 51 years of age and the most common cause was a fall from standing. Pre-hospital care must evolve to address the needs of a changing trauma patient demographic.

Keywords:
major trauma; emergency medical service; patient outcomes; falls; older adults

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Introduction

Injury is known to be a significant cause of preventable mortality and morbidity worldwide (1). Traditionally, major trauma has been viewed as a disease of the young (2), more specifically, a disease of young males caused by high energy transfer mechanisms of injury such as motor vehicle crashes and interpersonal violence (2). In keeping with this, emergency medical service (EMS) training and resources are often focussed on the management of this group. Similarly, community awareness of mortality from major trauma tends to also focus on this group (3).

Over recent years there has been an increase in the mean age of trauma patients together with major trauma as a result of falls from a low level (2). A better understanding of the true demographics of major trauma may help to inform clinical practice, enable better tailoring of paramedic education and improve patient outcomes.

Objective

The aim of this study was to describe the demographics, injury characteristics and outcomes of major trauma patients who were transported by ambulance to hospital in a metropolitan area.

Methods

Study design

We conducted a retrospective cohort study of adult (≥16 years of age) patients who were transported by St John Western Australia (SJ-WA) emergency ambulance in metropolitan Perth (Western Australia) with an injury severity score (ISS) greater than 15 (resulting from a blunt, penetrating or thermal mechanism of injury) between 1 January 2013 and 31 December 2016. Consistent with previous trauma studies, we excluded trauma resulting from drowning, hanging or poisoning (4,5). We also excluded patients who were not initially transported by SJ-WA from the incident scene and those not transported by road ambulance. Patients with late effects of injury (more than 24 hours post-trauma) and those who had no initial electronic ambulance transport record were also excluded.

Study setting

The metropolitan area of Perth has a population of approximately 2 million (6) and SJ-WA is the sole provider of emergency ambulances. Each emergency ambulance is staffed with at least one paramedic (with the second crew member being another paramedic or ambulance officer) and all crews have the capacity to provide advanced life support (excluding rapid sequence intubation) (7). SJ-WA is contracted to provide critical care paramedics to the helicopter emergency medical service, owned by the Department of Fire and Emergency Services. However, this service does not routinely operate in the metropolitan area of Perth.

During the study period, patients were transported to one of nine hospital emergency departments. Of these, three were tertiary and six were secondary hospitals. One of the tertiary hospitals is a Level 1 trauma centre (8,9). The five secondary hospitals and one private hospital provide definitive care for non-major trauma (8). It has been recommended by the Western Australia Department of Health that major trauma patients (defined as those with an injury that has the potential to cause prolonged disability or death) should be transported directly to the Level 1 trauma centre unless there is an imminent threat to life (7,10).

Data sources

There are four hospitals that contribute data to the Western Australian State Trauma Registry (WASTR): the three tertiary hospitals and one of the secondary hospitals. The registry also includes records for patients who are transferred after initial treatment at another hospital which did not provide data to the registry (11).

Patients were identified in the WASTR if they had an ISS greater than 15, their mode of arrival was recorded as 'ambulance' and the location of injury occurrence was described as 'metropolitan'. Demographic details, injury mechanism, injury characteristics, length of hospital stay, date and location of death were then extracted from the registry. Patient data was then linked with the electronic patient care record (ePCR) from the SJ-WA database using either deterministic or probabilistic matching (FRIL ver.2.1.5, Emory University and Centers for Disease Control and Prevention, Atlanta, Georgia, US). Date of birth, first and last names and residential address were used as key identifiers to link between the databases. The SJ-WA database contains data from the ePCR, completed for each case by EMS providers, together with data from the computer-aided dispatch system.

The WASTR includes 39 different mechanisms of injury codes. For the purpose of this study certain mechanisms of injury were excluded (as detailed above) and the remaining re-coded into eight specific codes: motor vehicle crash, motorbike crash, pedestrian, pedal cyclist, fall from height (height higher than standing level), fall from standing (including falls from the toilet or chair), violence and other (fire, sport related, other). The registry also provides a severity level for each injury according to the Abbreviated Injury Scale (AIS) ranging from 6 (fatal) to 1 (minor). AIS codes were used to identify whether a patient sustained a major injury in the six ISS body regions (head/neck, face, chest, abdomen, extremities and external). An AIS level of ≥3 was used to define major injury. We defined deaths as being either early (patients who were declared deceased in hospital within 24 hours of the emergency call being received) or late deaths (those who died within 30 days [excluding those declared deceased within 24 hours]). Patients who are recognised as life extinct pre-hospital are not included in the WASTR and thus not included in this study.

Statistical analysis

To describe the cohort, counts and percentages were used for categorical variables and median and inter-quartile ranges (IQR) for continuous variables. To describe trends in demographics, injury characteristics and outcomes across the calendar years 2013 to 2016 for dichotomous variables, the Cochran-Armitage test was used. For comparisons of continuous data, the Kruskal-Wallis test was used and the Pearson chi-square used for categorical variables. Patient demographics and mortality were compared between the mechanism of injury groups using counts and percentages and the Kruskal-Wallis test for continuous variables. A p-value of <0.05 was considered statistically significant. Data analysis was performed with IBM Statistical Package for Social Sciences (SPSS) Version 24.0 (IBM, Armonk, NY, US).

Ethics approval

Ethical approval was obtained from the Curtin University Human Research Ethics Committee (HR 128/2013). Ethics approval for access to the WA State Trauma Registry data was obtained from the Royal Perth Hospital Human Research Ethics Committee (PRN 464). Approval to access the SJ-WA data was obtained from the St John Research Governance Committee.

Author contributions

EB, HT and JF designed the study. HT undertook the data linkage. EB analysed and interpreted the data and drafted the manuscript. HT assisted in data analysis. HT, PB, DF and JF assisted in writing and providing a critical review of the manuscript. All authors gave the final approval for the submission.

Results

There were 1664 records in the WASTR pertaining to patients who were 16 years of age or more who had an ISS greater than 15 from a blunt, penetrating or thermal mechanism of injury and were transported from the incident scene by SJ-WA emergency ambulances during the 4-year study period. We were unable to obtain the initial emergency ambulance transport record for 34 patients, three records could not be linked and two records were duplicated in the registry (Figure 1).

Cohort characteristics

This left a study cohort of 1625 patients (Figure 1). The median age of patients was 51 years (IQR 30-75) and 1158 (71%) were male. The median ISS was 22 (IQR 17-27) and 67% (n=1081) had a major head injury. Falls from standing were the most common mechanism of injury with 460 (28%) patients injured by this mechanism. Motor vehicle crashes were the second most common cause of injury (n=259, 16%). During the study period, there was a total of 339 (21%) deaths recorded in the WASTR that met the study's inclusion criteria. Of these, 175 (52%) were early deaths, 158 (46%) were late deaths, and six occurred after 30 days (2%).

Changes during the study period

Over the study period, median age, ISS, length of stay of those who survived 30 days and the occurrence of serious complications did not change significantly (Table 1). The number of patients injured by a penetrating mechanism increased over the study period (p=0.008). However, blunt trauma was responsible for over 90% of the injuries throughout the study period.

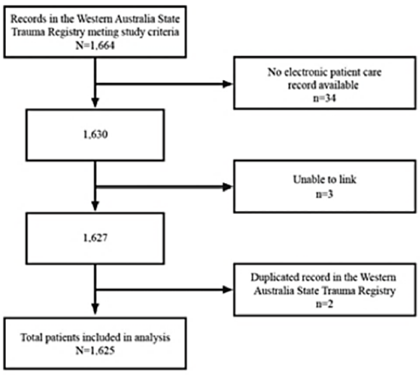

Figure 1. Included and excluded patients during the study period

Mechanism of injury characteristics
Throughout the study period, falls from standing were the most common cause of major trauma (n=460/1625, 28%) and 12% more patients were injured via this mechanism than motor vehicle crashes (n=259/1625, 16%) (Figure 2).

There was a significant difference in patient age between the mechanism of injury groups with those who fell from standing being the oldest at 80 years (IQR 66-87) and those injured in a violent mechanism the youngest at 32 years (IQR 25-44, p<0.001) (Figure 3).

Age and gender characteristics
There were more males with major trauma in all age cohorts except in the ≥85 years cohort. After the age of 45 years, there was an increasing number of females in each age cohort with females making up 54% of the ≥85 years of age cohort (Figure 4).

Table 1. Demographic and trauma characteristics of major trauma patients in the WASTR transported by SJ-WA during the study period

	2013	**2014**	**2015**	**2016**	**p-value**
Total patients	381	370	450	424	
Age median (IQR)	54 (30-77)	49 (28-74)	52 (29-74)	51 (31-75)	0.437
Male (%)	270 (71)	276 (75)	324 (72)	288 (68)	0.248†
Trauma characteristics					
Blunt injury (%)	375 (98)	358 (97)	427 (95)	404 (95)	**0.008†**
Penetrating injury (%)	6 (2)	12 (3)	23 (5)	20 (5)	
ISS median (IQR)	24 (17-27)	24 (17-29)	22 (18-27)	22 (17-27)	0.217
Injury characteristics					
Major head injury AIS ≥3 (%)	252 (66)	256 (69)	297 (66)	276 (65)	0.539†
Major chest injury (%)	144 (38)	134 (36)	177 (39)	150 (35)	0.699†
Major abdominal injury (%)	46 (12)	52 (14)	78 (17)	67 (16)	0.071†
Outcomes					
Early death (%)	45 (12)	43 (12)	46 (10)	41 (10)	0.257 †
Late death (%) ¶	42 (12)	34 (10)	42 (10)	40 (10)	0.410†
LOS in 30 day survivors median (IQR)	10 (5-18)	9 (5-17)	8 (4-15)	9 (5-18)	0.101
Serious complications (%) ††	105 (28)	87 (23)	106 (24)	109 (26)	0.583†
Mechanism of injury					
MVC (%)	57 (15)	61 (16)	69 (15)	72 (17)	
MBC (%)	46 (12)	46 (12)	63 (14)	62 (15)	
Pedestrian (%)	34 (9)	28 (8)	21 (5)	23 (5)	
Pedal cyclist (%)	15 (4)	22 (6)	17 (4)	15 (4)	0.387
Fall from height (%)	54 (14)	44 (12)	67 (15)	57 (13)	
Fall from standing (%)	113 (30)	95 (26)	133 (29)	119 (28)	
Violence (%)	26 (7)	40 (11)	49 (11)	44 (10)	
Other (%) ‡	36 (9)	34 (9)	31 (7)	32 (8)	
Transport destination					
Direct to trauma centre (%)	177 (47)	196 (53)	193 (43)	200 (47)	
Indirect to trauma centre (%)	96 (25)	99 (27)	149 (33)	115 (27)	**0.019**
No trauma centre (%)	108 (28)	75 (20)	108 (24)	109 (26)	

Notes: Data presented as count (percentage); data analysed with Cochran-Armitage test for trend, Kruskal-Wallis test, chi-square; † Cochran-Armitage test for trend; bold font indicates significance; LOS = length of stay; MVC = motor vehicle crash; MBC = motorbike crash; AIS = Abbreviated Injury Scale score; ¶ excluding deaths <24 hours; †† serious complications = acute kidney injury, acute myocardial infarction, acute respiratory distress syndrome, cardiac arrest, cardiac failure, deep vein thrombosis, pulmonary embolism, pneumonia, sepsis, stroke and unplanned return to the operating room (12); ‡ fire, sport related, other.

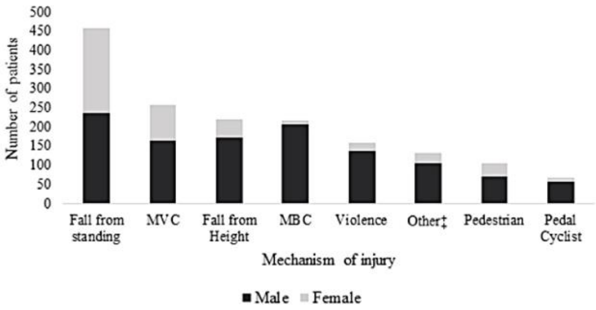

Figure 2. Number and gender of major trauma patients in the WASTR transported by SJ-WA per mechanism of injury during the study period

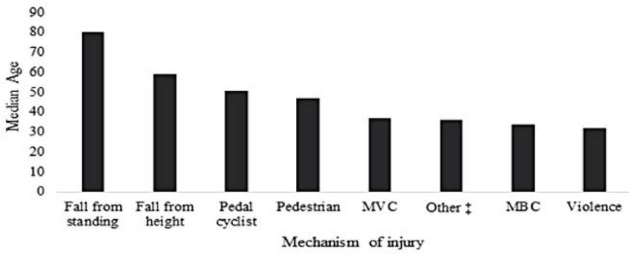

Figure 3. Median age of major trauma patients in the WASTR transported by SJ-WA during the study period

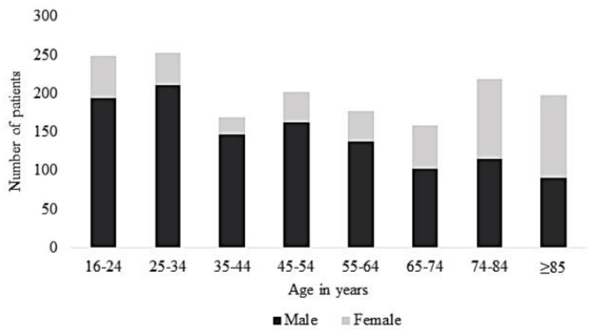

Figure 4. Number of major trauma patients in the WASTR transported by SJ-WA during the study period by age category and gender

Transport destination

Seven hundred and sixty-six patients were transported to the trauma centre directly (47%), 459 (28%) were transported indirectly and 400 (25%) were not transported to the trauma centre directly or indirectly (Figure 5). The median age was oldest in those who were not transported to the trauma centre either directly or indirectly (72 years IQR 46-84 vs. 45 years IQR 27-64, direct and 49 IQR 29-72 indirect, p=0.001). Similarly, those who did not receive trauma centre transport had the highest proportion of falls from standing (n=212/400, 53%, p<0.001), whereas the direct transport group had the highest proportion of motor vehicle crashes (n=152/766, 20%, p<0.001) (Figure 5).

Mortality characteristics

The median age of early deaths in hospital was 49 years (IQR 31-76) and the majority were male (n=127/175, 73%). The most common cause of early deaths was a fall from standing (n=45/175, 26%) and these patients were the oldest with a median age of 78 years (IQR 66-86 years). There was also a large number of early deaths resulting from motorbike crashes (n=32/175, 18%) with these patients having a median age of 34 years (IQR 21-46, p<0.001) (Table 2).

For late deaths, the median age was 77 years (IQR 51-86) and the majority were male (n=101/158, 64%). Falls from standing were responsible for almost half of the late deaths (n=69/158, 44%) and these patients were the oldest at 85 years (IQR 78-90, p<0.001) (Table 3).

Table 2. Number of early major trauma patient deaths in the WASTR transported by SJ-WA during the study period per mechanism of injury

Mechanism of injury	Number of deaths (%)	Median age (IQR)	p-value
MVC	18 (10)	33 (23-68)	
MBC	32 (18)	34 (21-46)	
Pedestrian	22 (13)	63 (42-82)	<0.001
Fall from height	20 (11)	41 (26-72)	
Fall from standing	45 (26)	78 (66-86)	
Violence	18 (10)	39 (32-48)	
Other ‡	20 (11)	47 (39-59)	

Notes: Kruskal-Wallis test for difference in median age; ‡ = fire, sport related, pedal cyclist, other; percentages are rounded to the nearest whole number

Discussion

This study described the characteristics of major trauma patients transported to hospital by emergency ambulance in the metropolitan area of Perth, Western Australia. We found that falls from standing were the most common cause of major trauma in patients transported to hospital and were the most common cause of both early and late trauma deaths. We have also shown that major trauma is not only a disease of the young, with more than half of the cohort being more than 51

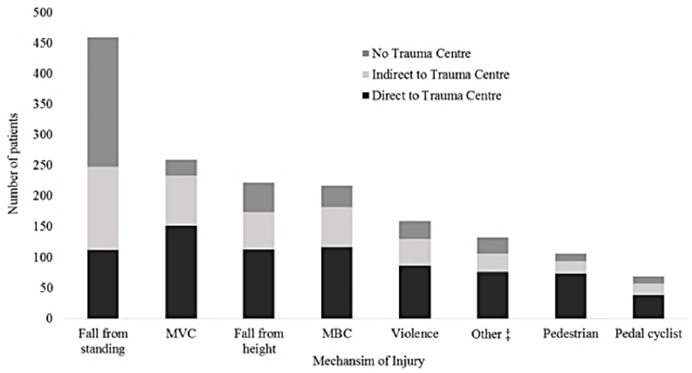

Figure 5. Number of major trauma patients in the WASTR transported by SJ-WA during the study period by transport destination and mechanism of injury

years of age. However, we have reported an alarming number of early deaths in young patients as a result of motorbike crashes.

Table 3. Number of late trauma patient deaths in the WASTR transported by SJ-WA between during the study period per mechanism of injury

Mechanism of injury	Number of deaths	Median age	
	(%)	(IQR)	p-value
MVC and MBC ††	24 (15)	50 (29-79)	
Pedestrian	13 (8)	62 (46-82)	<0.001
Fall from height	27 (17)	77 (60-84)	
Fall from standing	69 (44)	85 (78-90)	
Violence	10 (6)	31 (20-48)	
Other ‡	15 (9)	51 (27-68)	

Notes: Kruskal-Wallis test for difference in median age; †† less than five patients in one category; ‡ = fire, sport related, other; percentages are rounded to the nearest whole number

Older adults
An older median age of major trauma patient and the prominence of low falls as a cause of major trauma are not novel findings. A shift in the demographics of major trauma away from young males resulting from motor vehicle crashes and violence has also been shown in the United Kingdom with major trauma patients more than 75 years of age increasing from 8.1% in 1990 to 26.9% in 2013 (2). Similarly, in Sydney (Australia) the proportion of older major trauma patients was found to have increased from 1991-2010 (13).

The increase in older adults with major trauma creates complex issues. Age is an independent predictor of survival after major trauma (3) and compared to younger patients, older adults with major trauma are known to have higher mortality rates (14). Older adults are also predisposed to poor outcomes from co-morbidities, medication usage (eg. anticoagulation) and are susceptible to complications (3). Compounding these issues is the ability of older adults to appear deceivingly uninjured with overt physiological derangement often absent (15). It is also known that these patients have a reduced likelihood of trauma centre transport (16-19) and an increased likelihood of undertriage within hospital (20,21). Although the reduced odds of trauma centre transport are multi-faceted, treatment of older adults at non-major trauma centres is known to be associated with an increased likelihood of in-hospital mortality (16).

With a greater proportion of older adults with major trauma, trauma systems need to adapt to this shift in demographics (22). It is paramount that pre-hospital care evolves to ensure the needs of older persons following trauma are met (22). With the knowledge that the physiological response to trauma in older persons is different from younger adults, it is imperative that pre-hospital trauma triage tools reflect these differences (23) and an older adult specific trauma triage guideline may be necessary (24). However, the greatest survival gains in older adults are more likely to be achieved by injury prevention (25).

Falls
Falls are the second leading cause of accidental injury deaths worldwide after motor vehicle crashes (26). Similar to other studies, we found falls to be the most common cause of major trauma (23,27,28) and were responsible for the majority of both early and late major trauma deaths. This is contrary to community awareness on mortality from major trauma which is focused on young males involved in motor vehicle crashes (3). It is possible that EMS providers do not recognise that a fall from standing has the ability to cause major trauma. Therefore, the development of more specific major trauma triage guidelines may assist with the recognition of those with the potential to have major trauma and those who would benefit from trauma centre transport.

Motorbike crashes
After falls from standing, motorbike crashes were responsible for the highest number of early deaths and this cohort of patients had a median age of 34 years, which represents a large number of potential years of life lost. As opposed to those injured in low falls, patients fatally injured in motorbike crashes are unlikely to be under-recognised or undertriaged. Therefore, the biggest opportunity for improvement in outcomes in this cohort is likely to be from prevention.

Limitations

Patients who are recognised as life extinct pre-hospital are not captured by the WASTR and therefore were not captured by this study. It is important to note that not including pre-hospital deaths in our current study underestimates untimely deaths, however, this is a common limitation of studies using data from trauma registries (29,30).

Patients who exclusively attended a hospital that did not provide data to the WASTR were not captured by the study. It is possible that the demographics and characteristics of these patients are different from those captured in this study, meaning that our study is subject to survivor bias. However, as the Level 1 trauma centre treats approximately 80% of the state's major trauma (9), we believe that the majority of patients with major trauma would have been transported to a hospital that provided data to the registry.

It is important to consider that this study includes patients with major trauma defined as an ISS greater than 15. This retrospective diagnosis is made using information that is not available pre-hospital, for example, results from imaging. It is, therefore, important to develop ways in which major trauma can be identified pre-hospital, especially in older patients, to ensure that these patients receive appropriate care.

Conclusion

Major trauma does not only occur in the young. More than half of the major trauma patients transported by ambulance in our cohort were more than 51 years of age. In this study, falls from standing were the most common cause of major trauma. To improve patient outcomes, pre-hospital care must evolve to address the needs of a changing trauma patient demographic.

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Conflict of interest

The authors declare they have no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

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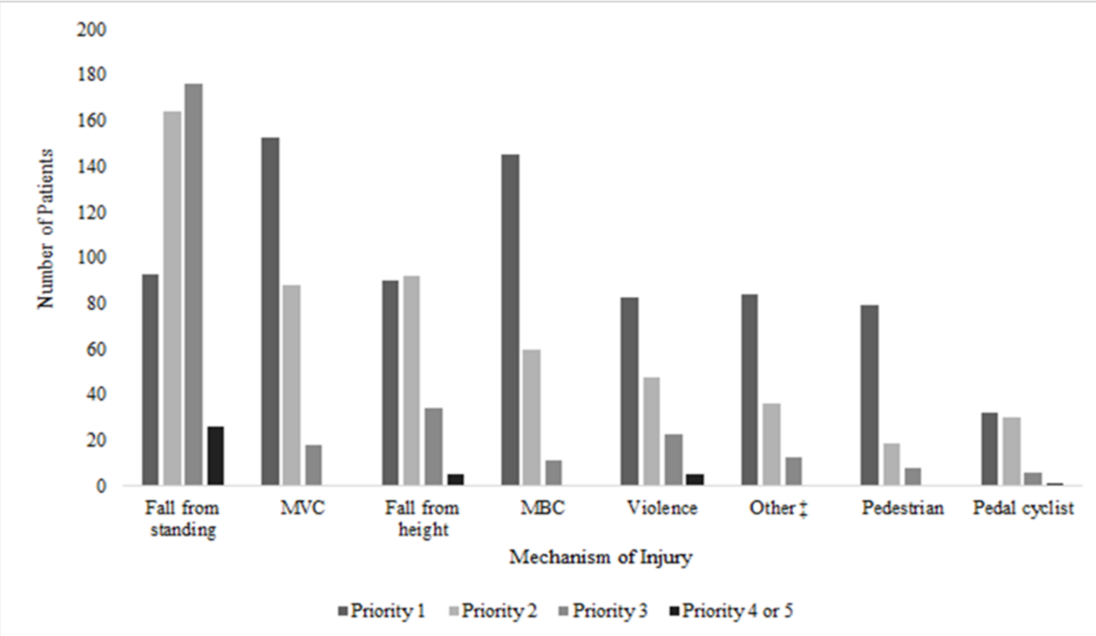
6.2 Extension of Results and Discussion

The following details further analysis of the data undertaken during the completion of the aforementioned study that did not form part of the accepted manuscript.

Extension of Results - Acuity

Almost half of the cohort were transported to their initial hospital destination (prior to any inter-hospital transfer) as a Priority 1 (acuity level 1) (n=759, 47%). Thirty-three percent of patients were transported as Priority 2 (n=537) and eighteen percent as Priority 3 (n=289). Thirty-seven patients were transported as Priority 4 or 5 (n=37). Falls from standing and falls from height were the only two mechanisms which did not have the majority of patients transported to the initial hospital destination as a Priority 1 (Figure 6). There were 90 (40%) patients with a fall from height as their mechanism of injury and 93 (20%) patients with a fall from standing as their mechanism of injury transported Priority 1 to hospital. For patients with a fall from standing as their mechanism of injury, 178 (38%) were prioritised as Priority 3 and 26 (6%) as Priority 4 or 5, meaning that those patients assigned lower acuity triage levels outweighed those with higher acuity levels.

Figure 6 Number of major trauma patients in the WA-STR transported by SJ-WA during the study period by transport acuity and mechanism of injury.



Four patients missing problem urgency. MVC=Motor vehicle crash, MBC=Motorbike crash ‡ Fire, sport-related, other

Extension of Results – Deaths

Falls from standing were the cause of most of the early (published manuscript Table 2) and late deaths (published manuscript Table 3). In relation to the proportion of deaths within 30-days per mechanism of injury, falls from standing were responsible for the second highest proportion (n=124/460, 25%) however, pedestrians had the overall highest proportion (n=35/106, 33%) (Table 4).

Table 4 Number and proportion of trauma patient deaths within 30-days in the WA-STR transported by SJ-WA during the study period per mechanism of injury.

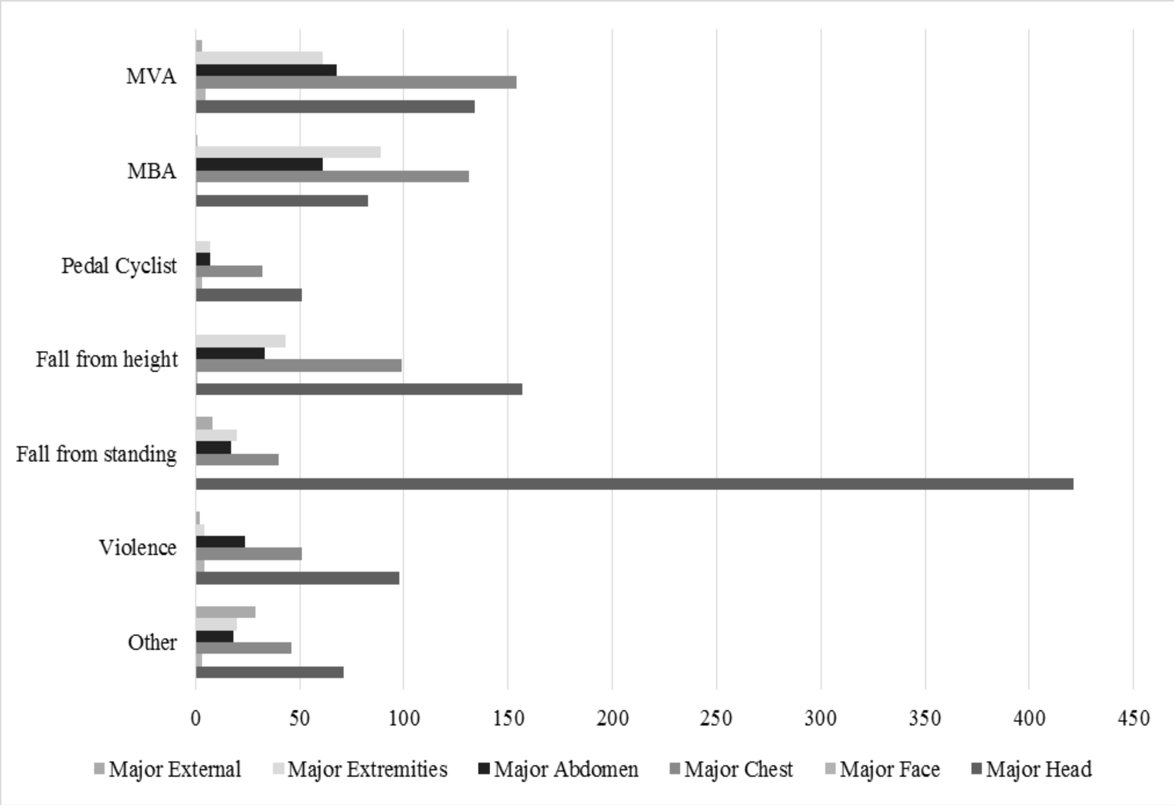
Mechanism of Injury	**N**	**Number of Deaths**	**Proportion of Deaths %**
MVC	259	39	15
MBC	217	35	16
Pedestrian	106	35	33
Fall from height	222	47	21
Fall from standing	460	114	25
Violence	159	28	18
Other ‡	202	35	17

MVC=Motor vehicle crash, MBC=Motorbike crash ‡ Fire, sport-related, other

Extension of Results – Injuries

Major head injuries were present in 421 patients with a fall from standing as their mechanism of injury (n=421/460, 91%). Head injuries were the most common mechanism of major injury in all mechanisms except MVCs and MBCs where major chest injuries were more predominant (n=154/259, 60% and n=131/217, 60% respectively) (Figure 7).

Figure 7 Major injuries (AIS ≥3) in major trauma patients in the WA-STR transported by SJ-WA during the study period per mechanism of injury.



Injury groups are not mutually exclusive.

Extension of Discussion - Acuity

As previously discussed, there is the possibility that EMS providers do not recognise that a fall from standing has the ability to cause major trauma. Further to this, older adults have the ability to appear deceptively uninjured with obvious physiological derangement often absent.[102] These factors may account for a large number of falls from standing that were triaged as acuity level 3 or below, yet were retrospectively found to have major trauma. Older adults with falls have previously been found to have higher rates of in-hospital undertriage and do not trigger trauma team activation systems.[35]

It is important to remember that a fall is not considered to be a mechanism of injury where major trauma should be suspected and direct transport to the Trauma Centre considered under the current SJ-WA clinical practice guidelines as detailed in Chapter 2, Section 2.11.[73] The guidelines also do not contain any physiological criteria, therefore, unless the patients have any of the specific anatomical criteria it is unlikely that they will be recognised as having major trauma.

Extension of Discussion – Injuries

Major head injuries were the most common major injury in all mechanisms except MVCs and MBAs. In those with a fall from standing, major head injuries were present in almost the entire cohort. It has recently been found that over a ten year study period, the proportion of hip fractures had more than halved, whilst severe head injuries had doubled.[118] The prevalence of severe head injuries is likely to be related to the use of anticoagulation and antiplatelet therapies in older adults.[119] However, head injuries can be difficult to identify prehospital as older patients with the equivalent severity of intracranial injury are known to have the ability to present with a higher Glasgow Coma Scale score than their younger counterparts.[120]

6.3 Summary

A retrospective cohort study was undertaken that included 1,625 patients with major trauma who were transported to hospital by EMS in metropolitan Perth. The median age was 51 years (IQR 30-75) and blunt trauma was responsible for over 90% of the injuries throughout the study period. However, the number of patients injured by a penetrating mechanism did increase over this timeframe (p=0.008). Falls from standing were the most common mechanism of injury with 460 (28%) patients injured by this mechanism. Falls from standing were also found to be the most common cause of both early and late deaths. A high number of early deaths in young patients as a result of MBCs were reported.

Older Adults

Although this study found an older median age of major trauma patient and the prominence of low falls as a cause of major trauma these are not novel findings.[60, 121] The increase in older adults with major trauma is also known to create complex issues including; higher mortality rates,[122] poorer outcomes due to co-morbidities, and medication usage (e.g. anticoagulation/antiplatelet) and the increased susceptibility to complications.[123] Other complexities surrounding older adults with major trauma include, the ability of older adults to appear deceivingly uninjured with physiological derangement often absent,[102] the reduced likelihood of Trauma Centre transport [5, 124-126] and the increased likelihood of undertriage within hospital.[35, 127]

Falls

The finding that falls from standing were the most common cause of major trauma is similar to other studies.[8, 24, 120] Interestingly, falls from standing were also responsible for the most of the early and late deaths. However, the highest proportion of falls from standing were found in the group of patients who did not receive Trauma Centre transport. It was suggested that EMS providers do not recognise that a fall from standing has the ability to cause major trauma.

Motorbike Crashes (MBC)

After falls from standing, MBCs were found to be responsible for the most early deaths and this cohort of patients had a median age of just 34 years of age. It is suggested that prevention is likely to be the biggest opportunity for improvement in outcomes for these major trauma patients.

The overall conclusion was that major trauma does not only occur in the young and to ensure the improvement of patient outcomes, prehospital care will need to evolve to address the needs of this changing trauma patient demographic.

Chapter 7 Prehospital Time and Major Trauma Patient Outcomes – Methodology

Following on from the descriptive analysis of the retrospective cohort of adult (≥16 years) patients with major trauma who were transported by a paramedic staffed EMS in metropolitan Perth, the next aim was to determine the association between specific prehospital factors and survival outcomes in major trauma patients.

The first prehospital factor examined was that of prehospital time.

7.1 Background

Quality prehospital care is an essential part of a trauma system. This care is critical to the survival of the severely injured trauma patient.[128] Timely access to Trauma Centre care is founded on the premise that the time immediately following a traumatic insult to the body, is a critical factor that will affect patient outcomes.[129, 130]

The 'Golden Hour'

Historically, the first hour after a patient received an injury has been named the 'golden hour' and there has been an emphasis on the importance of accessing definitive trauma care within this time period.[129] The implications of this term are that, if care is not commenced within the first hour after injury, morbidity and mortality will be affected.[131] This concept is used as justification for current trauma systems [131] and has also been widely used in research.[129] Furthermore, there has been the addition of the 'platinum ten minutes' [132] of trauma management. The 'platinum ten minutes' advocates that the major trauma patient with haemorrhagic shock should have no more than ten minutes of on-scene time.[132]

In 2001 Lerner and Moscati attempted to identify the origin of the 'golden hour' and the research on which the concept was based.[133] Lerner and Moscati found two articles [134, 135] that made reference to the concept originating from the work of Donald Trunkey. However, when they examined his works, they found no mention of the 'golden hour'. Lerner and Moscati also found other articles [136, 137] that attributed the 'golden hour' to the works of R Adams Cowley, one of the fathers of trauma care. They were able to find mention of the 'golden hour' by Cowley,[138] however, they were unable to find any references or data on which Cowley had based his work. This suggests that the basis of the concept was Cowley's experience and opinion.[131]

'Stay and Play' or 'Scoop and Run'?

The length of time EMS providers spend on scene treating a patient prior to transporting them to hospital is a widely debated topic with the existence of supportive data for both rapid transport ('scoop and run') and prehospital stabilisation ('stay and play'). When EMS providers 'scoop and run' the aim is to minimise the time between the occurrence of injury and surgical intervention at a Trauma Centre.[96] This approach postulates that for a trauma patient, time is the most critical factor and little to no interventions should be undertaken prior to transport.[32] Whereas, when EMS providers 'stay and play' they take time to initiate primary treatment, such as advanced life support and stabilise the patient prior to transport.[32]

There is a long-standing controversy between whether prehospital times should be shortened versus delaying arrival at hospital by providing additional treatment at the scene.[139] It has previously been suggested that advanced life support interventions increase scene times and delay expeditious transport of patients to definitive care.[140] In 1994 a study undertaken in Houston, Texas, USA showed improved outcomes in patients with penetrating thoracic injuries when intravenous fluids were delayed in those with hypotension.[141] Similarly, a Canadian study reported that advanced life support interventions did not improve outcomes in trauma patients and may have, when compared to basic life support, actually increased the mortality in severely injured trauma patients.[142] Contrary to this, an American study found that if interventions were performed by skilled EMS they were associated with significantly lower mortality and were not found to increase scene times or total prehospital time.[143]

7.2 Rationale

Studies have failed to reach a consensus as to the effect of prehospital time on major trauma patient outcomes.[96, 144, 145] Some studies have suggested that an increased total prehospital time is associated with increased mortality,[129, 130, 146] yet other studies have failed to find an association.[96, 144, 145] The lack of empirical evidence describing the exact influence of prehospital time on trauma patient outcome has previously been highlighted. [147] Therefore, there is an ongoing debate as to whether it is best to shorten the patient's prehospital time or to provide additional on-scene treatment prior to transport to definitive care.[139]

The aim of the study was:

> To determine the association between prehospital factors and survival outcomes in major trauma patients.

The specific research objectives were:

- To estimate the association between prehospital time of more than one hour and major trauma patient 30-day mortality.
- To estimate the association between prehospital time of more than one hour and major trauma patient length of hospital stay (in those who survived more than 30-days).
- To estimate the association between any individual prehospital time (response, on-scene, travel or total prehospital time) and major trauma patient 30-day mortality.
- To estimate the association between individual prehospital time (response, on-scene, travel or total prehospital time) and major trauma patient length of hospital stay (in those who survived more than 30-days).

The primary outcome of interest was death within 30-days post-injury (30-day mortality). The secondary outcome was the length of hospital stay in days (LOS), in those patients who survived for at least 30-days.

7.3 Study Design

To achieve the objectives, a retrospective cohort study of adult (≥16 years) patients with major trauma who were transported by SJ-WA emergency ambulances in metropolitan Perth, WA between 1st January 2013 and 31st December 2016 was undertaken. This study has been published and is presented in Chapter 8. Below is a more detailed explanation of the methodology used to undertake this study.

7.4 Study Setting

The setting for this study was the metropolitan area of Perth, WA, as fully described in Chapter 2, Section 2.11.

7.5 Inclusions and Exclusions

The inclusions and exclusions for this study are fully described in Chapter 5, Section 5.4 and 5.5.

7.6 Data Sources

For this study, the SJ-WA database and the WA-STR were used, both of which are fully described in Chapter 5, Section 5.6, together with how these databases were linked and the methods used to identify patients meeting the study criteria.

Western Australian State Trauma Registry (WA-STR)

Demographic details, injury mechanism, injury characteristics, length of hospital stay (recorded in full days from first hospital arrival to discharge) and patient discharge disposition (death, rehabilitation, home) were extracted from the WA-STR. The time that the patient arrived at the initial hospital destination was also extracted and if they were subsequently transferred to another hospital, to identify this hospital.

St John - Western Australia (SJ-WA) Database

From the SJ-WA database, the patient's initial hospital destination, response and transport priority (emergency driving conditions) were extracted. Also obtained from the SJ-WA database was the time that the emergency call was received, the time that the ambulance(s) and/or emergency vehicle(s) arrived on the scene, departed for hospital and arrived at hospital. Using the unique codes created by the ePCR tick boxes, prehospital interventions and the first recorded patient observations (respiratory rate, systolic blood pressure measurement and Glasgow Coma Scale score) were also extracted.

Data Cleaning - Prehospital Time Extraction

The prehospital times were calculated as the following time point intervals:

- *Response time* - the time from the emergency call (000 call) being received by the SJ-WA State Operations Centre to the arrival of the first SJ-WA ambulance/emergency vehicle on the scene of the incident.
- *On-scene time* - the time from the arrival on the scene of the first ambulance/ emergency vehicle to the departure of the patient from the scene to hospital.
- *Transport time* - the time from the departure of the patient from the scene to their arrival at the initial hospital destination (prior to any interhospital transfer).

The time that the emergency call (000 call) was received by the SJ-WA State Operations Centre until the arrival of the patient at the initial hospital destination (prior to subsequent inter-hospital transfer) was a sum of the above individual times and referred to as the *total prehospital time.* All time variables were calculated and reported in minutes.

As described in Chapter 5, Section 5.6, the PRECRU identification number recorded in the SJ-WA database was used, to group records (with individual ‘case numbers’) together that referred to the same patient. Using the ‘transport destination’ code it was possible to identify which ‘case number’ pertained to ‘backup’ ambulances or subsequent inter-hospital transfers and which ‘case numbers’ pertained to the ‘primary’ attending/transporting crew. The response time of the first ambulance/emergency vehicle on the scene (this could be the ‘primary’ attending crew, a clinical support paramedic or area manager) was defined as the response time. For all the other time variables, the times recorded by the ‘primary attending’ crew who subsequently transported the patient to their initial hospital destination were used.

All of the time intervals were inspected for possible ‘outliers’ e.g. where transport times and/or on-scene time intervals were physically impossible when compared with the patient’s time of arrival at hospital, which is recorded in the WA-STR. There were 60 patients identified with an outlier time variable. This was handled by calculating an average transport time using previously recorded transport time data from the same suburb to the same hospital under the same or similar emergency driving conditions (i.e. lights and sirens or normal road speed). The erroneous on-scene time was then calculated by subtracting the average travel time from the time between arrival at the scene and arrival at hospital.

Data Cleaning - Transport Groups

Using the information from both the SJ-WA database and the WA-STR three discrete transport groups were created:

- *Direct transports* – patients who were directly transported from the scene of the incident to the Trauma Centre (State Adult Major Trauma Centre with the Royal Australasian College of Surgeons Level I Major Trauma Verification Status).
- *Indirect transports* – patients who were transported to another metropolitan hospital prior to transfer to the Trauma Centre.
- *No Trauma Centre attendance* – patients who never attended the Trauma Centre before dying or being discharged.

Data Cleaning – Prehospital Observations

Using the observations extracted from the SJ-WA database the initial tRTS was calculated using the first recorded respiratory rate, systolic blood pressure measurement and Glasgow Coma Scale score.[59] The cut-off values for the tRTS were used to categorise the physiological parameters and to ensure that there were at least 10 patients per category. This was done to reduce bias and avoid unreliable CI calculation.[148]

7.7 Statistical Analysis

Descriptive Statistics

Summary statistics used to describe the cohort included median and IQR for continuous variables and counts and percentages for categorical variables. Patient and event characteristics were compared between prehospital time groups using chi-square for categorical variables and Mann-Whitney U test for continuous variables.

The 'Golden Hour'

The time from the initial emergency call to the arrival of the patient at the initial hospital destination was used as a proxy to represent total prehospital time, as the exact time of injury is often not known. To represent the 'golden hour' a binary variable of the total prehospital time was created. Those patients with a total prehospital time of less than one hour were placed in the <60 minute group and those with a total prehospital time of equal to or more than one hour were placed in the ≥60 minute group.

Prehospital Time Intervals

The individual prehospital time intervals; response, on-scene, transport and total prehospital time were treated as continuous variables, so information was not lost with the arbitrary cutoff of 60 minutes.

Inverse Probability of Treatment Weighting (IPTW)

As prehospital time could be affected by the predictors of outcomes, the logistic and linear regression models were derived with inverse probability of treatment weighting (IPTW) using the propensity scores.[149] The propensity score is the probability, between zero and one, of treatment (in this situation a prehospital time) being assigned based on observed baseline covariates.[150] As such it is the conditional probability that a patient will have a prehospital time of <60 or ≥60 minutes based on their important prognostic demographic and observation covariates.[151]

The propensity scores were computed with a binary logistic regression model for prehospital time <60 versus ≥60 minutes. To determine if prehospital time was associated with LOS linear regression models were derived with inverse probability of treatment weighting. The β coefficient produced by these models is a ratio of a natural log of (geometric) mean of LOS to time.

The models were adjusted for:

- ISS.
- Age.
- First tRTS.
- Type of injury (blunt/penetrating, no patients were identified as having isolated major thermal injuries).
- Transport destination (*Direct, Indirect* or *No Trauma Centre attendance*).

IPTW uses the propensity score to create a weight, based on the propensity score created.[151] Using this method, a weight was applied to each patient with a prehospital time of <60 minutes by the inverse of the probability that they would have a prehospital time of <60minutes and weighted each patient with a prehospital time of ≥60 minutes by the inverse probability that they would have a prehospital time of ≥60 minutes.[151]

The weight of each patient was calculated using 2 variables: Z (an indicator of the patient's treatment status being 0 in the prehospital time <60 minute group and 1 in the >60 minute group) and s (the propensity score of the patient). The weight (w) of the patient was equal to the inverse of the probability of being in the prehospital time group that they actually were.[151] Thus:

$$w=Z/s + (1-Z)/(1-s)$$

After the weighting, the balance in measured covariates between the prehospital time groups were examined, by comparing the standardised mean differences before and after weighting.[152] A difference of less than 10% indicated balance between the cohorts.[153] A finding of the standardised mean differences being >10% for a number of covariates would suggest that the propensity-score model was inadequate.[151] There were seventy-two patients who were missing values for tRTS and therefore could not be included in the weighting.

Logistic and Linear Regression Models

The weights were used to account for potential confounding when estimating the effect of prehospital time on 30-day mortality and LOS by incorporating the weights into subsequent analyses comparing the outcomes between the prehospital time groups. The advantage of using this method is that it reduces bias more than stratification and covariate adjustment using just the propensity scores.[151]

The GENLIN command of IBM Statistical Package for Social Sciences (SPSS) Version 24.0 (IBM, Armonk, NY, USA) for deriving models with weighting was used. To determine if prehospital time was associated with 30-day mortality, logistic regression models were used and for LOS, linear regression models were derived.

The outcomes were adjusted for the following confounders:

- Age.
- Sex.
- Type of injury (blunt/penetrating).
- ISS.
- Systolic blood pressure <90mmHg.
- Respiratory rate >29 per minute or <9 per minute.
- Glasgow Coma Scale score 13–15; 9–12; 6–8; 3–5.
- Number of types of prehospital interventions (advanced airway, [endotracheal intubation, cricothyroidotomy, supraglottic airway device insertion], needle thoracocentesis, vascular access [intravenous, intraosseous], pelvic splint, combat application tourniquet, spinal immobilisation).
- Transport destination (*Direct, Indirect* or *No Trauma Centre attendance*).

Heteroscedasticity in the LOS variable was observed, therefore, the natural logarithm of LOS in the linear regression analysis was used. Unadjusted OR and AOR and their 95% CI were then derived using the models with weighting. The association between time variables and hospital LOS were presented as exponentiated beta coefficients and their 95% CI. The continuous variable for total prehospital time and the binary <60 versus ≥60 minutes variables were entered into separate models from the other time variables due to significant collinearity.

The results of this study are reported in the next chapter, together with a discussion of these findings.

Chapter 8 Prehospital Time and Major Trauma Patient Outcomes

8.1 Overview

To achieve the aim of determining whether there is an association between prehospital time and outcomes, a retrospective cohort study of major trauma patients who were transported to hospital by a paramedic staffed EMS in Perth, WA between 1 January 2013 and 31 December 2016, was undertaken. The primary outcome of interest was death within 30-days post-injury (30-day mortality) and the secondary outcome was the length of hospital stay in days (LOS), in those patients who survived for at least 30-days. The specific research objectives were to use logistic and linear regression to determine the association between prehospital time of more than one hour or any individual prehospital time and death within 30 days or survivor LOS.

The findings are reported in the following manuscript that was published in Prehospital Emergency Care in 2019.

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Longer Prehospital Time Was Not Associated with Mortality in Major Trauma. Prehospital Emergency Care. 2018;23(4):527-537.

An extension of the discussion follows the manuscript and the tables pertaining to additional analyses can be found after the discussion.

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8.2 Abstract

Objective: To determine the association between prehospital time and outcomes in adult major trauma patients, transported by ambulance paramedics.

Methods: A retrospective cohort study of major trauma patients (Injury Severity Score >15) attended by St John Ambulance paramedics in Perth, Western Australia, who were transported to hospital between 1st January 2013 and 31st December 2016. Inverse probability of treatment weighting (IPTW) using the propensity score was performed to limit selection bias and confounding. The primary outcome was 30-day mortality and the secondary outcome was the length of hospital stay (LOS) for 30-day survivors. Multivariate logistic and log-linear regression analyses with IPTW were used to determine if prehospital time of more than the one hour (from receipt of the emergency call to arrival at hospital) or any individual prehospital time interval (response, on-scene, transport or total time) was associated with 30-day mortality or LOS.

Results: A total of 1,625 major trauma patients were included and 1,553 included in the IPTW sample. No significant association between prehospital time of one hour and 30-day mortality was found (adjusted odds ratio 1.10, 95% confidence interval (CI) 0.71-1.69). No association between any individual prehospital time interval and 30-day mortality was identified. In the 30-day survivors, one-minute increase of on-scene time was associated with 1.16 times (95% CI 1.03-1.31) longer LOS.

Conclusion: Longer prehospital times were not associated with an increased likelihood of 30-day mortality in major trauma patients transported to hospital by ambulance paramedics. We found no evidence to support the hypothesis that prehospital time longer than one hour resulted in an increased risk of 30-day mortality. However, longer on-scene time was associated with longer hospital LOS (for 30-day survivors). Our recommendation is that prehospital care is delivered in a timely fashion and delivery of the patient to hospital is reasonably prompt.

8.3 Introduction

Injury remains a leading cause of mortality and morbidity in the developed world.[7] Timely access to definitive care is founded on the premise that time is a critical factor affecting the outcome of the patient with major trauma.[129, 130] Indeed, the popular concept of the 'golden hour' of trauma management, advocates that the major trauma patient should have no more than a total of one hour from the occurrence of the injury before reaching definitive care, suggesting that prehospital times longer than this increase the risk of mortality and morbidity.[154] However the original concept of the 'golden hour' was not evidence-based [131] and subsequent studies have failed to reach a consensus as to the effect of prehospital time on major trauma patient outcomes.[96, 145, 155] Therefore, there is ongoing debate as to whether it is best to shorten the patient's prehospital time or to provide additional on-scene treatment prior to transport to definitive care.[139]

The objective of this study was to determine whether there is an association between prehospital time and outcomes in adult major trauma patients transported to hospital by ambulance paramedics in Perth, Western Australia. We hypothesized that longer prehospital times would be associated with an increased 30-day mortality and longer length of hospital stay (LOS) in 30-day survivors after controlling for known predictors of major trauma mortality, including increasing age and Injury Severity Score (ISS) and lower Glasgow Coma Scale (GCS) score.[156]

8.4 Methods

Study Design

We conducted a retrospective cohort study of patients aged ≥16 years with major trauma, defined as an ISS of >15 from a blunt or penetrating mechanism of injury. Patients who were transported between 1st January 2013 and 31st December 2016 by St John Ambulance Western Australia (SJA-WA) paramedics in metropolitan Perth, Western Australia (WA) either directly or indirectly to one of four hospitals who provide data to the WA State Trauma Registry, were included in the study.

Patients who died at the scene or exclusively attended a hospital that did not provide data to the WA State Trauma Registry were not included in this study. We excluded patients who were not transported from the scene of the incident by SJA-WA paramedics; those not arriving at hospital by road ambulance and those who had late effects of injury (those who presented to hospital more than 24-hours post-injury).[96] Similar to studies conducted elsewhere,[95, 96] cases involving drowning, hanging or poisoning were excluded, which is consistent with the definition of physical trauma 'as a body wound produced by sudden physical injury from impact, violence or accident'.[6] Patients were also excluded if their initial ambulance transport record could not be obtained.

Our primary outcome of interest was death within 30-days post-injury (30-day mortality). Our secondary outcome was the LOS in days, in those patients who survived for at least 30-days.

Study Setting

Perth, the capital city of WA, spans more than 6000km^2 and has a population of over two million, comprising 78% of the state's population.[64, 68] SJA-WA is a single tier ambulance service and the sole provider of emergency road ambulances in Perth. Within the metropolitan area, ambulances are staffed by paramedics who have the capacity to provide advanced-life support, excluding rapid sequence induction.[73]

Based on the information provided during the emergency telephone call, the SJA-WA State Operations Centre assign an ambulance response priority from one to three. A priority one is perceived to be a time critical condition and receives a 'lights and sirens' ambulance response.[70] Priority two and below are responded to at normal road speed. If, after arriving on the scene, the patient's condition is deemed time-critical by the attending paramedics, the patient is then transported to hospital as a priority one ('lights and sirens'). All other transported patients are conveyed to hospital at normal road speed.

During the study period, adult trauma patients in the metropolitan area who were transported by SJA-WA would have attended one of nine hospitals: three tertiary and six secondary hospitals. One of the tertiary hospitals was the designated Trauma Center.[87] The other two tertiary hospitals provided services for inpatient management of major trauma. The five secondary facilities and one private hospital provided definitive care for non-major trauma.[87] For this study, the designated Trauma Center (tertiary hospital), the two other tertiary hospitals and one of the secondary facilities provided data to the State Trauma Registry (including data for those patients transferred to these facilities after initial treatment at a metropolitan hospital that did not provide data to the registry).[116]

At the time of the study, SJA-WA clinical practice guidelines recommended that adult patients with major trauma (defined as any injury that has the potential to cause prolonged disability or death) should be taken directly to the designated Trauma Center where possible unless the patient's condition appeared imminently life-threatening. Paramedics were then permitted to divert to the nearest emergency department for patient stabilization.[73]

Data Sources

The four hospitals that contribute data to the State Trauma Registry use identical databases and data definitions.[116] Using the State Trauma Registry, patients with ISS >15 whose mode of arrival was recorded as ‘ambulance’ and location of trauma listed as ‘metropolitan’ were identified. Demographic details, injury mechanism, injury characteristics, LOS (recorded in full days from first hospital arrival to discharge) and patient discharge disposition (death, rehabilitation, home) were then extracted from the State Trauma Registry and the record linked to the patient’s ambulance transport record from the SJA-WA database using either deterministic or probabilistic matching (FRIL ver.2.1.5, Emory University and Centers for Disease Control and Prevention, Atlanta, Georgia, U.S.). A likelihood score indicating a correct link between the databases was created using the date of birth, first and last names and residential address as key identifiers.[98] Links were then checked manually if the score was close to a predetermined cut-off value. Linkage failure occurred if the information (e.g. name, date of birth) was missing in either the SJA-WA database or the State Trauma Registry.

Patient hospital destination, prehospital observations, response and transport priority were extracted from the SJA-WA database which contains data from the electronic patient care record (ePCR), completed for each case by paramedics, together with data from the computer-aided dispatch system. Time variables (response time; on-scene time; transport time) were also obtained from the SJA-WA database and defined as follows. Response times, as the time from the emergency call being received by the SJA-WA State Operations Centre to the arrival of the first SJA-WA emergency vehicle on the scene of the incident. On-scene times were defined as the time from the scene arrival of the first emergency vehicle to the departure of the patient from the scene to hospital. Transport time was defined as the time from the departure of the patient from the scene to the ambulance arrival at the initial hospital destination. Total prehospital time was calculated as the sum of all of these values, i.e. from the time that the emergency call was received by the SJA-WA State Operations Centre until the arrival of the patient at the initial hospital destination (prior to subsequent inter-hospital transfer). Time variables were reported in minutes.

The time intervals in the data were inspected for possible ‘outliers’ e.g. where transport times and/or on-scene time intervals are physically impossible when compared with the patient’s time of arrival at hospital. If an outlier was identified, an average transport time was calculated using previously recorded transport time data from the same suburb to the same hospital under the same or similar driving conditions (i.e. lights and sirens or normal road speed). The erroneous on-scene time was then calculated by subtracting the average travel time from the time between arrival at the scene and arrival at hospital (N=60 patients).

Three discrete transport groups were specified: (1) those who were directly transported from the scene of the incident to the Trauma Center, defined as *direct transports*; (2) those patients who attended another metropolitan hospital prior to transfer to the Trauma Center, defined as *indirect transports*; and (3) those patients who never attended the Trauma Center before dying or being discharged, classified as *no Trauma Center attendance*.

Initial triage Revised Trauma Score (tRTS) was calculated from the first recorded respiratory rate, systolic blood pressure measurement (SBP) and Glasgow Coma Scale (GCS).[59] The cut-off values for the tRTS informed categorization of the physiological parameters and these were determined so that there would be at least 10 patients per category to reduce bias and avoid unreliable confidence interval calculation.[148] We defined major injury as an injury with Abbreviated Injury Scale ≥3

Statistical Analysis

Descriptive statistics were used to describe the cohort including median and inter-quartile range (IQR) for continuous variables and counts and percentages for categorical variables. Patient and event characteristics were compared among the groups using chi-square for categorical variables and Mann-Whitney U test for continuous variables. As the exact time of the occurrence of injury is unknown, we used the time from the initial emergency call to the arrival of the patient at their initial hospital destination to represent total prehospital time for comparison against the 'golden hour'. We then created a binary variable of this total prehospital time (<60 versus ≥60 minutes). All other time intervals were treated as continuous variables so information was not lost with this arbitrary cutoff.

To determine if prehospital time was associated with 30-day mortality logistic regression models were used and for LOS linear regression models were derived. The outcomes were adjusted for the following confounders: age, sex, type of injury (blunt/penetrating) ISS, SBP, respiratory rate, GCS, number of types of prehospital interventions (advanced airway, [endotracheal intubation, cricothyroidotomy, supraglottic airway device insertion], needle thoracocentesis, vascular access [intravenous, intraosseous], pelvic splint, combat application tourniquet, spinal immobilization) and hospital destination.

Because prehospital time could be affected by the predictors of outcomes, the logistic and linear regression models were derived with inverse probability of treatment weighting (IPTW) using the propensity scores.[149] The GENLIN command of IBM SPSS was used for deriving models with weighting. The propensity scores were computed with a binary logistic regression model for prehospital time <60 versus ≥60 minutes and adjustment for ISS, age, first tRTS, type of injury (blunt/penetrating, no patients were identified as having isolated major thermal injuries) and hospital destination. Covariate balances were checked by the comparison of standardized mean differences before and after weighting.[152] A difference of less than 10% indicated balancing between the cohorts.[153] Seventy-two patients were missing values for tRTS and therefore could not be included in the weighting.

The natural logarithm of LOS was used in the linear regression analysis as a dependent variable because heteroscedasticity was observed. Unadjusted odds ratios (OR) and adjusted odds ratios (AOR) and their 95% confidence intervals (CI) were then calculated. The association between time variables and hospital LOS were presented as exponentiated beta coefficients and their 95% CI. The continuous variable for total prehospital time and the binary <60 versus ≥60 minutes variables were entered into separate models from the other time variables due to significant collinearity.

We conducted sensitivity analyses to assess the robustness of our results. We excluded all patients in the total cohort who required cardio-pulmonary resuscitation. We also analyzed subgroups of those with a first prehospital SBP <90mmHg, those with major head injuries (AIS ≥3) and those who went directly to the Trauma Center. We also analyzed the association between prehospital time and mortality in one, three and seven days.

Potential interactions were tested and the presence of effect modification was deemed significant if a *p*-value of the interaction term was less than 0.05. Data analysis was performed with IBM Statistical Package for Social Sciences (SPSS) Version 24.0 (IBM, Armonk, NY, USA). A *p*-value <0.05 was considered to be statistically significant.

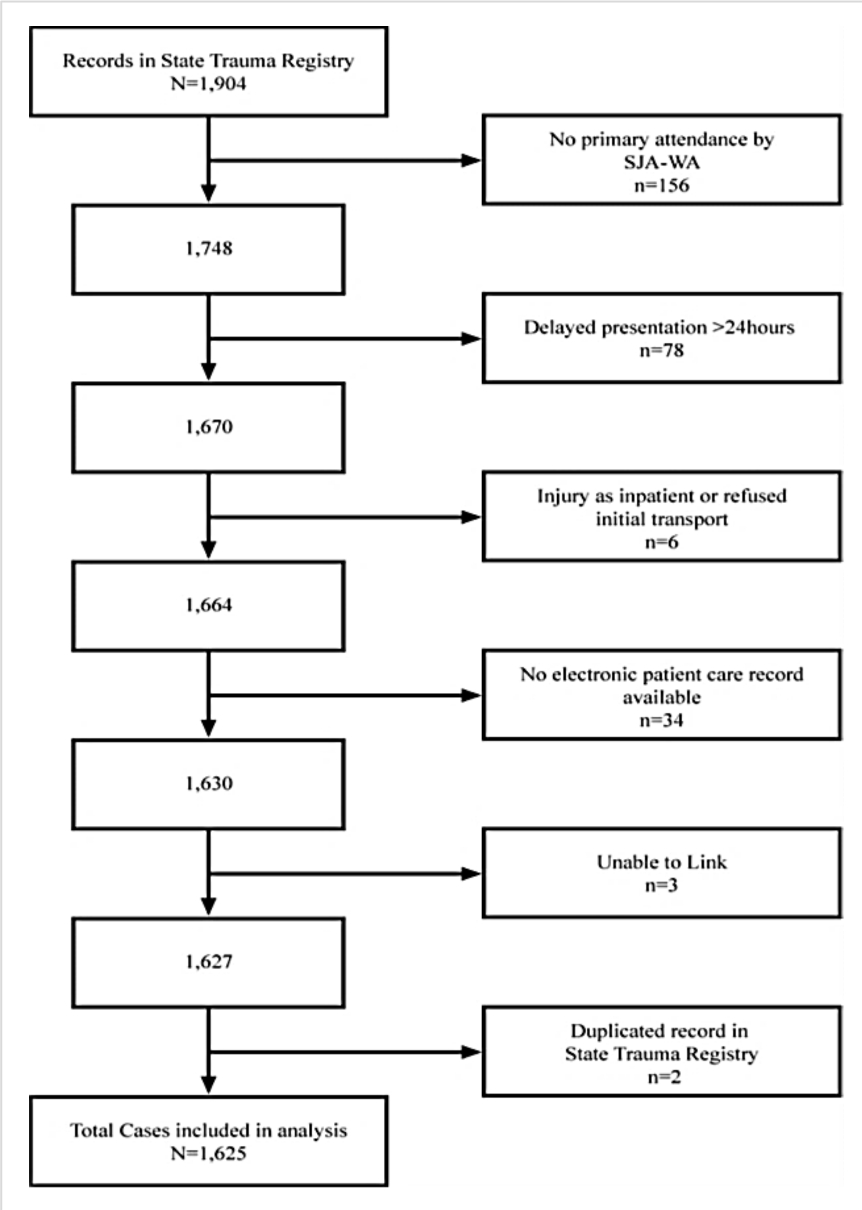
Ethics Approval

Ethical approval was obtained from the Curtin University Human Research Ethics Committee (HR 128/2013). Ethics approval for access to the State Trauma Registry data was obtained from the Royal Perth Hospital Human Research Ethics Committee (PRN 464). Approval to access the SJA-WA data was obtained from the St John Ambulance Research Governance Committee.

8.5 Results

The State Trauma Registry contained 1,664 records that met the study inclusion criteria. Thirty-four patients, although transported by SJA-WA, did not have an available ePCR (PCR not recorded electronically). We were unable to link three records, possibly due to incorrect identifiers or incorrect recording of the mode of transport in the State Trauma Registry and two patients were found to be duplicated in the registry. A total of 1,625 patients were included in the unadjusted analysis (Figure 1).

Figure 1 Flowchart of included and excluded patients ≥16 years of age with major trauma, defined as an Injury Severity Score of >15 from a blunt, penetrating or thermal mechanism of injury who were preliminarily attended by St John Ambulance WA (SJA-WA) paramedics in metropolitan Perth, WA and transported either directly or indirectly to one of four hospitals who provided data to the WA State Trauma Registry (STR) between 1st January 2013 and 31st December 2016.



After IPTW, there were 1,553 major trauma patients in the study cohort and the covariate imbalance of factors such as ISS, tRTS and transport destination were mostly eliminated (Table 1).

Table 1 Demographic and trauma characteristics of all major trauma patients before and after inverse probability of treatment weighting (IPTW) who were transported by SJA-WA paramedics in the metropolitan area stratified by prehospital total time.

	All patients before IPTW *N=1,625*			**IPTW Sample** *N=1,553*		
	< 60 mins *N=1022* **(63%)**	**≥ 60 mins** *N=603* **(37%)**	**SMD**	**< 60 mins** *N=971* **(62%)**	**≥ 60 mins** *N=582* **(37%)**	**SMD**
Patient Demographics						
Age median (IQR)	51 (30-76)	51 (30-74)	0.04	52 (30-75)	52 (30-75)	0.01
Male (%)	727 (71)	431 (72)	0.01	691 (71)	417 (72)	0.00
Trauma Characteristics (%)						
Blunt	976 (95.5)	588 (97.5)	0.11	927 (95)	567 (97)	0.10
Penetrating	46 (5)	15 (2)	0.11	55 (5)	15 (3)	0.10
Injury Severity Score	25 (17-29)	21 (17-26)	0.30	25 (17-29)	21 (17-26)	0.02
Mechanism of Injury (%)						
MVC	124 (12)	135 (22)	0.28	117 (12)	130 (22)	0.27
MBC	115 (11)	102 (17)	0.16	110 (11)	98 (17)	0.17
Pedestrian	84 (8)	22 (4)	0.20	78 (8)	22 (4)	0.17
Pedal Cyclist	45 (4)	24 (4)	0.02	42 (4)	23 (4)	0.00
Fall from Height	137 (13)	85 (14)	0.02	134 (14)	84 (14)	0.00
Falls from Standing	316 (31)	144 (24)	0.16	308 (32)	142 (24)	0.18
Violence (gunshot, stabbing, assault)	123 (12)	36 (6)	0.21	114 (12)	35 (6)	0.21
Other [a]	78 (8)	55 (9)	0.54	68 (7)	48 (8)	0.04
Injury Location (%)						
Major Head	733 (72)	348 (58)	0.30	701 (72)	339 (58)	0.30
Major Chest	369 (36)	236 (39)	0.06	346 (36)	230 (40)	0.08
Major Abdomen	141 (14)	99 (16)	0.06	137 (14)	96 (16)	0.06
Major Extremities	144 (14)	137 (23)	0.23	132 (14)	131 (22)	0.21
Major External	27 (3)	16 (2.7)	0.01	17 (2.0)	10 (2)	0.00
Transport Destination (%)						
Direct Trauma Center	458 (45)	308 (51)	0.12	428 (44)	295 (51)	0.14
Indirect Trauma Center	297 (29)	162 (27)	0.04	286 (30)	158 (27)	0.07
Non Trauma Center	267 (26)	133 (22)	0.09	257 (26)	129 (22)	0.09

	All patients before IPTW *N=1,625*			IPTW Sample *N=1,553*		
	< 60 mins *N=1022* **(63%)**	**≥ 60 mins** *N=603* **(37%)**	**SMD**	**< 60 mins** *N=971* **(62%)**	**≥ 60 mins** *N=582* **(37%)**	**SMD**
Prehospital Observations [(b)]						
tRTS Initial	12 (10-12)	12 (11-12)	0.36	12 (10-12)	12 (11-12)	0.03
SBP <90mmHg	198 (19)	114 (19)	0.01	182 (19)	107 (18)	0.03
Respiratory Rate 10-29	831 (81)	531 (88)	0.18	795 (82)	517 (89)	0.20
Respiratory Rate >29	92 (9)	52 (9)	0.01	85 (9)	48 (8)	0.04
Respiratory Rate ≤ 9	94 (9)	18 (3)	0.26	91 (9)	17 (3)	0.25
GCS 13-15	641 (63)	490 (81)	0.42	612 (63)	475 (82)	0.44
GCS 9-12	98 (10)	43 (7)	0.09	92 (9)	41 (7)	0.07
GCS 6-8	89 (9)	28 (5)	0.16	86 (9)	27 (5)	0.16
GCS 3-5	192 (19)	41 (7)	0.36	181 (19)	39 (7)	0.36

Note. IPTW – Inverse probability of treatment weighting. Weighted for prehospital time <60 or ≥60. Weighted on ISS, tRTS, transport destination, age and blunt/penetrating injury. Abbreviations are as follows; GCS=Glasgow Coma Scale, IQR=interquartile range, MBC=motor bike crash, MVC= motor vehicle crash, SBP = systolic blood pressure, SMD=standardized mean difference, tRTS= triage Revised Trauma Score. Major Injury=Abbreviated Injury Scale ≥3. Data are presented as median (IQR-interquartile range) or count (percentages [whole numbers]). (a) Fire, sport related, other (b) Includes 72 patients with physiological values missing before IPTW.

Table 2 Prehospital time, response and transport priority among an inverse probability of treatment weighted (IPTW) sample of major trauma patients who were transported by SJA-WA paramedics in the metropolitan area stratified by prehospital total time.

	IPTW sample *N1,553*		
	< 60 mins *N 971*	**≥ 60 mins** *N 582*	
Prehospital Time	**Median (IQR)**	**Median (IQR)**	***p***
Response Time	10 (7-12)	13 (10-17)	<0.001
On-Scene Time	22 (17-27)	36 (30-45)	<0.001
Transport Time	12 (8-16)	20 (14-28)	<0.001
Total Prehospital Time	46 (39-52)	70 (63-80)	<0.001
Response Priority	**N (%)**	**N (%)**	***p***
Priority One	1252 (81)	1205 (78)	
Priority Two	278 (18)	315 (20)	0.001
Priority Three	21 (1)	48 (2)	
Transport Priority (%)[(a)]	**N (%)**	**N (%)**	***p***
Priority One	723 (46)	714 (45)	
Priority Two	457 (29)	620 (40)	<0.001
Priority Three	368 (23)	235 (15)	

Note. IPTW – Inverse probability of treatment weighting. Weighted for prehospital time <60 or ≥60. Weighted on ISS, tRTS, transport destination, age and blunt/penetrating injury. Data are presented as median (IQR-interquartile range) or count (percentage) Time variables are presented in minutes. Data analyzed with Mann Whitney U test or Chi-Square. (a) Includes 3 patients missing transport priority.

All component time intervals in the ≥60 minute group were statistically significantly longer than those in the <60 minute group (all $p<0.05$) (Table 2).

In the IPTW multivariate logistic regression analysis, no significant association between transported patients who had a prehospital time of ≥60 minutes and 30-day mortality was found (AOR 1.10, 95% CI 0.71-1.69) (Table 2). Similarly, we were unable to identify any individual time interval in the prehospital phase of the trauma patient's journey that had any significant association with 30-day mortality in either cohort (Table 3). We were also unable to identify any association between prehospital time of ≥60 minutes or total prehospital time and 30-day mortality in the sensitivity analysis of subgroups (Appendix 1). Similarly, no associations were found between prehospital time of ≥60 minutes or total prehospital time and one, three or seven-day mortality (Appendix 2).

Table 3 Adjusted and unadjusted odds ratios (OR) and 95% confidence intervals (CI) for 30-day mortality for major trauma patients who were transported by SJA-WA paramedics in the metropolitan area.

	All Patients ***N 1,625***	**IPTW Sample** ***N 1,553***
	Unadjusted OR (95% CI)	**Adjusted OR (95% CI)**
Prehospital time		
< 60 minutes	*Reference*	*Reference*
≥ 60 minutes	0.48 (0.37-0.64)	1.10 (0.71-1.69)
Total Time	0.32 (0.22-0.46)	1.15 (0.60-2.19)
Response Time	0.65 (0.51-0.82)	1.00 (0.64-1.59)
On-Scene Time	0.69 (0.53-0.89)	1.15 (0.65-2.04)
Transport Time	0.61 (0.51-0.74)	1.09 (0.75-1.59)
Age, years	1.02 (1.01-1.02)	1.06 (1.05-1.07)
Male Sex	1.18 (0.91-1.54)	1.17 (0.75-1.81)
Blunt Injury	*Reference*	*Reference*
Penetrating Injury	2.27 (1.33-3.89)	12 (3.80-36)
Injury Severity Score		
16-24	*Reference*	*Reference*
25-50	8.20 (5.95-11)	5.21 (3.38-8.04)
>50	63 (30-133)	76 (16-359)
Systolic Blood Pressure		
SBP ≥ 90mmHg	*Reference*	*Reference*
SBP <90mmHg	4.77 (3.63-6.26)	2.41 (1.32-4.39)

	All Patients *N 1,625*	IPTW Sample *N 1,553*
	Unadjusted OR (95% CI)	**Adjusted OR (95% CI)**
Respiratory Rate		
10-29 per min	*Reference*	*Reference*
>29 per min	1.90 (1.26-2.86)	0.97 (0.49-1.90)
≤ 9 per min	45 (25-82)	4.82 (1.30-18)
Glasgow Coma Scale		
13-15	*Reference*	*Reference*
9-12	4.65 (3.02-7.14)	5.10 (2.83-9.18)
6-8	6.08 (3.90-9.46)	9.42 (5.17-17)
3-5	31 (22-45)	46 (21-98)
Prehospital Interventions		
Number of Interventions	1.65 (1.44-1.89)	1.29 (0.97-1.71)
Hospital Destination		
Direct Trauma Center	*Reference*	*Reference*
Indirect Trauma Center	0.46 (0.33-0.66)	1.18 (0.67-2.07)
No Trauma Center	1.94 (1.47-2.54)	3.66 (2.20-6.09)

Note. IPTW – Inverse probability of treatment weighting. Weighted for prehospital time <60 or ≥60. Weighted on ISS, tRTS, transport destination, age and blunt/penetrating injury. Abbreviations are as follows; SBP= systolic blood pressure, OR= odds ratio, CI= confidence interval. Total prehospital time and prehospital time ≥60 were entered into separate models due to significant multi collinearity with the other time variables.. Interventions; advanced airway, [endotracheal intubation, cricothyroidotomy, supraglottic airway device insertion] needle thoracocentesis, vascular access [intravenous, intraosseous], pelvic splint, combat application tourniquet, spinal immobilization.

Non-attendance at the Trauma Center was associated with 3.66 times the odds of 30-day mortality (95% CI 2.20-6.09) (Table 3). Similarly penetrating injury, older age, higher ISS, GCS <12, systolic blood pressure (SBP) <90mmHg and respiratory rate ≤9 were factors that had a statistically significant association with mortality.

In those patients who survived at least 30-days, there was no association between a prehospital time of ≥60 minutes and a longer LOS (Table 4). However, in the 30-day survivors, one-minute increase of on-scene time was associated with 1.16 times (95% CI 1.03-1.31) longer LOS (Table 4). There was no evidence of effect modification between any time interval variable and clinical variable (all interactions $p>0.05$).

Table 4 Adjusted effects of more than one hour prehospital time and one minute increases in total, response, on-scene and transport time on the length of hospital stay (LOS, days) for major trauma patients who survived at least 30-days.

	IPTW Sample *N 1,553*
	Exp (B) (95%CI)
Prehospital Time	
<60 minutes	*Reference*
≥ 60 minutes	1.02 (0.92-1.13)
Total time	1.10 (0.94-1.29)
Response Time	1.05 (0.94-1.17)
On-Scene Time	1.16 (1.03-1.31)
Transport Time	0.93 (0.85-1.01)

Note. IPTW – Inverse probability of treatment weighting. Weighted for prehospital time <60 or ≥60. Weighted on ISS, tRTS, transport destination, age and blunt/penetrating injury.

Total prehospital time and prehospital time ≥60 were entered into separate models due to significant multi collinearity with the other time variables. Controlling for age, sex, transport destination, Glasgow Coma Scale, systolic blood pressure <90mmHg, respiratory rate, ISS cat and type of trauma (blunt/penetrating), number of interventions; advanced airway, [endotracheal intubation, cricothyroidotomy, supraglottic airway device insertion], needle thoracocentesis, vascular access [intravenous, intraosseous], pelvic splint, combat application tourniquet, spinal immobilization. Log-normal model and results represent multiplicative increases in LOS per 1 minute increase in prehospital time. Exp (B) indicates the exponentiated coefficient. LOS=length of stay.

8.6 Discussion

This retrospective cohort study of adult major trauma patients transported to hospital by ambulance paramedics attempted to determine if an association existed between prehospital time and patient outcomes. The hypothesis that longer prehospital times would be associated with increased odds of 30-day mortality was not supported by this study, even after controlling for known predictors of major trauma mortality. Moreover, we were unable to demonstrate an association between prehospital time ≥60 minutes (the so-called 'golden hour') and 30-day mortality or hospital LOS (in 30-day survivors) for transported patients. However, we did report an association between longer on-scene time and longer hospital LOS (in 30-day survivors).

The 'Golden Hour' and Mortality

Trauma patients are a heterogeneous group, which creates challenges in demonstrating the effect of time on outcome when a proportion of patients have no time-dependent outcome.[155] Our inability to find an association between prehospital time of more than the 'golden hour' and mortality is not unique. Previous research conducted on different patient populations, in different trauma systems and care delivery models have also failed to demonstrate a relationship between increasing prehospital time and mortality.[139, 155, 157, 158] Conversely, some studies have reported an apparent association between an increase in prehospital time and a decrease in mortality.[96, 145, 159] A recent study reported that despite being hypotensive on arrival, severely injured trauma patients with vital signs, had a substantially lower risk of mortality if they had prolonged prehospital times.[159] These findings suggest that prehospital time is unlikely to be a crucial factor in the management of all major trauma patients.

Individual Time Intervals and Mortality

It has been suggested that individual time intervals may be more related to the patient survival outcome than total prehospital time.[160] Whilst we did not find any association between response time and 30-day mortality, it is important to note that our study was based in the metropolitan area and the association between longer response times and mortality has previously been demonstrated in rural areas.[146] Moreover, patients who died at the scene were not captured in this study. It has been suggested that patients who are declared deceased on-scene may be those subjected to longer response times.[157] The time after the ambulance arrival is already known to be 60% less hazardous than the time from injury to the arrival of the ambulance [14] which suggests that those who survive to the arrival of the ambulance are in the survivor cohort.

The most debated time interval in the literature is that of the time spent on the scene of the incident. It has been shown previously that swift delivery to definitive care is beneficial in unstable patients with penetrating trauma [95, 160, 161] and those with severe head injuries.[130] However, in blunt trauma this association has not been so clearly demonstrated.[147] Despite our study reporting longer on-scene times than previous studies [95, 160] we still failed to find an increased likelihood of 30-day mortality. It has, however, been suggested that this apparent lack of association between longer prehospital times and death is strongly influenced by paramedics' perception of serious injury and acuity. Paramedics have the ability to quickly identify life-threats, thus, spending minimal time on-scene and taking more time with the less severely injured patients.[95, 96, 155]

Individual Time Intervals and Hospital LOS

In those patients who survived at least 30-days, we demonstrated an association between increasing on-scene times and longer LOS. Our study is one of a few that have looked at hospital LOS as an outcome in relation to prehospital times. One study found that in patients <65 years of age, total prehospital time correlated significantly with LOS but not mortality.[162] Conversely, another study found no association between LOS and total prehospital time in rural areas.[158] Our finding of an association between longer on-scene times and longer LOS in those who survived at least 30-days could be attributed to these patients being those who had their immediate life threats corrected in the additional time spent on-scene and thus were less likely to die.

Our study supports the concept that definitive care for a trauma patient should be provided at a Trauma Center.[26] Patients in this study were almost four times more likely to die in 30-days post major trauma if they never attended the Trauma Center. Therefore, it may be more pertinent to refer to the time from injury to definitive care as being pre-Trauma Center time and not prehospital time. As we have shown that prehospital time is not associated with an increased probability of 30-day mortality, but no attendance at a Trauma Center is, it seems imperative that further research is undertaken to ascertain whether prehospital times could safely be extended to enable major trauma patients to directly attend a Trauma Center.

It is apparent that the evidence surrounding prehospital times and their effect on patient survival outcomes is still equivocal. Therefore, our recommendation is that prehospital care is delivered in a timely fashion and the transport of the patient to hospital occurs reasonably promptly.

8.7 Strengths and Limitations

Our study is one of few studies investigating the association between prehospital time and outcomes that have used IPTW to reduce the risk of confounding. Nonetheless, there may have been unknown confounders that influenced associations seen in the multivariate analysis. Also, our small sample size may have been prone to type II error. However, our sample size is similar to previous studies.[96, 162] The inability to measure exact prehospital times is a limitation of most time-related prehospital research.[96] For example, time variables were calculated from the time that the call was received and not the actual time the injury was sustained, a time that is often unknown. Similarly, there is no distinction within the on-scene time that depicts the difference between the time spent extricating the patient from time spent treating the patient. Furthermore, missing prehospital physiological information may have influenced our results, however, this accounted for less than 5% of the data.

As with all studies using retrospective trauma registry data our study is subject to a potential survivor bias. Patients who died prehospital and those who exclusively attended a hospital that did not provide data to the State Trauma Registry were not captured by the study. However, not all the hospitals that contribute data to the registry are tertiary hospitals or Trauma Centers, thus, some patients who exclusively attended a secondary facility were captured by the study.

8.8 Conclusion

We found no association between prehospital times longer than the 'golden hour' and 30-day mortality in major trauma patients and we were unable to find a specific prehospital time interval that was associated with an increased probability of 30-day mortality. However, longer on-scene times were associated with longer hospital LOS in patients who survived at least 30-days. Based on these findings our recommendation is that prehospital trauma care be delivered in a timely fashion and transport of the patient to hospital is reasonably prompt.

Appendix 1 Summary of multivariate logistic regression sensitivity analysis of 30-day mortality of an inverse probability of treatment weighted (IPTW) sample of major trauma patients presented as adjusted odds ratio and confidence intervals.

	IPTW Sample ***N 1,553***
	Adjusted OR (95% CI)
Excluding prehospital CPR	
Total	1,451
<60 minutes	*Reference*
≥ 60 minutes	1.10 (0.70-1.72)
Total Time	1.08 (0.53-2.21)
Prehospital SBP <90mmHg	
Total	289
<60 minutes	*Reference*
≥ 60 minutes	1.22 (0.45-3.27)
Total Time	1.62 (0.44-5.92)
Major Head Injury	
Total	1,040
<60 minutes	*Reference*
≥ 60 minutes	1.25 (0.77-2.03)
Total Time	1.54 (0.76-3.15)

	IPTW Sample *N 1,553*
	Adjusted OR (95% CI)
Direct to Trauma Center	
Total	723
<60 minutes	*Reference*
≥ 60 minutes	0.85 (0.43-1.65)
Total Time	0.74 (0.30-1.80)

Note. Data presented as median and interquartile range (IQR). Total prehospital time and prehospital time ≥60 were entered into separate models due to significant multi collinearity with the other time variables. Controlling for age, sex, transport destination, Glasgow Coma Scale, systolic blood pressure <90mmHg, respiratory rate, ISS cat and type of trauma (blunt/penetrating), number of interventions; advanced airway, [endotracheal intubation, cricothyroidotomy, supraglottic airway device insertion], needle thoracocentesis, vascular access [intravenous, intraosseous], pelvic splint, combat application tourniquet, spinal immobilization.

Appendix 2 Summary of multivariate logistic regression sensitivity analysis of one, three and seven day mortality of an inverse probability of treatment weighted (IPTW) sample of major trauma patients presented as adjusted odds ratio and confidence intervals.

	IPTW Sample *N 1,553*
	Adjusted OR (95% CI)
Death in One Day	
<60mins	Reference
≥60mins	1.18 (0.68-2.03)
Total Time	1.19 (0.53-2.67)
Death in Three Days	
<60 minutes	Reference
≥ 60 minutes	1.31 (0.81-2.12)
Total Time	1.41 (0.69-2.88)
Death in Seven Days	
<60 minutes	Reference
≥ 60 minutes	1.14 (0.72-1.82)
Total Time	1.17 (0.58-2.37)

Note. Data presented as median and interquartile range (IQR). Total prehospital time and prehospital time ≥60 were entered into separate models due to significant multi collinearity with the other time variables. Controlling for age, sex, transport destination, Glasgow Coma Scale, systolic blood pressure <90mmHg, respiratory rate, ISS cat and type of trauma (blunt/penetrating), number of interventions; advanced airway, [endotracheal intubation, cricothyroidotomy, supraglottic airway device insertion], needle thoracocentesis, vascular access [intravenous, intraosseous], pelvic splint, combat application tourniquet, spinal immobilization.

END OF MANUSCRIPT

8.9 Extension of Results

Table 5 Overall prehospital time intervals presented as median and IQR

Prehospital Time	All patients before IPTW *N=1,625* Median (IQR)
Response Time	11 (8-14)
On-Scene Time	26 (19-34)
Transport Time	14 (9-21)
Total Time	53 (42-67)

Note. Time values presented in minutes, IQR-interquartile range

8.10 Extension of Discussion

'Stay and Play' or 'Scoop and Run'?

The time spent on the scene of an incident is the most debated time interval in the literature and the one that is the most amenable to modification. The time taken to respond to an emergency call and the time taken to transport a trauma patient to hospital is often dependent on traffic, weather conditions, geography and proximity to destination; factors that are beyond the control of EMS providers.[163] However, there are a number of factors that EMS providers do have some control over, that impact prehospital time. These being the time they spend on-scene and the interventions that they choose to perform.[163] As discussed previously, there are two discrete philosophies re 'on-scene time' namely: (1) that the patient should be rapidly removed from the scene, with minimal to no interventions ('scoop and run'); or (2) that the patient should be stabilised prior to transport ('stay and play').[143, 160]

This study did not find an association between on-scene time and 30-day mortality, therefore, providing no evidence to support either philosophy in relation to mortality. Although it has been shown previously that swift delivery to definitive care is beneficial in unstable patients with penetrating trauma [95, 160, 161, 164] and those with severe head injuries,[130, 165] it is important to consider that the aetiology of trauma in metropolitan Perth is predominantly blunt force, with penetrating trauma accounting for less than 4% of the study cohort. This may have been why no association between prehospital time and 30-day mortality was found and similarly may limit the generalisability of this study.[166] However, other studies of patients with blunt force trauma have also failed to clearly demonstrate an association between on-scene time and outcome.[147]

With respect to the ‘platinum ten minutes’[132] concept, there were not enough patients with an on-scene time ≤10 minutes to determine an association with either 30-day mortality or LOS (in 30-day survivors). Interestingly, the shortest reported median on-scene time of 22 minutes (IQR 17-27 in <60-minute group) and the overall median on-scene time of 26 minutes (IQR 19-34 minutes) are much longer than reported by previous studies (median 13 minutes reported in California [95] and 15 minutes reported in Pennsylvania [160]). These longer scene times could possibly be due to the configuration of the emergency ambulance crew, i.e. two crew members responding in an ambulance as opposed to a fire-based EMS with multiple responders attending. Despite these differences, no increased likelihood of 30-day mortality with these longer on-scene times was identified.

The inability of the analysis and other studies to demonstrate any association between prehospital time in excess of the ‘golden hour’ and increasing mortality (in certain studies showing the inverse), could lead one to postulate that time is not a crucial factor in the management of the major trauma patient. However, it is important to use caution when extrapolating these results into clinical practice. Thus, as has previously been asserted, timely prehospital care should not be discontinued based on these findings.[96]

8.11 Summary

The retrospective cohort study attempted to determine if there was an association between prehospital time and patient outcomes by using logistic and linear regression models derived with inverse probability of treatment weighting (IPTW) using the propensity scores. A total of 1,625 major trauma patients were included in the study. No association between longer prehospital times and increased odds of 30-day mortality was found. Neither was an association found between prehospital time ≥60 minutes (the so-called ‘golden hour’) and 30-day mortality or hospital LOS (in 30-day survivors) for transported patients. However, an association between longer on-scene time and longer hospital LOS (in 30-day survivors) was identified.[139, 155, 157, 15895, 96, 155] The finding of an increased likelihood of death if care was not provided at the Trauma Centre led to the undertaking of the comparison of mortality in major trauma patients transported directly or indirectly to the Trauma Centre versus non-transfer to the Trauma Centre, which is described in the following chapter.

Chapter 9 Transport Destination for Major Trauma Patients – Methodology

In the previous chapter, the association between prehospital time and outcomes in adult major trauma patients transported to hospital by EMS in Perth, WA was examined. Whilst undertaking the aforementioned study it was found that there was an association between 30-day mortality and Trauma Centre transport. To gain more understanding of the association between 30-day mortality and the Trauma Centre transport, further examination of the characteristics and outcomes of major trauma patients and their transport destinations was then undertaken. Transport destination was defined as being either direct or indirect transport to the Trauma Centre or non-transport to the Trauma Centre (i.e. those patients who died or were discharged from the initial hospital and not transferred to the Trauma Centre). The hypothesis was that those not transported to the Trauma Centre would have different characteristics and outcomes from those transported directly and indirectly to the Trauma Centre.

9.1 Background

EMS providers are responsible for determining the most appropriate facility to which trauma patients should be transported, and prehospital triage should ensure the transport of the right patient to the right hospital.[42] Major trauma patients have a significantly lower risk of death if their care is provided at a high-level Trauma Centre [26] therefore, for the severely injured trauma patient, the hospital destination should be a high-level Trauma Centre.[8, 26, 43, 44]

9.2 Rationale

The centralisation of Trauma Centres results in the right hospital for the trauma patient not always being the closest hospital. The decision must, therefore, be made as to whether to bypass the closest hospital and transport the patient directly to a Trauma Centre or to divert to the closest hospital for stabilisation, increasing the time to definitive care.[167] Whether major trauma patients should be transported directly to the Trauma Centre is a contentious issue and there is uncertainty as to whether direct transport reduces the risk of death.[13, 167, 168] The aim of this study was to examine and compare the characteristics and outcomes of major trauma patients between transport destinations.

The specific research aim was:

> To examine and compare the characteristics and outcomes of major trauma patients between transport destinations (Trauma Centre versus non-Trauma Centre).

The research objectives were:

- To describe and compare the characteristics of major trauma patients between transport destinations.
- To describe and compare the outcomes of major trauma patients between transport destinations.

9.3 Study Design

To achieve the aforementioned objective, a retrospective cohort study of adult (≥16 years) patients with major trauma who were transported by SJ-WA emergency ambulances in metropolitan Perth, WA between 1st January 2013 and 31st December 2016 was undertaken. This study has been published and is presented in Chapter 10. The following is an extension of the methodology used to undertake this study.

9.4 Study Setting

The setting for this study was the metropolitan area of Perth, WA as fully described in Chapter 2, Section 2.11.

Transport of Major Trauma Patients

As previously described in Chapter 2, Section 2.11, adult trauma patients (≥16 years) who were transported to hospital during the study period would have attended one of nine hospitals: three tertiary and six secondary hospitals. One of these tertiary hospitals was the designated State Adult Major Trauma Centre with the Royal Australasian College of Surgeons Level I Major Trauma Verification Status.[87] It was recommended by the WA Department of Health and the SJ-WA clinical practice guidelines that major trauma patients were transported to this Level I Trauma Centre directly.[73, 91] As discussed in Chapter 2, Section 2.9, an ISS >15 is a retrospective diagnosis that cannot be calculated prehospital, therefore, the SJ-WA clinical practice guidelines list situations where major trauma should be suspected and direct transport to the Trauma Centre should be considered (Thesis Appendix D).[73] These situations are detailed in Chapter 2, Section 2.11 and include the mechanism of injuries and anatomical criteria but not physiological criteria.

The metropolitan area of Perth, WA spans more than 6000km^2 and the Trauma Centre is situated in the centre of the city.[68] Therefore, paramedics and ambulance officers were permitted to divert to the nearest emergency department for stabilisation if the patient had an imminent life-threat.[73, 87] This meant that major trauma patients were not always transported directly to the Trauma Centre. In these cases, the patient would have been transported to one of the other two tertiary hospitals, five secondary facilities or one private emergency department. The two tertiary hospitals had the ability to provide limited services for inpatient management for a small number of major trauma patients upon agreement with the Trauma Centre. The five secondary facilities and one private hospital had the capacity to provide definitive care for non-major trauma.[87]

In cases where adult major trauma patients were transported to hospitals other than the Trauma Centre, The Department of Health provided a guideline which listed situations where inter-hospital transfer to the Trauma Centre, should be considered, and early liaison with the Trauma Centre was recommended (Thesis Appendix H).[91]

Derangement to vital signs:

- Respiratory rate <10 or >29 per minute.
- Oxygen saturations <94%.
- Systolic blood pressure <100mmHg.
- Glasgow Coma Scale score <14.
- Heart rate <50 or >120 per minute.

Or … Injuries:

- Flail chest.
- Multiple body regions injured.
- Two or more proximal long bone fractures.
- Amputation/crush injury (proximal to wrist or ankle).
- Degloved or mangled extremity.
- Suspected spinal injury.
- Open or depressed skull fracture.
- Pelvic fractures.
- Penetrating injury head/neck/torso (proximal to elbows/knees).

If a trauma patient met the above criteria and the transfer was appropriate, it was recommended that they were rapidly prepared for early inter-hospital transfer to the Trauma Centre.[91] For patients not meeting the above criteria, complete trauma evaluation and serial observations were required in those with high-risk mechanisms or high-risk populations.[91]

These included:

- Motor vehicle crash >60km/h.
- Motorbike crash >30km/h.
- Pedestrian/cyclist.
- Ejection.
- Fatality within the same vehicle.
- Fall >3 metres.
- Cabin intrusion (>30cm occupant's side or >45 cm any side).
- Explosion.
- Age >65 or <14 years.
- Pregnancy.
- Anticoagulant usage.

9.5 Inclusions and Exclusions

The inclusions and exclusions for this study are fully described in Chapter 5, Section 5.4 and 5.5.

9.6 Data Sources

For this study, the SJ-WA database and the WA-STR were used, both of which are fully described in Chapter 5, Section 5.6, together with how these databases were linked and the methods used to identify patients meeting the study criteria.

Western Australian State Trauma Registry (WA-STR)

Demographic details, injury mechanism, injury characteristics, length of hospital stay (recorded in full days from first hospital arrival to discharge) and patient discharge disposition (death, rehabilitation, home) were extracted from the WA-STR. Also extracted were the patient's initial hospital destination and the hospital they were subsequently transferred to (if this occurred).

St John - Western Australia Database (SJ-WA)

The patients' initial hospital destination was extracted from the SJ-WA database. Using the unique codes created by the ePCR tick boxes, the information in regard to prehospital interventions and observations (respiratory rate, systolic blood pressure measurement and Glasgow Coma Scale score) were also extracted.

Data Cleansing -Transport Groups

Using the information from both the SJ-WA database and the WA-STR three discrete transport groups were created:

- *Direct transports* – patients who were directly transported from the scene of the incident to the Trauma Centre.
- *Indirect transports* – patients who were transported to another metropolitan hospital prior to transfer to the Trauma Centre.
- *Non-transfers* – patients who never attended the Trauma Centre before being discharged alive or dying in hospital.

Data Cleaning – Prehospital Observations

As described in Chapter 5, Section 5.6 each individual patient had a unique PRECRU identification number. However, for every PRECRU identification number there could be multiple records (‘case numbers’). The ‘transport destination’ code was used to identify which ‘case number’ pertained to ‘backup’ ambulances and which ‘case numbers’ pertained to the ‘primary’ attending/transporting crew and any subsequent inter-hospital transfer. All the ePCR data that pertained to each individual patient was examined to ascertain whether they had any of the following observations at any time prehospital:

- Respiratory rate <9 or >29 per minute.
- Systolic blood pressure <90mmHg.
- Glasgow Coma Scale score ≤8.

The cut-off values for the tRTS [59] were used to categorise the physiological parameters and to ensure that there were at least 10 patients per category to reduce bias and avoid unreliable CI calculation.[148]

Data Cleaning – Prehospital Time

As described in Chapter 7, Section 7.6, the time that the emergency call (000 call) was received by the SJ-WA State Operations Centre until the arrival of the patient at the initial hospital destination (prior to subsequent inter-hospital transfer) was used as the total prehospital time. This time variable was calculated and reported in minutes.

9.7 Statistical Analysis

Descriptive Statistics

To describe the cohort, descriptive statistics were used, including median and IQR for continuous variables and counts and percentages for categorical variables. The differences between the groups were assessed using the Kruskal-Wallis test for continuous variables and Pearson chi-square or Fisher's exact for categorical variables. A p-value <0.05 was regarded as statistically significant.

The results of this study are reported in the next chapter, along with a discussion of these findings.

Chapter 10 Transport Destination for Major Trauma Patients

10.1 Overview

To achieve the aim of examining and comparing the characteristics and outcomes of major trauma patients between transport destinations a retrospective cohort study was undertaken. The specific research objectives were to describe and compare the characteristics and outcomes of major trauma patients between transport destinations.

The findings of this study are reported in the following manuscript.

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. A Comparison of Major Trauma Patient Transport Destination in Metropolitan Perth, Western Australia. Australasian Emergency Care. 2019. [In Press].

Permission to include the manuscript in this thesis has been obtained from Elsevier and a copy of the permission is included in Thesis Appendix I.

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Research paper

A comparison of major trauma patient transport destination in metropolitan Perth, Western Australia

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ABSTRACT

Background: Despite evidence of a lower risk of death, major trauma patients are not always transported to Trauma Centres. This study examines the characteristics and outcomes of major trauma patients between transport destinations.
Methods: A retrospective cohort study of major trauma patients (Injury Severity Score >15) transported by ambulance was undertaken. Cases were divided into transport destination groups: (1) *Direct*, those transported to the Trauma Centre directly from the scene; (2) *Indirect*, those transported to another hospital prior to Trauma Centre transfer and (3) *Non-transfers*, those transported to a non-Trauma Centre and never subsequently transferred. Median and interquartile range (IQR) were used to describe the groups and differences were assessed using the Kruskal–Wallis test for continuous variables and Pearson chi-square for categorical.
Results: A total of 1625 patients were included. The median age was oldest in the *non-transfers* cohort (72 years IQR 46–84). This group had the highest proportion of falls from standing and head injuries (n = 298/400, 75%, $p < 0.001$). The *non-transfers* had the highest proportion of 30-day mortality (n = 134/400, 34%).
Conclusions: There were significant differences between the groups with older adults, falls and head injuries over-represented in the non-transfer group. Considering the ageing population, trauma systems will need to adapt.

Background

Major trauma patients are reported to have a significantly lower risk of death if their care is provided in a Trauma Centre [1,2]. In an optimal trauma system, prehospital triage ensures the transport of the right patient to the right hospital [3]. This system of care involves trauma patients being transported to a small number of specialised Trauma Centres, staffed and equipped to provide multidisciplinary care to severely injured patients, as opposed to the closest hospital facility.[2,4,5] However, whether all major trauma patients should attend a Trauma Centre directly, bypassing closer lower level hospitals is a contentious issue and there is currently uncertainty as to whether direct transport reduces the risk of death [6–8]. Therefore, the decision as to where to transport major trauma patients is inherently complex and must consider the patients' physiological and anatomical injury severity, distance to the Trauma Centre and traffic conditions [9].

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The Western Australian (WA) Department of Health recommends that major trauma patients (defined as any injury that has the potential to cause prolonged disability or death) are transported directly to the Level 1 Trauma Centre [10]. The St John-WA (SJ-WA) Clinical Practice Guidelines highlight certain situations in which major trauma should be considered and direct transport to the Level 1 Trauma Centre initiated [11]. These include both mechanism of injury and anatomical criteria but exclude any physiological criteria. Mechanisms of injury include but are not limited to: motorbike crashes >30 km/h with injuries, motor vehicle crashes >60 km/h with injuries and falls from >3 m. The anatomical criteria include amongst others: flail chest, pelvic fractures, open or depressed skull fractures and suspected spinal injuries [11]. If the patient has an imminent life-threat, paramedics are permitted to divert to the nearest emergency department for stabilisation [11,12]. The patient should then be prepared for rapid and early inter-hospital transfer to the Trauma Centre [10]. As the metropolitan area of Perth, WA spans more than 6000 km^2 with the sole Level 1 Trauma Centre located in the centre of the city [13] major trauma patients are not always transported to the Trauma Centre directly, with initial resuscitation and stabilisation often provided at a closer hospital facility prior to secondary transfer [11,12].

The aim of this study was to examine and compare the characteristics and outcomes of major trauma patients between transport destinations in the metropolitan area of Perth, WA. Transport destination was defined as being either direct or indirect transport to the Trauma Centre or non-transport to the Trauma Centre (i.e. those patients who died or were discharged from the initial hospital and not transferred to the Trauma Centre). We hypothesised that those not transported to the Trauma Centre would have different characteristics and outcomes from those transported directly and indirectly to the Trauma Centre.

Methods

Study design

We conducted a retrospective cohort study of patients aged ≥16 years with major trauma, defined as an Injury Severity Score (ISS) >15 from a blunt or penetrating mechanism of injury, who were transported by SJ-WA in metropolitan Perth between 1st January 2013 and 31st of December 2016. Consistent with previous studies [14,15] and the definition of physical trauma being 'a body wound produced by sudden physical injury from impact, violence or accident' [16], cases involving drowning, hanging or poisoning were excluded. Also excluded from the study were patients who were not transported (i.e. from the scene of the incident) by SJ-WA, patients not transported by road ambulance (i.e. helicopter or fixed-winged aircraft) and those with late effects of injury (more than 24-h post-injury), or if their initial ambulance transport record could not be obtained.

Study setting

SJ-WA is the sole provider of emergency ambulance services in WA, serving a population of over 2.5 million, with 78% of the state's population residing in the metropolitan area of Perth [17]. All metropolitan emergency ambulances are double-staffed with at least one qualified paramedic and all crews can provide advanced-life support, but not rapid sequence intubation [11]. Adult trauma patients who were transported during the study period would have attended one of nine hospitals: three tertiary and six secondary hospitals. One of the tertiary hospitals was the Level 1 Trauma Centre [12]. The other two tertiary hospitals provided services for limited inpatient management for a small number of major trauma patients upon agreement with the Level 1 Trauma Centre. The five secondary facilities and one private hospital provided definitive care for non-major trauma [12].

Data sources

Four hospitals contribute data to the State Trauma Registry. These include the three tertiary hospitals (including the Level 1 Trauma Centre) and one of the secondary hospitals. Included in the registry are data for patients transferred to one of these facilities after initial treatment at a metropolitan hospital that did not provide data to the registry [18]. Patients were identified in the State Trauma Registry if their ISS was >15, their mode of arrival was recorded as 'ambulance' and the location of where their injury occurred was depicted as 'metropolitan'.

Demographic details, injury mechanism, injury characteristics and discharge disposition (death, home, rehabilitation) were then extracted and linked with the ambulance transport record from the SJ-WA database using either deterministic or probabilistic matching (FRIL ver.2.1.5, Emory University and Centers for Disease Control and Prevention, Atlanta, Georgia, U.S.). Key identifiers (date of birth, first and last names and residential address) were used to create a likelihood score indicating a correct link between the databases. If the score was close to a predetermined cut-off value they were manually checked. Linkage failure occurred if the key identifiers were missing in the SJ-WA database.

Patient transport destination, prehospital observations and prehospital times were extracted from the SJ-WA database. This database contains information from the electronic patient care record (ePCR), completed for each case by paramedics, together with data from the computer-aided dispatch system. Cases were divided into three groups, based on transport destination: (1) *Direct*, those who were transported to the Trauma Centre directly from the scene of the incident. (2) *Indirect*, those patients who were transported to another metropolitan hospital prior to Trauma Centre transfer and (3) *Non-transfers*, those major trauma patients who were transported to one of the other three hospitals but never attended the Trauma Centre prior to death or discharge.

The cut-off values for the triage Revised Trauma Score informed categorisation of the physiological parameters as follows: a systolic blood pressure measurement (SBP) <90 mmHg, a Glasgow Coma Scale score (GCS) of ≤8 and respiratory rate of ≤9 or >29 on any prehospital recording [19]. A severity level of each injury was measured according to the Abbreviated Injury Scale (AIS) ranging from 6 (fatal) to 1 (minor). AIS codes were used to identify whether a patient sustained a major injury in the six ISS body regions (head/neck, face, chest, abdomen, extremities and external). We defined major injury as an injury with AIS ≥ 3 and serious complications were defined as being acute kidney injury, acute myocardial infarction, acute respiratory distress syndrome, cardiac arrest, cardiac failure, deep vein thrombosis, pulmonary embolism, pneumonia, sepsis, stroke and unplanned return to the operating room [20].

Statistical analysis

It was anticipated that the data would be non-normally distributed, therefore, to describe the cohort we used median and interquartile range (IQR) for continuous variables and counts and percentages for categorical variables. Group differences were assessed using the Kruskal–Wallis test for continuous variables and Pearson chi-square or Fisher's exact for categorical variables. A *p*-value <0.05 was regarded as statistically significant. Data analysis was performed with IBM Statistical Package for Social Sciences (SPSS) Version 24.0 (IBM, Armonk, NY, USA).

Ethics approval

Ethical approval was obtained from the Curtin University Human Research Ethics Committee (HR 128/2013). Ethics approval for access to the State Trauma Registry data was obtained from the Royal Perth Hospital Human Research Ethics Committee (PRN 464). Approval to access SJ-WA data was obtained from the SJ-WA Research Governance Committee.

Results

From the State Trauma Registry, we identified 1904 major trauma cases occurring in the metropolitan area of Perth between 1st January 2013 and 31st of December 2016 of which 1664 met the study inclusion criteria. Of these, the initial ambulance transport record for 34 cases could not be obtained. Three cases could not be linked, possibly due to inaccurate identifiers or incorrect recording of the mode of transport in the registry and two cases were duplicated in the registry (Fig. 1). Of the 1625 patients included in the study, 766 (47%) were transported to the Trauma Centre *directly*, 459 (28%) were transported *indirectly* to the Trauma Centre and 400 (25%) were *non-transfers* (Table 1). The median age was oldest in the *non-transfers* cohort (72 years IQR 46–84 versus 45 years IQR 27–64, *direct* and 49 IQR 29–72 *indirect*, $p = 0.001$). The *non-transfers* group had the highest proportion of falls from standing (n = 212/400, 53%, $p < 0.001$) whereas the *direct* transport group had the highest proportion of motor vehicle crashes (n = 152/766, 20%, $p < 0.001$) (Table 1). The *indirect* transport group had the lowest incidence of prehospital systolic blood pressure <90 mmHg (n = 45/459, $p < 0.001$) respiratory rate of <9 or >29 (n = 41/459, 9%, $p < 0.001$) and a GCS ≤ 8 (n = 61/459, 13%, $p < 0.001$). Similarly, the *indirect* transport group had the lowest proportion of patients requiring prehospital cardiopulmonary resuscitation (CPR) (n = 6, 1.3%) whereas the *non-transfers* had the highest (n = 43, 10.8%, $p < 0.001$) (Table 1).

The median ISS was highest in the *direct* cohort (24 IQR 18–30 versus 22 IQR 17–26 *indirect* and *non-transfers* $p < 0.001$). Patterns of injuries were different between the study groups with the *non-transfers* having the highest proportion of major head injuries (n = 298/400, 75%, $p < 0.001$) and the least chest and abdominal injuries (Table 2).There was a total of 333 deaths in 30-days with 154 (46%) occurring in the *direct* group, 48 (15%) in the *indirect* and 131 (39%) in the *non-transfer* group ($p < 0.001$). Those in the *non-transfer* group had the highest proportion of 30-day mortality (n = 131/400, 33%). In the *direct* transport group the 30-day survivors had the longest LOS (10 days, IQR 5–21, $p < 0.001$) and there was the highest proportion of serious complications (n = 248, 32%, $p < 0.001$) (Table 2).

Discussion

Our study found significant differences between major trauma patients who were transported *directly* or *indirectly* to the Trauma Centre by ambulance and those who never received Trauma Centre care, during the study period. The *non-transfers* group were older, with a higher proportion of head injuries and falls from standing as their mechanism of injury. The *non-transfer* group also had the highest proportion of prehospital CPR and death within 30-days. Those in the *indirect* group had the lowest incidence of prehospital CPR, death in the emergency department and death within 30-days and the *direct* group had the highest ISS and the lowest median age.

The triage of major trauma patients is a critical process in a trauma system and often relies on decision tools consisting of physiological, anatomical, mechanism of injury and special considerations criteria [9]. Transport destination decisions for major trauma patients are multifaceted, however, they are likely to be based on the need for immediate resuscitation, traffic conditions [9] and geographic distance between the incident and the Trauma Centre [21,22]. The paramedics' decision not to take patients directly to the Trauma Centre is difficult to determine retrospectively and could be that the responsibility of single-handedly managing a critical patient prompted the paramedics to seek the closest emergency department or that the severity of the trauma was not initially identified.

Those in the *indirect* group had the smallest number of deaths compared to those in the *direct* and *non-transfer* groups. These patients also had the least evidence of prehospital physiological derangement suggesting that they were a more stable cohort [7]. It has recently been demonstrated that a 'trial of life' effect is present in severely injured blunt trauma patients who arrive at a Trauma Centre with vital signs, despite prolonged prehospital times and these patients have been found to have a substantially lower risk of subsequent mortality [23]. It is therefore plausible that there were fewer deaths in the *indirect* group as these patients had already undergone a trial of life and had less risk of mortality than those who were transported *directly* to the Trauma Centre and those who were never transported to the Trauma Centre.

On inspection of the *non-transfers* group, it was found that these patients were older, with a higher percentage of head injuries and falls from standing as their mechanism of injury. These differences may have influenced the clinical decisions of the paramedics as to where to transport patients. For example, head injuries are more likely to require immediate airway interventions, thus making transport to the nearest hospital more likely [24]. Conversely, it has been shown that older adults with severe injuries are less likely to be transported to a Trauma Centre than younger adults [25,26]. Reasons for this include the ability of older adults to appear deceptively uninjured due to their lack of apparent physiological derangement [27,28] and presence of occult hypoperfusion, which is difficult to identify [29]. Furthermore, there is often the presence of comorbidities, polypharmacy, anticoagulation/antiplatelet therapies and physiologic changes that can alter the response to injury [29]. Concerningly, the undertriaging of older adults increases the odds of mortality [26,28].

Major trauma is often associated with injuries that result in gross anatomical disruption or external haemorrhage which are easily recognised [30]. This may account for the higher proportion of patients injured in high energy transfer mechanisms of injury, such as motor vehicle crashes and the higher median ISS in the *direct* group. It is important to highlight that an ISS > 15 is a retrospective diagnosis which is made using information such as imaging, that is not available prehospital [31]. The current SJ-WA Major Trauma Guideline does not include a fall <3 m as a consideration for Level 1 Trauma Centre transport. Therefore, for a patient of any age with a fall from standing to be recognised as potentially having major trauma they would have to meet one of the anatomical criteria in the SJ-WA Major Trauma Guideline. Closed head injuries, which are highly prevalent in older adults because of increased use of anticoagulation and antiplatelet therapy [32], are not listed as an anatomical criterion. It is, therefore, unlikely that a patient with a fall from standing and a concomitant closed head injury would be considered for Trauma Centre transport and this, therefore, may account for the high proportion of falls in the *non-transfer* group.

The reasons for these patients in the *non-transfer* group not subsequently being transferred to the Trauma Centre are not understood. It is possible that the decision not to transfer may have been influenced by the patient's instability or the perception that the transfer would be futile due to pre-existing comorbidities or functional status. Furthermore, death may have occurred prior to transfer [33] or a decision made on end of life care.

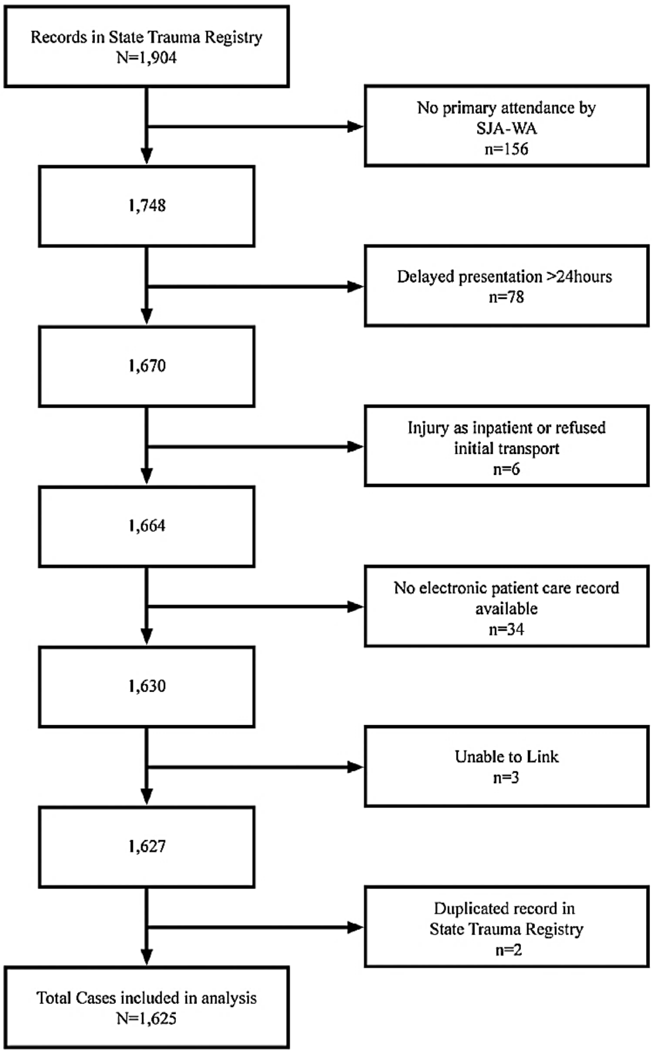

Fig. 1. Flowchart of included and excluded patients [38]. Permission to reproduce figure gained from Prehospital Emergency Care [38].

Major trauma has traditionally been viewed as a disease of the young [33]. However, in Australia, an increase in the proportion of major trauma patients aged ≥65 has been observed [34] and we have previously demonstrated that in the metropolitan area of Perth the median age of those with major trauma is 51 years of age and the most common mechanism of injury is a fall from standing [31]. Although mortality in older adults is known to be higher than their younger counterparts [35], it has been suggested that with appropriately configured services, good outcomes can be achieved [36]. Given this shift in major trauma to a greater proportion of older adults, trauma systems need to adapt to these changes [33]. Developing ways in which to identify major trauma in older patients prehospital is essential to enable these patients to receive appropriate care. It has previously been shown that the adoption of specific prehospital trauma triage criteria can significantly improve the detection of older patients requiring specialised care [37]. However, this will need to occur without reducing triage specificity. Further to this, training should be provided to paramedics regarding the altered response to trauma in older adults, which may assist in ensuring appropriate care for these patients [25]. In light of our findings, we suggest that there may be benefit in the addition of older adults as a special population in the Major Trauma Guideline.

Limitations

Our study has the following potential limitations. Data regarding the decision making of the paramedics were not available. Therefore, it is not known whether the patient's initial transport

Table 1
Demographic, mechanism of injury and physiologic data comparing major trauma patients transported by SJ-WA *directly* or *indirectly* to the Trauma Centre and *non-transfers*.

	Direct Median (IQR) or count (%)	Indirect Median (IQR) or count (%)	Non-transfers Median (IQR) or count (%)	*p*-value
Total	766 (47)	459 (28)	400 (25)	
Patient demographics				
Age	45 (27–64)	49 (29–72)	72 (46–84)	0.001*
Male sex	589 (76.9)	329 (71.7)	240 (60)	<0.001*
Mechanism				<0.001*
MVC	152 (20)	81 (18)	26 (7)	
MBC	116 (15)	67 (15)	34 (9)	
Pedestrian	73 (10)	21 (5)	12 (3)	
Pedal cyclist	38 (5)	19 (4)	12 (3)	
Fall from height	113 (15)	61 (13)	48 (12)	
Falls from standing	112 (15)	136 (30)	212 (53)	
Violence (gunshot, stabbing, assault)	86 (11)	44 (10)	29 (7)	
Other (fire, sport related, other)	76 (10)	30 (7)	27 (7)	
Prehospital characteristics				
Prehospital CPR	53 (6.9)	6 (1.3)	43 (10.8)	<0.001*
Prehospital observations				
SBP <90 mmHg	189 (25)	45 (10)	78 (20)	<0.001*
Respiratory Rate ≤9 or >29	156 (20)	41 (9)	59 (15)	<0.001*
GCS ≤ 8	209 (27)	61 (13)	80 (20)	<0.001*
Prehospital time[a]				
Total pre-hospital time (IQR)	55 (44–69)	51 (40–65)	53 (42–63)	0.001*

Data analysed with Kruskal–Wallis test for continuous variables and Pearson chi-squared or Fisher's exact for categorical variables. Presented as median (IQR-interquartile range) or count (percentage) Time variables are presented in minutes. * Significant.
Abbreviations: CPR = Cardiopulmonary Resuscitation, GCS = Glasgow Coma Scale score, MBC = Motorbike crash, MVC = Motor vehicle crash, SBP = Systolic blood pressure.
[a] Time from the emergency call being received to the patient's arrival at hospital.

Table 2
Injury characteristics and outcomes data comparing major trauma patients transported by SJ-WA *directly* or *indirectly* to the Trauma Centre and *non-transfers*.

	Direct Median (IQR) or count (%)	Indirect Median (IQR) or count (%)	Non-transfers Median (IQR) or count (%)	*p*-value
Total	766 (47)	459 (28)	400 (25)	
Trauma characteristics				
Injury severity score	24 (18–30)	22 (17–26)	22 (17–26)	<0.001*
Blunt trauma	725 (94.6)	449 (97.8)	390 (97.5)	0.006*
Major injury				
Head/Neck	453 (59)	330 (72)	298 (75)	<0.001*
Face[a]	11 (1)	5 (1)	2 (1)	0.359
Chest	329 (43)	166 (36)	110 (28)	<0.001*
Abdomen	128 (17)	69 (15)	46 (12)	0.060
Extremities	179 (23)	59 (13)	43 (11)	<0.001*
External[a]	31 (4)	2 (0.4)	10 (3)	0.001*
Mortality outcomes				
Death in 30-days	154 (20)	48 (10)	131 (33)	<0.001*
Died in emergency department	54 (7.0)	4 (0.9)	47 (11.8)	<0.001*
Outcomes				
Survivor length of stay	10 (5–21)	8 (5–14)	8 (3–15)	<0.001*
Any serious complication	248 (32)	109 (24)	50 (13)	<0.001*

Data analysed with Kruskal–Wallis test for continuous variables and Pearson chi-squared or Fisher's exact for categorical variables. presented as median (IQR-interquartile range) or count (percentage) Time variables are presented in minutes. * Significant.
[a] Fishers Exact Test. Major Injury AIS > 3.

destination was the Trauma Centre but diversion to a closer hospital for stabilisation from imminent life threats was required.

As with all studies using retrospective trauma registry data, the studies are subject to potential survivor bias. Patients who exclusively attended a hospital that did not provide data to the State Trauma Registry were not featured in the registry and these patients may have had different outcomes and characteristics from those included in the study.

Conclusion

We found significant differences between major trauma patients transported directly or indirectly to the Trauma Centre and those who were never transported to the Trauma Centre prior to death or discharge; with older adults, falls and head injuries over-represented in the non-transfer group. Considering the ageing population, trauma systems will need to adapt to these changes.

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Ethics approval

Ethical approval was obtained from the Curtin University Human Research Ethics Committee (HR 128/2013). Ethics approval for access to the State Trauma Registry data was obtained from the Royal Perth Hospital Human Research Ethics Committee (PRN

464). Approval to access St John (SJ-WA) data was obtained from the SJ-WA Research Governance Committee.

Declarations of Interest and Provenance

Paul Bailey is the Medical Director for St John Western Australia (SJ-WA) and Judith Finn receives partial salary support from SJ-WA. Elizabeth Brown is an SJ-WA Paramedic and PhD candidate and the recipient of a Scholarship funded by a National Health and Medical Research Council (NHMRC) Centre for Research Excellence grant.

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Paul Bailey is the Clinical Medical Director for SJ-WA.

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Gavin Pereira has no conflicts of interest.

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There are no other potential conflicts of interest to declare. The authors alone are responsible for the content and writing of the paper.

What is known

- As part of an optimal trauma system, prehospital triage should ensure transport of the right patient to the right hospital.
- Severely injured trauma patients should be treated at high-level Trauma Centres.
- Inaccurate prehospital triage results in patients who require Trauma Centre care not receiving this care or having access to this care delayed.

What this paper adds

- This study provides an overview of the characteristics and outcomes of major trauma patients by type of hospital destination.
- Those patients who were transported directly to the Trauma Centre were the youngest with the highest ISS.
- Those patients not receiving Trauma Centre care were older, had a higher proportion of major head injuries with falls as their mechanism of injury.

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10.2 Summary

The aim of this study was to examine and compare the characteristics and outcomes of major trauma patients between transport destinations. The critical process of triage of major trauma patients in a trauma system was discussed and the reliance on decision tools consisting of physiological, anatomical, mechanism of injury and special considerations criteria highlighted.[32] Furthermore, a suggestion was made that those in the *indirect* group were a more stable cohort as they had the least evidence of prehospital physiological derangement.[167] Evidenced by the smallest number of deaths occurring in this group.

The differences between the transport groups and the clinical decisions of the paramedics were discussed. A suggestion was made that the differences between the transport groups may have influenced transport decisions. For example, head injuries would be more likely to require immediate airway interventions, thus making transport to the nearest hospital more likely.[169] The reduction in likelihood of Trauma Centre in older adults was also discussed.[5, 170] Also highlighted was that patients with a fall from standing as their mechanism of injury would not meet the current SJ-WA major trauma guideline. Therefore, it would be unlikely that a patient with a fall from standing and a concomitant closed head injury would be considered for Trauma Centre transport which would account for the high proportion of falls in the *non-transfer* group.

The demographics and injury characteristics of patients in the *non-transfer* group led to the hypothesis that there was an association between age and Trauma Centre transport. To test this hypothesis the study, which is detailed in the following chapters, was undertaken.

Chapter 11 Older Adults and Trauma Centre Transport – Methodology

In the previous chapter, the characteristics and outcomes of major trauma patients between transport destinations were examined and compared. The transport destinations were defined as being either *direct* or *indirec*t transport to the Trauma Centre or *non-transfers*. The characteristics of those patients in the *non-transfers* group were significantly different from those in the other two groups. Given that the highest trauma incidence rate was in those 85-years and over (as described in the first study – see Chapter 4), further investigation of older adults with major trauma was deemed to be important.

It was hypothesised that:

- There would be a difference in the characteristics of major trauma between older and younger patients.
- Older age would be associated with a reduced likelihood of transport to the Trauma Centre.
- Non-Trauma Centre transport would be associated with in-hospital mortality in older adults, after controlling for known predictors of death in trauma.

11.1 Background

In many parts of the world, including Australia, older adults make up the most rapidly increasing section of the population.[68, 121] With a rapidly ageing Australian population, EMS attendances to these patients is likely to increase significantly over the coming decade.[171] Age is known to be a predictor of mortality in trauma, with patients aged ≥55 years injured in motor vehicle crashes or high falls, having a 12% increase in mortality for every one year increase in age.[172] Injured older adults also have greater morbidity and mortality than younger adults with similar injuries [173] and the existence of chronic comorbid conditions increases the risk of death after trauma.[122, 174] Older adults also have poorer outcomes due to higher rates of intensive care unit admissions,[175] an increased susceptibility to complications,[123, 176] complex social circumstances and need for longer recovery times post injury.[101] Despite the inherent complexities of treating older adults with major trauma, there is evidence to suggest that Trauma Centre care allows those who survive to function independently for several years post-injury.[177] In consideration of this it is imperative that older adults with major trauma have the severity of their injury recognised and appropriate hospital transport undertaken.[178]

11.2 Rationale

With the aging population, it is important to gain an understanding of the patterns of injury and outcomes of older adult major trauma patients as well as reviewing how these patients are managed by EMS.

The research aim was:

> To examine older adults with major trauma transported by EMS as a specific interest group of patients.

The specific research objectives were:

- To describe the demographics and injury characteristics of major trauma patients transported to hospital by EMS.
- To estimate the association between older age and EMS transport to a Trauma Centre.
- To estimate the association between Trauma Centre transport and in-hospital mortality in older adults with major trauma.

The exposure of interest was age. The primary outcome in this study was transport to the Trauma Centre. The secondary outcome was in-hospital mortality.

11.3 Study Design

To achieve the aforementioned objectives, a retrospective cohort study was undertaken, consisting of adult (≥16 years) patients with major trauma who were transported by SJ-WA emergency ambulances in metropolitan Perth, WA between 1st January 2013 and 31st December 2016.

11.4 Study Setting

The setting for this study was the metropolitan area of Perth, WA as fully described in Chapter 2, Section 2.11.

11.5 Inclusions and Exclusions

The inclusions and exclusions for this study are fully described in Chapter 5, Sections 5.4 and 5.5.

11.6 Data Sources

For this study, the SJ-WA database and the WA-STR were used, both of which are fully described in Chapter 5, Section 5.6, together with how these databases were linked and the methods used to identify patients meeting the study criteria. The methods used to extract the data are also described in Chapter 7, Section 7.6 and Chapter 9, Section 9.6.

Data Cleansing – Age and Hospital Destination

Information from both the SJ-WA database and the WA-STR was used to create two discrete transport groups:

- *Trauma Centre transport* – those patients who were in the *direct transports* group (patients who were directly transported from the scene of the incident to the Trauma Centre) or in the *indirect transports* group (patients who were transported to another metropolitan hospital prior to transfer to the Trauma Centre).
- *Non-Trauma Centre transport* – those patients in the *non-transfers* group (patients who never attended the Trauma Centre before being discharged alive or dying in hospital).

Older adults were defined as those aged ≥65 years. For comparison of older age groups, subcategories were created, these being ages 65-74, 75-84 and 85 years and over.

Data Cleaning – Prehospital Observations

As previously described in Chapter 5, Section 5.6, the PRECRU identification number was used to group cases together that pertained to the same patient. As detailed in Chapter 9, Section 9.6, all the ePCR data that referred to each individual patient was examined to determine if they had any of the following observations at any time prehospital:

- Respiratory rate of <9 or >29 per minute.
- Systolic blood pressure of <90mmHg.
- Glasgow Coma Scale score of ≤8.

11.7 Statistical Analysis

Descriptive Statistics

The summary statistics used to describe the cohort included: median and inter-quartile range (IQR) for continuous variables and counts and percentages for categorical variables. Differences between the age groups were assessed using the Kruskal-Wallis test for continuous variables and Pearson chi-square for categorical. A *p*-value <0.05 was considered to be statistically significant.

Logistic Regression for Trauma Centre Transport

Binary logistic regression was used to determine whether age ≥65 years was associated with transport to the Trauma Centre. The model was adjusted for variables with *p*-value <0.2 in the univariate analysis.[179]

These were:

- Mechanism of Injury.
- ISS.
- The first recorded prehospital Glasgow Coma Scale score.
- Major head injury (AIS ≥3).
- Major chest injury (AIS ≥3).
- Major abdomen injury (AIS ≥3).
- Major extremity injury (AIS ≥3).
- Sex.

Inverse Probability of Treatment Weighting (IPTW)

As transport destination for those ≥65 years could be affected by the predictors of outcomes, the logistic regression models were derived with IPTW using the propensity scores,[149] as previously described in Chapter 7, Section 7.7. The propensity scores were computed with a binary logistic regression model for transport destination (transport to the *Trauma Centre* versus transport to *Non-Trauma Centre*).

The model was adjusted for:

- ISS ≥25.
- Age.
- Major head injury (AIS ≥3).
- An incidence of a systolic blood pressure <90mmHg at any time prehospital.
- An incidence of a Glasgow Coma Scale score ≤8 at any time prehospital.

- An incidence of a respiratory rate <9 or >29 at any time prehospital.

Using this method, a weight was applied to each patient transported to the *Trauma Centre* by the inverse of the probability that they would have been transported to the *Trauma Centre* and weighted each patient transported to a *Non-Trauma Centre* by the inverse probability that they would have been transported to a *Non-Trauma Centre*.[151]

As previously described, the balance in measured covariates between the transport groups, were examined by comparing the standardised mean differences before and after the weighting.[152]

Logistic Regression for In-Hospital Mortality

Weights were then used to account for the confounding when estimating the effect of transport destination on in-hospital mortality. This was done by incorporating the weights into subsequent analyses comparing the outcomes between the transport groups.

The GENLIN command of IBM SPSS was used for deriving the model with weighting. To determine if transport destination was associated with in-hospital mortality in major trauma patients ≥65 years logistic regression models were derived.

The outcomes were adjusted for the following confounders:

- ISS ≥25.
- Age.
- Major head injury (AIS ≥3).
- An incidence of a systolic blood pressure <90mmHg anytime prehospital.
- An incidence of a Glasgow Coma Scale score ≤8 anytime prehospital.
- An incidence of a respiratory rate <9 or >29 per minute at any time prehospital.
- Transport to the *Trauma Centre*.

The results of this study are reported in the following chapter, along with a discussion of these results.

Chapter 12 Older Adults and Trauma Centre Transport

12.1 Overview

To achieve the aim of examining older adults with major trauma as a specific patient sub-group, a retrospective cohort study was undertaken consisting of adult (≥16 years) patients with major trauma who were transported by SJ-WA emergency ambulances in metropolitan Perth, WA, between 1st January 2013 and 31st December 2016. The specific objectives of this study were to (1) describe the demographics and injury characteristics of older adults with major trauma transported to hospital by EMS providers, (2) to determine the association between older age and EMS Trauma Centre transport and (3) to determine the association between Trauma Centre transport and in-hospital mortality in older adults with major trauma.

The findings of this study are reported in the following manuscript.

Brown E, Tohira H, Bailey P, Fatovich D, Pereira G, Finn J. Older Age is Associated with a Reduced Likelihood of Ambulance Transport to a Trauma Centre after Major Trauma in Perth. Emergency Medicine Australasia. 2019;31:763-71.

Permission to include the manuscript in this thesis has been obtained from John Wiley and Sons and a copy of the License Agreement is included in Thesis Appendix J.

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ORIGINAL RESEARCH

Older age is associated with a reduced likelihood of ambulance transport to a trauma centre after major trauma in Perth

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Abstract

Objective: To describe the characteristics and outcomes of older adult (≥65 years) major trauma patients in comparison with younger adults (16–64 years). To determine whether older age is associated with a reduced likelihood of transport (directly or indirectly) to a major trauma centre and whether this is associated with in-hospital mortality.

Methods: A retrospective cohort study of major trauma patients transported to hospital by St John Ambulance paramedics in Perth, Western Australia, between 1 January 2013 and 31 December 2016. Multivariate logistic regression was used to test the relationship between age and major trauma centre transport. Multivariate logistic regression analysis using inverse probability of treatment weighting was used to determine if major trauma centre transport was associated with in-hospital mortality in older adults.

Results: One thousand six hundred and twenty-five patients were included; of these 576 (35%) were ≥65 years. In comparison with younger adults, older adults had more falls as their mechanism of injury (n = 358 [62%] *versus* n = 102 [10%], $P \le 0.001$) and more major head injuries (n = 472 [82%] *versus* n = 609 [58%], $P \le 0.001$). Older adults had lower odds (adjusted odds ratio 0.52, 95% confidence interval [CI] 0.35–0.78) of major trauma centre transport and this was associated with 1.7 times the likelihood of in-hospital mortality (95% CI 1.04–2.7).

Conclusions: Older adults who were not transported to the trauma centre had an increased odds of in-hospital mortality. However, older age was associated with a significantly reduced likelihood of trauma centre transport. With the aging population, the development of specific prehospital triage criteria to enable the complexities of this higher-risk population to be identified is important.

Key findings

- Older age was associated with a significantly reduced likelihood of trauma centre transport.
- Older adults who were not transported to the trauma centre had an increased odds of in-hospital mortality.
- The most common cause of major trauma was a fall from standing.

Key words: *emergency medical services, major trauma, older adults, prehospital care.*

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Introduction

Major trauma has traditionally been viewed as a disease of the young,[1] more specifically, a disease of young males caused by high energy transfer mechanisms of injury.[1] However, in Australia, an increase in the proportion of patients with major trauma aged ≥65 years has been observed,[2] an increase that exceeds rates expected from population growth.[3]

Age is a well described predictor of morbidity and mortality after trauma[4,5] and patients with major trauma have a significantly lower mortality rate if their care is provided in a major trauma centre (TC).[6] However, the likelihood of

TC transportation has been shown to decrease with age.[7] The likelihood of non-major TC transportation increases by the age of 60 years[8] even when TC prehospital triage criteria are met.[7,9–11]

As the population is aging,[12] it is important that prehospital care evolves to better understand the needs of older persons following trauma.[3] Therefore, the objectives of this study were to: (i) compare characteristics of older major trauma patients with those of younger patients; (ii) compare characteristics of older adult major trauma patients across three age groups; (iii) determine whether older patients are less likely to be transported to the TC than younger patients (directly or indirectly); and (iv) determine the association between non-major TC transport and in-hospital mortality in older adults.

We hypothesised that: (i) there would be a difference in the characteristics of major trauma between older and younger patients; (ii) older age would be associated with a reduced likelihood of transport to the TC; and (iii) that non-major TC transport would be associated with in-hospital mortality in older adults, after controlling for known predictors of death in trauma.[13]

Methods

Study design

We conducted a retrospective cohort study of adult (≥16 years) major trauma patients with an Injury Severity Score (ISS) >15 from a blunt, penetrating or thermal mechanism of injury who were transported by St John Ambulance Western Australia (SJA-WA) in metropolitan Perth between 1 January 2013 and 31 December 2016. This time period was selected as it was the most recent complete calendar year period with data available. The exposure of interest was age. The primary outcome was transport to the TC and the secondary outcome, in-hospital mortality. We defined older persons as those aged ≥65 years, which is also in accordance with previous definitions of older persons in trauma studies.[2,3]

In keeping with the definition of trauma being 'a body wound produced by sudden physical injury from impact, violence or accident'[14] we excluded trauma resulting from drowning, hanging or poisoning. This definition is also consistent with previous trauma studies.[15,16] Patients not transported (i.e. from the scene of the incident) by SJA-WA and patients not transported by road ambulance were excluded from the study. Those with late effects of injury (more than 24-h post-trauma) and those who had no obtainable initial electronic ambulance transport record were also excluded.

Similar to studies conducted elsewhere, we categorised older adults into three groups for comparison: 65–74, 75–84 and 85 years or older.[3]

Study setting

The metropolitan area of Perth, Western Australia (WA) has a population of approximately 2 million, which is 78% of the state's population.[17] Over 65 year olds make up 13% of the state's population, with 79% of these living in the Perth metropolitan area.[18] SJA-WA is the sole provider of emergency ambulance services. Each ambulance is staffed with at least one paramedic and a second crew member who is either qualified or in-training. All crews have the capacity to provide advanced life support, excluding rapid sequence induction.[19]

During the study period, major trauma patients in Perth were transported to one of nine hospitals: three tertiary and six secondary hospitals. One of the tertiary hospitals is a Level 1 TC and formally verified by the Royal Australasian College of Surgeons.[20,21] The other two tertiary hospitals are Level 2 TCs (non-major TC) and therefore could provide services and inpatient management for a limited number of major trauma patients, on agreement with the TC if the patient's injuries were not considered severe enough to warrant transfer to the TC.[20] The five secondary hospitals and one private hospital provide definitive care for non-major trauma (non-major TC).[20]

For the duration of the study it was recommended by the WA Department of Health, that major trauma patients, defined as any injury that has the potential to cause prolonged disability or death, should be transported directly to the TC.[19,22] However, if there was an imminent life-threat, paramedics were permitted to divert to the nearest ED for patient stabilisation.[19,20] It was then recommended that the patient should be prepared for rapid and early inter-hospital transfer to the TC (indirect transport).[22]

Data sources

There are four hospitals that contribute data to the State Trauma Registry using the same data definitions. These hospitals are the three tertiary hospitals, including the TC and one of the secondary hospitals. Patients are also included in the registry if they are transferred to one of these facilities after initial treatment at another hospital that did not provide data to the registry.[23]

We identified patients in the State Trauma Registry if their ISS was >15, their mode of arrival was recorded as 'ambulance' and the location of injury occurrence was described as 'metropolitan'. We then extracted demographic details, injury mechanism, injury characteristics, length of hospital stay and date of death. We linked these data with the ambulance transport record from the SJA-WA database using either deterministic or probabilistic matching (FRIL version 2.1.5, Emory University and Centers for Disease Control and Prevention, Atlanta, GA, USA). Date of birth, first and last names and residential address were used as key identifiers to create a score indicating likelihood of a correct link between the databases. These scores were then manually checked if they were close to a predetermined cut-off value. If the key identifiers were missing in the SJA-WA database then linkage failure occurred. The SJA-WA database contains data from the electronic patient care record (ePCR), completed for each case by paramedics, together with data from the computer-aided dispatch system. From this database, we extracted the

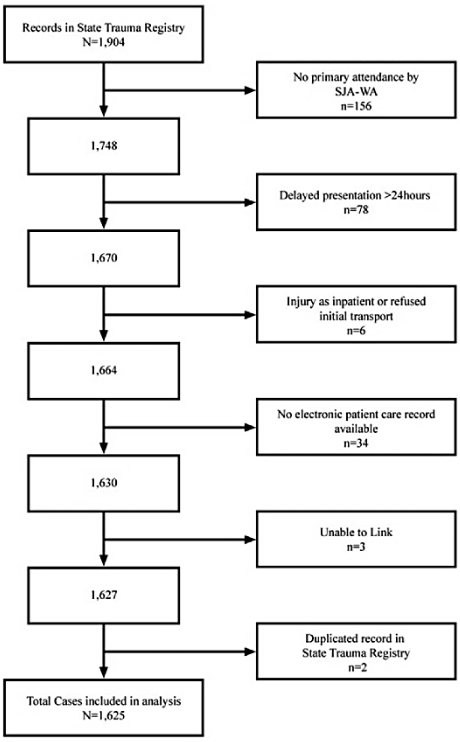

Figure 1. *Flowchart of included and excluded patients ≥16 years of age with major trauma, defined as an Injury Severity Score of >15 from a blunt, penetrating or thermal mechanism of injury and transported by St John Ambulance WA (SJA-WA) in the Perth metropolitan area, WA either directly or indirectly to one of four hospitals who provided data to the WA State Trauma Registry between 1 January 2013 and 31 December 2016.*[26]

patient transport destination and prehospital observations.

A severity level for each injury was measured according to the Abbreviated Injury Scale (AIS) ranging from 6 (fatal) to 1 (minor). We used AIS codes to identify whether a patient sustained a major injury in the six ISS body regions (head/neck, face, chest, abdomen, extremities and external). We defined major injury as an injury with AIS ≥3. The cut-off values for the Triage Revised Trauma Score informed categorisation of the physiological parameters (Glasgow Coma Scale Score [GCS], systolic blood pressure [SBP] and respiratory rate) and these were determined so that there would be at least 10 patients per category to reduce bias and improve precision.[24]

Statistical analysis

To describe the cohort, median and interquartile range (IQR) were used for continuous variables and counts and percentages for categorical variables. Differences between the age groups were assessed using the Kruskal–Wallis test for continuous variables and Pearson χ^2 for categorical variables. Binary logistic regression was used to determine whether age ≥65 years was associated with a likelihood of transport to the TC while adjusting for mechanism of injury, ISS, first prehospital GCS, major injuries in head, chest, abdomen and extremities and sex. Unadjusted odds ratios (ORs), adjusted odds ratios (AORs) and their 95% confidence intervals (CIs) were calculated. A *P*-value <0.05 was regarded as statistically significant. Potential interactions were tested and the presence of effect modification was deemed significant if a *P*-value of the interaction term was less than 0.05. The Hosmer–Lemeshow χ^2 test was used to assess goodness of fit of the model.

We used logistic regression to estimate the OR and their 95% CIs for in-hospital mortality to compare older adults (≥65 years) transported to the TC (directly or indirectly) with non-major TC transport. Adjustment was made for the following predictors: ISS ≥25, age, the presence of a major head injury and the incidence of a SBP <90 mmHg, GCS ≤8 and respiratory rate <9 or >29 at any time prehospital. The logistic regression model was applied with inverse probability of treatment weighting (IPTW) using the propensity scores.[25] Propensity scores were computed with binary logistic regression including the same predictors as the main model except the variable indicating a destination (transport to TC or non-major TC), which was used as the dependent variable. Assessment of the imbalance of predictors was undertaken by comparing the standardised mean difference before and after IPTW.

With the sample size in this study we had 90% power to detect ORs for TC transport of <0.67 and >1.59 for older patients (≥65 years) compared to younger patients (<65 years) at the 5% significance level assuming that 80% of younger adult patients receive TC transport.

Data analysis was performed with IBM Statistical Package for Social Sciences (SPSS) Version 24.0 (IBM, Armonk, NY, USA).

Ethics approval

Ethical approval was obtained from the Curtin University Human Research Ethics Committee (HR 128/2013). Ethics approval for access to the State Trauma Registry data was obtained from the Royal Perth Hospital Human Research Ethics Committee (PRN 464). Approval to access the SJA-WA data was obtained from the St John

TABLE 1. *Comparison of demographic, event and injury characteristics between adults with major trauma (ISS >15) aged 16–64 and ≥65 years†*

	Overall N = 1625	Age 16–64 years N = 1049	Age ≥65 years N = 576	P-value
Sex				
Male	1158 (71)	851 (81)	307 (53)	
Female	467 (29)	198 (19)	269 (47)	<0.001
Age (years)	51 (30–75)	36 (25–50)	80 (74–87)	<0.001
Outcome‡				
In-hospital mortality	339 (21)	169 (15)	170 (30)	<0.001
Death in ED	105 (6.5)	76 (7.2)	29 (5.0)	0.083
Survived to hospital discharge LOS median (IQR)	9 (5–17)	9 (5–17)	8 (5–16)	0.167
Any serious complications§	407 (25)	268 (25)	139 (24)	0.529
Prehospital CPR	102 (6.3)	87 (8.3)	15 (2.6)	<0.001
Injury Severity Score median (IQR)	22 (17–27)	24 (17–29)	22 (17–26)	<0.001
Major head injury	1081 (66)	609 (58)	472 (82)	<0.001
Major chest injury	605 (37)	475 (45)	130 (23)	<0.001
Major abdominal injury	243 (15)	208 (20)	35 (6.1)	<0.001
Major external injury	43 (2)	32 (3.1)	11 (1.9)	0.171
Major extremity injury	281 (17)	223 (21)	58 (10)	<0.001
Mechanism of injury				
Fall from standing	460 (28)	102 (10)	358 (62)	
Fall from height	222 (14)	141 (13)	81 (14)	
Motor vehicle crash	259 (16)	196 (19)	63 (11)	
Motor bike crash	217 (13)	212 (20)	5 (1.0)	<0.001
Pedal cyclist	69 (4.0)	51 (5.0)	18 (3.0)	
Pedestrian	106 (7.0)	74 (7.0)	32 (6.0)	
Violence	159 (10)	151 (14)	8 (1.0)	
Other¶	133 (8.0)	122 (12)	11 (2.0)	
Location of injury occurrence				
Home	513 (32)	218 (21)	295 (51)	
Residential institution	95 (6)	4 (1.0)	91 (16)	
Street or highway	670 (41)	546 (52)	124 (21)	<0.001
Public area	117 (7)	89 (8.0)	28 (5)	
Other	230 (14)	192 (18)	38 (7)	
Response priority				
Priority 1	1290 (79)	932 (89)	358 (62)	
Priority 2	304 (19)	112 (10.5)	192 (33)	<0.001
Priority 3	31 (2)	5 (0.5)	26 (5)	
Transport priority††				
Priority 1	759 (47)	592 (56)	167 (29)	
Priority 2	537 (33)	340 (32)	197 (34)	<0.001
Priority 3 and lower	326 (20)	114 (11)	212 (37)	
Hospital destination				
Direct to major trauma centre	766 (47)	578 (55)	188 (33)	
Indirect to major trauma centre	459 (28)	303 (29)	156 (27)	<0.001
Non-major trauma centre	400 (25)	168 (16)	232 (40)	

†Data are presented as count (percentage). Data analysed with Mann–Whitney *U*-test or χ^2. ‡Major injury = Abbreviated Injury Scale Score ≥3. §Serious complications = acute kidney injury, acute myocardial infarction, acute respiratory distress syndrome, cardiac arrest, cardiac failure, deep vein thrombosis, pulmonary embolism, pneumonia, sepsis, stroke and unplanned return to the operating room.[27] ¶Fire, sport related, other. ††Three patients missing transport priority in the 16–64 year cohort. Response priority = call to scene. Transport priority = scene to hospital.

TABLE 2. *Comparison of demographic, event and injury characteristics between older adults with major trauma (ISS >15) stratified by age group†*

	Age 65–74 years (*N* = 159)	Age 75–84 years (*N* = 219)	Age ≥85 years (*N* = 198)	*P*-value
Sex				
Male	102 (64)	115 (52)	90 (45)	0.002
Female	57 (36)	104 (48)	108 (55)	
Outcome				
In-hospital mortality	38 (24)	63 (29)	69 (35)	0.075
Death in ED	8 (5)	12 (6)	9 (5)	0.909
Survived to hospital discharge LOS median (IQR)	10 (5–19)	9 (4–15)	7 (3–15)	0.013
Injury characteristics‡				
Any serious complications§	42 (26)	51 (23)	46 (23)	0.731
Injury Severity Score median (IQR)	25 (17–29)	24 (17–26)	21 (17–26)	0.004
Major head injury	119 (75)	179 (82)	174 (88)	0.006
Major chest injury	55 (35)	50 (23)	25 (13)	<0.001
Major abdominal injury	12 (7.5)	17 (7.8)	6 (3.0)	0.086
Major extremity injury	17 (11)	23 (10)	18 (10)	0.851
Mechanism of injury				
Fall from standing	61 (38)	136 (62)	161 (81)	
Fall from height	31 (20)	32 (15)	18 (9.0)	<0.001
Motor vehicle crash¶	29 (18)	29 (13)	10 (5.0)	
Pedestrian	8 (5.0)	16 (7.0)	8 (4.0)	
Other††	30 (19)	6 (3.0)	1 (1.0)	
Location of injury occurrence				
Home	74 (47)	112 (51)	109 (55)	
Residential institution	3 (2.0)	28 (13)	60 (30)	<0.001
Street or highway	56 (35)	48 (22)	20 (10)	
Public area	8 (5.0)	15 (7.0)	5 (3.0)	
Other	18 (11)	16 (7.0)	4 (2.0)	
Response priority				
Priority 1	121 (76)	138 (63)	99 (50)	
Priority 2	34 (21)	70 (32)	88 (44)	<0.001
Priority 3	4 (3.0)	11 (5.0)	11 (6.0)	
Transport priority				
Priority 1	61 (38)	69 (31)	37 (19)	
Priority 2	67 (42)	80 (37)	50 (25)	<0.001
Priority 3 and lower	31 (20)	70 (32)	111 (56)	
Hospital destination				
Direct to major trauma centre	53 (33)	73 (33)	62 (31)	
Indirect to major trauma centre	55 (35)	63 (29)	38 (19)	0.004
Non-major trauma centre	51 (32)	83 (38)	98 (50)	

†Data are presented as count (percentage). Data analysed with Kruskal–Wallis or χ^2. ‡Major injury = Abbreviated Injury Scale Score ≥3. §Serious complications = acute kidney injury, acute myocardial infarction, acute respiratory distress syndrome, cardiac arrest, cardiac failure, deep vein thrombosis, pulmonary embolism, pneumonia, sepsis, stroke and unplanned return to the operating room.[27] ¶Includes motorbike crash. ††Includes violence, pedal cyclists, fire, sport related, other.

Ambulance Research Governance Committee.

Results

We identified 1664 major trauma patients with an ISS >15 from a blunt, penetrating or thermal mechanism of injury who were transported by SJA-WA in metropolitan Perth during the 4 year study period. Of these 1664 records; we could not obtain the initial ambulance transport record for 34 cases. Three cases could not be linked, possibly because of inaccurate identifiers or incorrect recording of the mode of transport in the registry and two cases were duplicated in the registry (Fig. 1).

Included in the study were 1625 major trauma patients. Of these 576 (35%) were ≥65 years of age. In the younger adult group (16–64 years), the median age was 36 years (IQR 25–50) and 851 (81%) were male; whereas in the older adult group (≥65) the median age was 80 years (IQR 74–87) and 307 (53%) were male (Table 1).

Overall, the most common mechanism of injury was a fall from standing (*n* = 460, 28%) with 12% more patients injured by this mechanism than the second most common mechanism, motor vehicle crashes (*n* = 259, 16%). For the younger adult group motorbike crashes were the most common mechanism of injury (*n* = 212, 20%); whereas falls from standing were the most common in the older adult group (*n* = 358, 62%) (Table 1). Other differences included the location where the injury occurred; in the younger adult group, this was most commonly on a street or highway (*n* = 546, 52%) whereas the older adult group injuries most commonly occurred at home (*n* = 295, 51%). The presence of major head injuries was also greater in older adults (*n* = 472 [82%] *versus* *n* = 609 [58%], $P \leq 0.001$).

As age increased the proportion of female patients increased and in the oldest age group (≥85 years) females accounted for 55% (*n* = 108) compared with 36% (*n* = 57) in those aged 65–74 years (Table 2). A

TABLE 3. *Unadjusted and multivariate logistic regression analysis for trauma centre transport (direct/indirect) in major trauma patients who were transported by SJA-WA paramedics in the metropolitan area*

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Age		
16–64 years	Reference	Reference
65–74 years	0.40 (0.28–0.59)	0.52 (0.35–0.78)
75–84 years	0.31 (0.23–0.43)	0.48 (0.33–0.71)
≥85 years	0.19 (0.14–0.27)	0.37 (0.24–0.55)
Mechanism of injury		
Other†	Reference	Reference
Fall from standing	0.23 (0.18–0.29)	0.47 (0.33–0.67)
Other‡	Reference	Reference
Motor vehicle crash	3.4 (2.2–5.2)	2.5 (1.6–4.0)
Other§	Reference	Reference
Motor bike crash	1.9 (1.3–2.8)	1.1 (0.70–1.7)
Other¶	Reference	Reference
Pedestrian	2.7 (1.5–5.0)	2.5 (1.3–5.0)
Prehospital Glasgow Coma Scale		
13–15	Reference	Reference
9–12	0.76 (0.52–1.1)	0.79 (0.51–1.2)
6–8	1.6 (0.95–2.6)	1.5 (0.84–2.5)
3–5	0.94 (0.68–1.3)	0.58 (0.40–0.85)
Injury Severity Score		
16–24	Reference	Reference
≥25	0.92 (0.73–1.6)	0.92 (0.70–1.2)
Major injury		
Absent or AIS <3	Reference	Reference
Major head injury	0.61 (0.47–0.78)	1.3 (0.88–1.9)
Absent or AIS <3	Reference	Reference
Major chest injury	1.8 (1.4–2.3)	1.03 (0.74–1.4)
Absent or AIS <3	Reference	Reference
Major abdominal injury	1.5 (1.05–2.1)	0.88 (0.59–1.3)
Absent or AIS <3	Reference	Reference
Major extremity injury	2.0 (1.4–2.8)	1.4 (0.96–2.1)
Sex		
Female	Reference	Reference
Male	2.0 (1.6–2.5)	1.4 (1.1–1.8)

†Includes motor vehicle crash, motorbike crash, pedestrian, violence, pedal cyclist and falls from height, fire, sport related, other. ‡Includes falls from standing, motorbike crash, pedestrian, violence, pedal cyclist and falls from height, fire, sport related, other. §Includes falls from standing, motor vehicle crash, pedestrian, violence, pedal cyclist and falls from height, fire, sport related, other. ¶Falls from standing, motor vehicle crash, motorbike crash, pedestrian, violence, pedal cyclist and falls from height, fire, sport related, other.

median ISS of 21 (IQR 17–26) in the oldest age group (≥85 years) was significantly lower than the ISS of 25 (IQR 17–29) for 65–74 group ($P = 0.004$).

Younger adults had the lowest percentage of deaths in-hospital ($n = 169$ [15%] *versus* $n = 170$ [30%], $P < 0.001$) (Table 1). The majority of patients in the younger adult group were taken directly to the TC ($n = 578$, 55%) whereas the majority of patients in the older adult group were non-major TC transports ($n = 232$ [40%], $P < 0.001$) (Table 1). In the oldest group (≥85 years) 50% ($n = 98$) were non-major TC transports compared to 32% ($n = 51$) of those aged 65–74 years and 38% ($n = 83$) of those aged 75–85 years (Table 2).

A multivariate logistic regression model was applied with transport to the TC as an outcome, adjusting for age, sex, mechanisms of injury, prehospital GCS, ISS, existence of major head, chest, abdominal and/or extremity injuries. This model showed a reduction in the odds of TC transport with increasing age (Table 3). Compared to younger adults, those aged 65–74 years had a 48% reduction in the odds of being transported to the TC (AOR 0.52, 95% CI 0.35–0.78) and those aged ≥85 years had a 63% reduction (AOR 0.37, 95% CI 0.24–0.55) (Table 3). Overall, a fall from standing resulted in more than 53% reduced odds of TC transport (AOR 0.47, 95% CI 0.33–0.67). Positive predictors of TC transport included motor vehicle crash (AOR 2.5, 95% CI 1.6–4.0) and male gender (AOR 1.4, 95% CI 1.1–1.8). There was no evidence of effect modification between the age variable and any other variable (all interactions $P > 0.05$). There was little evidence of poor model fit (Hosmer–Lemeshow $\chi^2 = 6.04$, $P = 0.64$).

After weighting, the potential imbalance between the transport groups was mostly eliminated as shown by the standardised mean difference (Appendix S1) except for age. The IPTW multivariate logistic regression analysis showed that in patients ≥65 years non-major TC transport was associated with 1.7 times increased likelihood of in-

TABLE 4. *Unadjusted and multivariate logistic regression analysis for in-hospital mortality using IPTW for major trauma patients age ≥65 years of age who were transported by SJA-WA paramedics in the metropolitan area*

	Univariate OR (95% CI)	Adjusted OR (95% CI)
Transported to trauma centre		
Yes	Reference	Reference
No	1.5 (1.1–2.2)	1.7 (1.04–2.7)
Age (years)	1.03 (1.00–1.05)	1.06 (1.03–1.1)
Injury Severity Score		
16–24	Reference	Reference
≥25	7.2 (4.7–10)	5.1 (3.1–8.2)
Prehospital SBP		
SBP ≥90 mmHg	Reference	Reference
SBP <90 mmHg	3.7 (2.1–6.6)	2.1 (0.87–4.9)
Prehospital respiratory rate		
10–29 per min	Reference	Reference
≤9 or >29 per min	8.6 (4.6–15)	5.9 (2.8–12)
Prehospital Glasgow Coma Scale		
9–15	Reference	Reference
3–8	16 (9.3–30)	8.8 (4.8–16)
Major head injury		
AIS <3	Reference	Reference
AIS ≥3	2.1 (1.2–3.6)	1.8 (0.80–4.0)

hospital mortality (95% CI 1.04–2.7) (Table 4). Similarly, ISS ≥25, age, GCS ≤8 or a respiratory rate ≤9 or >29 per min any time prehospital were also significantly associated with increased likelihood of in-hospital mortality.

Discussion

This study compared the characteristics of major trauma in younger and older patients. Consistent with previous studies of major trauma in older adults, we found that falls from standing were the most common mechanism of injury[1–3] and as age increased the proportion of falls increased.[3] Similar to a study undertaken in Victoria, we found that with each increasing age group the proportion of patients who received definitive care at a non-major TC increased.[3] Furthermore, we identified an in-hospital mortality benefit in older adults transported to the TC, which is consistent with previous research of adult major trauma patients[6] and a study of minimally injured (ISS <9) older adults.[28]

We identified that the odds of transport to the TC in older adults was between 48% and 63% lower than their younger counterparts. This trend is consistent with previous research.[7,10,29] A study from Victoria that examined age and prehospital triage destination reported that for older patients the odds of transportation to a major trauma service were between 23.7% and 41.1% lower than for patients aged 16–25 years.[10] A reduction in the likelihood of TC transport of 52% for those ≥65 years (AOR 0.48, 95% CI 0.30–0.76) was also reported in Baltimore, USA, where trauma patients were defined as those being declared priority 1 status by emergency medical personnel.[29] Similarly, in urban New South Wales, age >70 years was associated with a 62% reduction (AOR 0.38, 95% CI 0.29–0.49) in those meeting a prehospital trauma triage protocol, which recommends TC transport.[7]

The reasons why older adults have a reduced odds of TC transport is likely to be because of multiple factors. Older adults are known to have the ability to sustain major trauma as a result of low-velocity mechanisms such as falls[8] and falls have also been found to be associated with a decreased likelihood of TC transport.[7,11,30] Seriously injured older adults can appear deceptively uninjured, often failing to display overt physiological derangement.[31] For example, it has been found that for the equivalent severity of intracranial injury, the presenting GCS is higher in older adults than their younger counterparts, suggesting that the severity of major head injuries may not initially be apparent.[32] Furthermore, older adults often have significant comorbidities, polypharmacy, anticoagulation therapy and physiologic changes that can alter their response to injury or occult hypoperfusion, which require high levels of suspicion to recognise.[8]

It has been suggested that a lack of paramedic training about trauma in older adults contributes to older persons not being transported to TCs.[29] Conversely, it is possible that paramedics do recognise the severity of the patient's condition and consider active trauma care as futile because of age, injury severity, existing comorbidities and likely prognosis and therefore, choose not to transport older patients to the TC. This may also account for older patients not being subsequently transferred to the TC after initial stabilisation at another hospital with the assessment that transfer to the TC is inappropriate for that patient.[3,10] It has also been suggested that older adults may prefer to attend non-major TCs because of their prior history at local hospitals.[3]

Standard adult triage criteria have been found to be too restrictive in identifying the need for TC care in older adults.[33] However, the adoption of specific field triage criteria have been shown to significantly improve the detection of older adults requiring this specialised care.[33] At present, no specific field triage criteria for the management of older adult trauma patients is in use by SJA-WA paramedics. As we have previously highlighted, the incidence of trauma in metropolitan Perth is the highest in those ≥85 years[34] with older adults comprising 35% of the major trauma patients in our current study. It is therefore important that we develop specific prehospital triage criteria to enable the identification of these higher-risk patients in whom TC transport would be beneficial.

Limitations

As with any observational study design there may have been unknown confounders that influenced associations seen in the multivariate analysis. Patients who died at the scene or exclusively attended a hospital that did not provide data to the WA State Trauma Registry were not captured by the study. Therefore, this study is not population-based. However, this is more likely to have resulted in an underestimation of the reduction in the likelihood of transport direct to the designated TC in older adults.

Conclusion

Older age was associated with a significantly reduced likelihood of TC transport. The reasons for this are likely to be complex. However, as the population is aging, the development of specific prehospital triage criteria to enable the complexities of this higher-risk patient population to be identified is important.

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Competing interests

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Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Appendix S1. Demographic and trauma characteristics of patients with major trauma, before and after IPTW, stratified by transport destination.

Appendix S1 Demographic and trauma characteristics of patients with major trauma, before and after IPTW, stratified by transport destination

	All patients N 576			All patients after IPTW N 576		
	No Trauma Centre Transport	**Trauma Centre Transport**	**SMD**	**No Trauma Centre Transport**	**Trauma Centre Transport**	**SMD**
Age	82 (±8.0)	79 (±8.5)	0.36	82 (±8.2)	79 (±8.5)	0.33
ISS ≥25	109 (47)	164 (48)	0.02	269 (47)	272 (47)	0.00
SBP <90mmHg	22 (9.5)	32 (9.3)	0.00	53 (9.2)	53 (9.2)	0.00
Respiratory Rate ≤9 or >29 per min	16 (6.9)	41 (12)	0.18	56 (9.7)	57 (9.9)	0.01
GCS ≤8	35 (15)	50 (15)	0.00	84 (15)	85 (15)	0.00
Major Head Injury (AIS ≥3)	204 (88)	268 (78)	0.27	473 (82)	472 (82)	0.00

Note. Abbreviations are as follows. AIS=Abbreviated Injury Scale, GCS=Glasgow Coma Scale, IPTW=Inverse Probability of Treatment Weighting, SBP =Systolic Blood Pressure, SMD= Standardised Mean Difference.

12.2 Summary

Of the 1,625 major trauma patients included in this study, 576 (35%) were ≥65 years of age. The odds of transport to the Trauma Centre in older adults was between 48% and 63% lower than their younger counterparts. An in-hospital mortality benefit in older adults who were transported, both directly and indirectly, to the Trauma Centre was identified, with those not transported to the Trauma Centre being 1.7 times more likely to die in-hospital.

Trauma Centre Transport

It was found that the majority of patients in the younger adult group were taken directly to the Trauma Centre whereas the majority of patients in the older adult group were not. After adjusting for age, sex, mechanisms of injury, prehospital Glasgow Coma Scale score, ISS, the existence of major head, chest, abdominal and/or extremity injuries, an association between Trauma Centre transport and increasing age was identified. Compared to those <65 years of age, those aged 65-74 years had a 48% reduction in the odds of being transported to the Trauma Centre and those aged ≥85 years had a 63% reduction, which is consistent with previous research.[63, 124, 170]

In-Hospital Mortality

To ascertain whether this reduced likelihood of Trauma Centre transport was associated with in-hospital mortality in older adults, an IPTW multivariate logistic regression analysis was undertaken. This analysis showed that in patients ≥65 years, non-Trauma Centre transport was associated with 1.7 times increased likelihood of in-hospital mortality.

Undertriage

Possible reasons for the association between older age and non-Trauma Centre transport in major trauma patients were considered. Reasons suggested included, the ability of seriously injured older adults to appear deceptively uninjured, due to a lack of obvious physiological derangement.[180] The presence of significant comorbidities, polypharmacy, anticoagulation therapy and the physiologic changes and their ability to alter the older adults' response to injury were discussed. It was suggested that the adoption of specific field triage criteria by SJ-WA paramedics might improve the detection of older adults requiring transport to the Trauma Centre. However, it was not possible to ascertain the rationale underpinning the paramedics' decision not to transport these older patients directly to the Trauma Centre.

The finding of an association between older age and a reduced likelihood of transport to a Trauma Centre in the metropolitan area of WA led to questioning as to whether this was reported in other EMS jurisdictions. A systematic review of the literature was therefore undertaken with the aim of addressing the question: “are older patients with major trauma more or less likely than younger patients to be transported to a Trauma Centre by EMS?”

The methods used to undertake this review and the systematic review itself are detailed in the following chapter.

Chapter 13 Older Adults and Trauma Centre Transport – A Systematic Review

13.1 Overview

After finding an association between age and Trauma Centre transport in the Perth metropolitan area, an investigation as to whether this finding was evident in other EMS jurisdictions was undertaken. To do this, a systematic review of the literature was performed. The aim of this review was to identify and synthesise the published evidence regarding the association between age and EMS Trauma Centre transport; and more specifically to answer the question, "are older patients with major trauma more or less likely to be transported to a Trauma Centre by EMS than younger patients?"

Five databases (Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Scopus, Cochrane Library) and the grey literature were searched to identify studies that reported an association between age and Trauma Centre transport where an older age was compared to a younger age. Prior to commencing the search, the protocol was registered with PROSPERO, the international prospective register of systematic reviews and meta-analysis. A copy of the registration document is contained in the Thesis Appendix K. The review was completed following the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) checklist for the transparent reporting of systematic reviews.[181] A copy of this checklist is provided in Thesis Appendix L. The findings of this systematic review are reported in the following manuscript that has been submitted for publication. Tables and figures not hosted in the manuscript can be located in Thesis Appendix L.

Brown E, Tohira H, Bailey P, Finn J. Is Age Associated with Emergency Medical Service Transport to a Trauma Centre in Patients with Major Trauma? A Systematic Review.

13.2 Abstract

Introduction: Older adults with major trauma are known to have higher mortality rates than their younger counterparts and there is a known survival benefit of treatment in Trauma Centres. This systematic review sought to answer the question: are older patients with major trauma more or less likely to be transported to a Trauma Centre by EMS than younger patients?

Methods: The following databases were searched: Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Scopus, Cochrane Library and grey literature until 7th of March 2019. Studies meeting each of the following criteria were included: 1) comparative study, including randomised controlled trials, cohort studies, cross-sectional studies, case-control studies; 2) study participants must be patients with major trauma; 3) the patients must have been initially transported from the accident scene to hospital by EMS and 4) the study must report the association between major trauma patient, age and Trauma Centre transport.

Results: We identified 3,365 unique citations and one study was identified through other sources. In total, seventeen studies were included. The studies defined major trauma patients either by the meeting of prehospital trauma triage criteria or a retrospective diagnosis. All of the included studies reported that older age was associated with a reduced likelihood of EMS Trauma Centre transport when compared to younger age in major trauma patients

Conclusions: Ensuring that older major trauma patients have access to appropriate care is important. This may be achieved by employing interventions aimed at reducing the rate of undertriaging, including trauma triage criteria and EMS training.

13.3 Introduction

In both developed and developing countries, injury is known to be a significant cause of morbidity and mortality.[7, 93] Major trauma has traditionally been perceived as being a disease of the young.[121] However, over recent years the mean age of patients with major trauma has increased [121] and older adults with major trauma are known to have higher mortality rates than their younger counterparts.[122]

Emergency Medical Services (EMS) are often the first point of medical care for patients with trauma, with the prevention of further injury, initiation of resuscitation and timely transport to an appropriate hospital facility the key objectives of this care.[12, 13] The survival benefit of Trauma Centre (TC) care is well documented,[26, 182] and this survival benefit has also been shown to be present in older adults with major trauma.[5, 183] Despite this, it is suggested that older patients with major trauma are less likely to be transported by EMS to specialised trauma services (undertriaged).[124, 126, 184]

Objective

This systematic review sought to answer the question of whether older patients with major trauma are more or less likely to be transported to a TC by EMS than younger patients.

13.4 Methods

Protocol and Registration

The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement was followed for this systematic review and meta-analysis.[181] Details of the protocol for this systematic review were registered on PROSPERO (CRD42018115532) and can be accessed at https://www.crd.york.ac.uk/PROSPERO.

Eligibility Criteria

To be included in this review, studies needed to meet all of the following criteria: 1) be a comparative study, including randomised control trials, cohort studies, cross-sectional studies, case-control studies; 2) study participants must be patients with major trauma; 3) the patients must have been initially transported from the accident scene to hospital by EMS and 4) the study must report the association between major trauma patient age and TC transport. We excluded reviews, letters, editorials, case studies, and all other commentaries. The literature search was not limited by language or publication date.

Information Sources

To identify studies eligible for review, computerised searches of bibliographic databases were performed. We searched Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Scopus, Cochrane Library and grey literature via Mednar until the 7th of March 2019.

Search Strategy

Our search strategy involved three key concepts: 1) major trauma 2) age and 3) EMS transport to a TC (see Appendix 1). Terms were mapped to the appropriate MeSH/EMTREE subject headings and "exploded". Keywords relating to these three concepts were combined with the boolean operator 'AND'. We used review articles to find other relevant articles and identified additional sources through the articles' reference lists.

Study Selection

To select potentially relevant papers, EB performed the database search and conducted a review based on title and abstract to identify potentially relevant studies. Full-text articles were obtained if the abstract contained relevant information or if more information was required to inform inclusion or exclusion. To ensure the eligibility criteria were met, included studies were then independently assessed by EB and HT. Discrepancies were resolved by consensus. As the authors of this systematic review are the authors of one of the studies included in the review,[5] an independent person assessed that study to ensure the eligibility criteria were met.

Data Collection Process and Data Items

Descriptive, methodological and outcome data were extracted from the included studies using a pre-determined electronic spreadsheet developed by EB. Data extracted included the year of publication, research design, sample size, the population of interest, predictor and outcome measures. EB extracted information and double-checked the accuracy and details of the extracted data.

Risk of Bias in Individual Studies

The checklist developed by GRADE for methodological assessment of observational studies which can be found in table 5.5 of the GRADE handbook was used to assess the methodological quality of studies included in this systematic review.[185] Results were collated and accuracy independently checked by two authors (EB and HT). The consensus was reached by discussion. As the authors of this review are the authors of one of the studies included in this review [5] the risk of bias for this study was undertaken by an independent person.

Summary Measures

Odds ratios (OR) were used to compare the likelihood of EMS transport to a TC between younger and older major trauma patients. Crude OR were calculated for studies that provided numbers of patients transported and not transported by EMS to a TC and their ages. When the raw number of patients, their ages and/or their transport destination were not available then these numbers were calculated from the available data. If the extraction of raw numbers was not possible from the data in the paper, the study authors were contacted for further information. If no response was received the findings were only included in the descriptive summation of results.

Statistical Analysis and Synthesis of Results

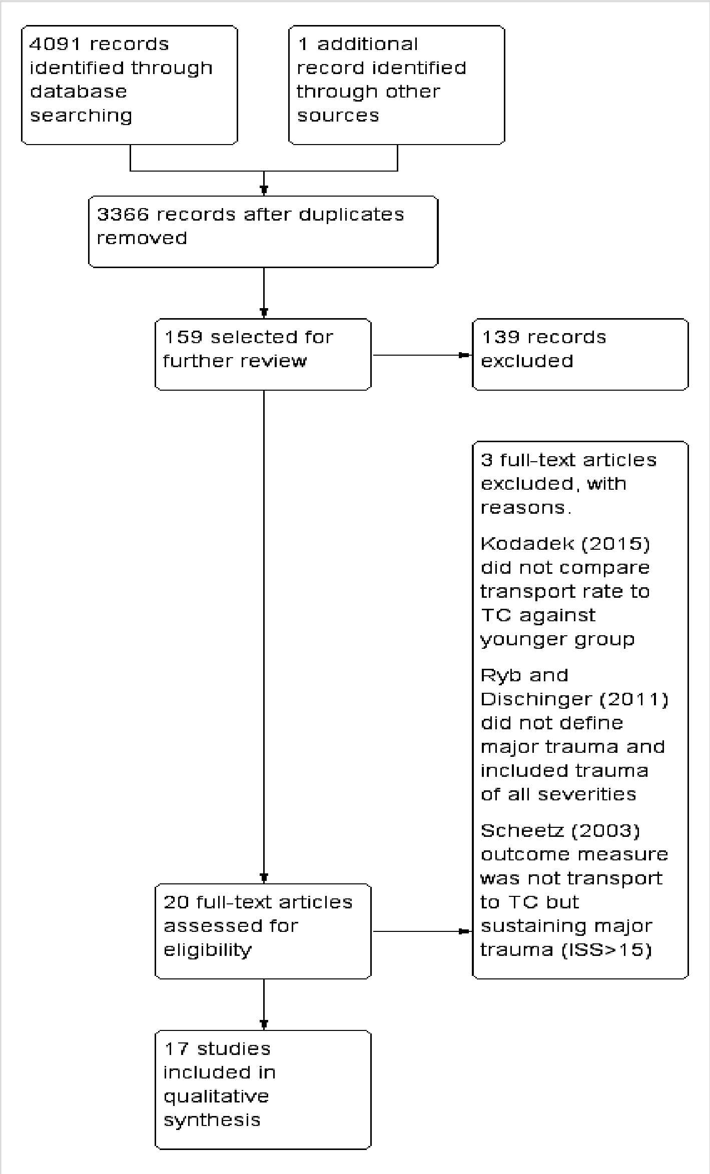
The outcome of interest was transport to a TC by EMS in patients with major trauma. The likelihood of EMS TC transport in younger and older major trauma patients was compared using odds ratios (OR) and 95% confidence intervals (95% CI). Statistical heterogeneity between studies was assessed using the I^2 statistic and we applied the rule that results would not be pooled if I^2 exceeded 50% (high heterogeneity).[186] Results were summarised by forest plots of the OR if two or more studies reported data for older and younger age groups. RevMan Version 5.3.5. was used to create the Forest plots [187] and Funnel plots were examined for publication bias.

13.5 Results

Study Selection

Our search strategy yielded 3,365 unique citations and one study was identified through other sources (a study that was undertaken by ourselves and had been accepted for publication).[5] EB screened the titles and abstracts, identifying twenty potentially relevant articles.[5, 63, 124, 125, 170, 184, 188-201] The full text of these articles was then reviewed by EB and HT for eligibility according to the inclusion criteria. We excluded three studies,[194, 197, 198] the first because only patients over 55 years were included with no comparison age,[194] the second because major trauma was not defined and patients with trauma of all severities were included [197] and the third as the outcome was not transport to a TC, but sustaining major trauma.[198] In total, seventeen studies met the selection criteria and were included in the systematic review (Figure. 1).[5, 63, 124, 125, 170, 184, 188-193, 195, 196, 199-201]

Figure 1 PRISMA flow diagram.



Study Characteristics

The characteristics of the included studies are summarised in Table 1. All studies were retrospective with the majority being retrospective cohort studies. To define major trauma, five studies used a prehospital trauma triage criteria,[124, 125, 170, 189, 196] eleven studies used a retrospective major trauma diagnosis [5, 63, 184, 188, 190, 191, 193, 195, 199-201] and one study used death in the emergency department.[192] The majority of studies were undertaken in the United States of America, three were undertaken in Australia [5, 47, 124] and one in Canada.[125]

Table 1 Characteristics of included studies.

Study	Country	Study Design	Sample Size	Population	Exclusion	Exposure	Comparison	Outcome
Baez et al (2003)	USA	Retrospective cross-sectional	1,068	Patients ≥18yrs who met at least one criterion from Step One or Step Two of the American College of Surgeons Trauma Triage Criteria and had an ISS >15	Patients with poisoning, single-system burns, and the late effects of injuries	Not defined	Not defined	EMS transport to either Level I or Level II TC or transport to Non-TC
Brown et al (2019)	Australia	Retrospective cohort	1,625	Patients ≥16yrs with ISS >15	Patients with poisoning, drowning, hanging or late effects of injury	Age ≥65yrs	Age 16-64yrs	EMS transport to a Level I TC or transport to Non-TC
Chang et al (2008)	USA	Retrospective cohort	26,565	Patients who met American College of Surgeons Trauma Triage Criteria for physiology, injury pattern and mechanism of injury who were subjectively declared priority 1 status by EMS personnel	Patients being transferred between hospitals	Age ≥65yrs	Age <65yrs	EMS transport to Level I, Level II or Level III TC or EMS transport to a Non-TC
Cox et al (2014)	Australia	Retrospective cohort	60,751 7,461 of these retrospectively confirmed major trauma	Patients ≥16yrs who met a Trauma Triage Criteria. These were then retrospectively defined as major trauma if they had one or more of the following; ISS >12, Intensive Care Unit admission with mechanical ventilation >24hrs or urgent surgery	Patients with injuries secondary to a non-traumatic cause	Age >55yrs	Age 16-55yrs	EMS transport to Major Trauma Service equivalent to Level I TC or EMS transport to Non-TC

Study	Country	Study Design	Sample Size	Population	Exclusion	Exposure	Comparison	Outcome
Davis et al (2012)	USA	Retrospective cohort	2,051	Patients ≥15yrs with an injury-related diagnosis or an emergency classified admission. Trauma patients were then defined as meeting a Trauma Triage Criteria or retrospectively defined as major trauma if they had ISS ≥16	No exclusions	Age ≥55yrs	Age 15-54yrs	EMS transport to Level II TC or EMS transport to Non-TC
Doumouras et al (2012)	Canada	Retrospective cohort	898	Patients ≥16yrs who met physiologic Toronto Field Trauma Triage Criteria	Patients injured as a result of burns, drowning, suffocation, electric shock, poisoning or non-mechanical causes of injury, those patients for whom the TC was the closest hospital	Age ≥65yrs	Age 16-64yrs	EMS transport to Level I or EMS transport to Non-TC. Excluding those whom the closest hospital was a TC
Fitzharris et al (2012)	Australia	Retrospective cohort	9,344	Patients of all ages who met one or more physiologic, anatomic or mechanism Trauma Triage Criteria	Patients who refused treatment, patients who were only assisted, those patients transported by air, patients who were dead on examination, those recorded as 'other' and inter-hospital transfers	Age ≥50yrs	Age <50yrs	EMS transport to Major TC or Regional TC or EMS transport to Non-TC

Study	Country	Study Design	Sample Size	Population	Exclusion	Exposure	Comparison	Outcome
Flottemesch et al (2016)	USA	Retrospective cohort	140,766	Patients ≥18yrs with head injury AIS ≥4	Patients being transferred from other acute care hospitals and patients who were initially treated at s Level III TC	Age 45-64yrs; 65-84yrs; 85+yrs	Age 18-44yrs	Initial treatment at a Level I or Level II TC or initial treatment Level IV or V TC
Garwe et al (2017)	USA	Retrospective cohort	84,930	Patients aged ≥17yrs who met Oklahoma's major trauma definition	Patients who died at scene, those who had overexertion injuries, submersions, poisonings, asphyxiation and those with injuries caused by pre-existing conditions (e.g. osteoporosis)	Age ≥55yrs	Age 17-55yrs	EMS transport to Level I or Level II TC or EMS transport to Non-TC
Holst et al (2016)	USA	Retrospective cohort	3,971	Patients aged ≥18yrs with a trauma related emergency department visit, defined by the injury variable in the National emergency department Sample, which resulted in death in the emergency department	No exclusions stated	Age 35-49yrs, 50-64yrs and ≥65yrs	Age 18-34yrs	EMS transport to Level I or Level II TC or EMS transport to Non-TC

Study	Country	Study Design	Sample Size	Population	Exclusion	Exposure	Comparison	Outcome
Hsia et al (2011)	USA	Retrospective cohort	430,081	Patients aged ≥18yrs with trauma defined by ICD 9 codes of 800-904.9, 910-929.9 and 950-959.9	Patients without external cause of injuries, scheduled admissions or those admitted for the late effects of injury. Patients with ICD-9 codes indicative of drowning, bites and stings, overexertion, poisoning or suffocation, those with ICD-9 codes for minor injuries and those with closed hip fractures	Age ≤65yrs	Age 18-64yrs	Admission to a Level I or Level II TC or admission to a Non-TC
Lane et al (2003)	USA	Retrospective cross-sectional	8,980	Patients with an ICD-9 code signifying an injury as an external cause of the principal diagnosis and an ISS >15	Those with no E-code, those with burn as the only injury, those with the late effects of injury, and those with an E-code but no codable injury diagnosis (800-959)	Age ≥65yrs	Age <65yrs	Discharge from Level I or Level II TC or discharge from Non-TC

Study	Country	Study Design	Sample Size	Population	Exclusion	Exposure	Comparison	Outcome
Ma et al (1998)	USA	Retrospective cohort	7,652	Patients of all ages who met at least one criteria of the Trauma Triage Criteria for physiology, anatomic injury severity and mechanism of injury.	Patients with incomplete physiological parameters recorded. Patients attending a hospital outside of Maryland, invalid entries and those attending military hospitals	Age ≥75yrs	Age <75yrs	EMS transport to a Level I or Level II TC or EMS transport to Non-TC.
Nakamura et al (2012)	USA	Retrospective cohort	46,414 met Trauma Triage Criteria 8,007 had ISS ≥ 16	Patients with an EMS primary impression recorded as "injury" or "trauma" who met Trauma Triage Criteria and/or had an ISS ≥16	Inter-hospital transfers without the initial presentation involving EMS, non-transported patients and deaths on scene	Age ≥61yrs	Age <61yrs	EMS transport to a Level I or Level II TC or EMS transport to a Level III to V TC or Non-TC.
Scheetz (2004)	USA	Retrospective cohort	817	Patients aged >25yrs sustaining injuries in motor vehicle crashes with an ISS ≥16	No exclusions	Age ≥65yrs	Age 25-64yrs	Admission to a Level I or Level II TC or admission to a Non-TC
Xiang et al (2014)	USA	Retrospective cohort	36,395	Patients with ISS ≥16 in the Nationwide emergency department Sample (NEDS)	Patients with only late effects of injury (ICD-9 codes 905-909.9) or injuries due to foreign bodies (ICD-9 code 930-939.9)	Age ≥65yrs	Age 18-64yrs	EMS transport to Level I or Level II TC or EMS transport to Level III TC or Non-TC including inter-hospital transfers.

Study	Country	Study Design	Sample Size	Population	Exclusion	Exposure	Comparison	Outcome
Zimmer-Gembeck et al (1995)	USA	Retrospective cohort	2,628	Patients with a hospital discharge diagnosis in the ICD-9-CM range of 800-959 trauma patients meeting triage criteria and ISS ≥16	Patients with only late effects of injury (ICD-9 codes 905-909) or injuries due to foreign bodies (ICD-9 code 930-939)	Age >65yrs	Age ≤65yrs	Admission to Level I TC or admission to Non-TC

Abbreviations: AIS=Abbreviated Injury Scale, EMS=Emergency Medical Service, ICD=International Classification of Diseases, ISS=Injury Severity Score, Non-TC=Non-Trauma Centre, TC=Trauma Centre.

Risk of Bias within Studies

Bias was assessed using the checklist developed by GRADE for observational studies (Table 5.5 of the GRADE handbook) [185] and presented in Appendix 2. All studies were judged as having a high risk of confounding as it would not be possible to control for all factors that may affect the EMS providers' transport decision. No study was excluded for it's methodological quality.

Results of Individual Studies

The results of the individual studies will be reported under the specific criterion that the study used to define major trauma. Additional data were requested from nine authors [63, 124, 184, 188, 190, 191, 193, 196, 201] and responses were received from two authors.[193, 201]

Table 2 Results from individual studies.

Study	Exposure Age	Hospital Destination	Comparison Age	Hospital Destination	Measure-ment	Unadjusted	Adjusted	Adjusted for confounders
Baez et al (2003)	Not defined- Reported Mean	Not specified	Not defined Reported Mean	Not specified	Mean ± SD	Mean age TC=46.62 (±18.54) Mean age Non-TC=63.63 (±16.02) p<0.001.	Not stated	Not stated
Brown et al (2019)	Age ≥65yrs	TC =188 Non-TC =232	Age 16-64yrs	TC =578 Non-TC =168	OR for TC transport	Age ≥65yrs OR=0.24 (95%CI 0.18-0.32)	Age 65-74yrs AOR=0.52 (95%CI 0.35-0.78) Age75-84yrs AOR=0.48 (95%CI 0.33-0.71) Age ≥85yrs AOR=0.37 (95%CI 0.24-0.55)	Mechanism of injury, prehospital GCS, ISS, major injury (AIS ≥3), sex
Chang et al (2008)	Age ≥65yrs with age 50-69yrs, ≥70yrs as subgroups	TC =1,800 Non-TC =1,790	Age <65yrs with age <50yrs the reference for subgroups.	TC =18,882 Non-TC =4,093	OR for TC transport	Age ≥65yrs OR=0.22 (95%CI 0.20-0.23).	Age ≥65yrs AOR=0.48 (95% CI 0.30-0.76) Subgroups: Age 50-69yrs AOR=0.67 (95%CI 0.57-0.77) and: Age ≥70yrs AOR=0.45 (95%CI 0.39-0.53).	Year, sex, physiology, injury, or mechanism criteria, transport reasons, EMS provider training level, presence or absence of 18 specific injuries and jurisdictional region.

Study	Exposure Age	Hospital Destination	Comparison Age	Hospital Destination	Measure-ment	Unadjusted	Adjusted	Adjusted for confounders
Cox et al (2014)	Age >55yrs. with age 26-35yrs; 36-45yrs; 46-55yrs; 56-65yrs; 66-75yrs; 76-85yrs; ≥86yrs as subgroups	Not specified	Age 16-55yrs with age: 16-25yrs the reference for subgroups.	Not specified	OR for TC transport	Age >55yrs OR= 0.43 (95%CI 0.42-0.44).	Age 26-35yrs OR=1.03 (95%CI 0.95-1.12) Age 36-45yrs AOR=0.90 (95%CI 0.83-0.97) Age 46-55yrs AOR=0.85 (95%CI 0.78-0.93) Age 56-65yrs AOR=0.76 (95%CI 0.69-0.83) Age 66-75yrs AOR=0.68 (95%CI 0.62-0.75) Age 76-85yrs AOR=0.58 (95%CI 0.54-0.64) Age >86yrs AOR=0.62 (95%CI 0.56-0.68).	Trauma cause, ISS, Paramedic type, comorbidities, inter-hospital transfer, transport time, Paramedic judgement, injury count, region.
Davis et al (2012)	Age ≥55yrs	Not specified	Age 15-54yrs	Not specified	OR for discharge from TC	Age ≥55yrs OR=0.39. Compared to non-trauma patients, patients meeting Prehospital Trauma Triage Criteria: Age 15-54yrs OR=4.86 (95%CI 3.51-6.74)	Not stated	Not stated

Study	Exposure Age	Hospital Destination	Comparison Age	Hospital Destination	Measure-ment	Unadjusted	Adjusted	Adjusted for confounders
						and: Age ≥55yrs OR=1.36 (95%CI 1.05-1.74). Compared to non-trauma patients, patients with ISS ≥16: Age 15-54yrs OR=6.53 (95%CI 4.07-10.47) and: Age ≥55yrs OR=1.67 (95% 1.08-2.58).		
Doumouras et al (2012)	Age ≥65yrs	TC=85 Non-TC =215	Age 16-64yrs with age 16-24yrs, 25-40yrs, 41-54yrs, 55-64yrs as subgroups	TC=329 Non-TC =206	OR for TC destination	Age ≥65yrs OR 0.25 (95%CI 0.18-0.34).	Age 16-24yrs AOR=3.51 (95% CI 2.00-6.17) Age 25-40yrs AOR=2.29 (95%CI 1.35-3.87) Age 41-54yrs AOR=2.21 (95% CI 1.38-3.55) and: Age 55-64yrs AOR=1.86 (95% CI 0.99-3.51).	Sex, mechanism, GCS, systolic blood pressure, respiratory rate, heart rate, differential distance.

Study	Exposure Age	Hospital Destination	Comparison Age	Hospital Destination	Measure-ment	Unadjusted	Adjusted	Adjusted for confounders
Fitzharris et al (2012)	Age ≥70yrs with age 5.0-14.9yrs, 15-29.9yrs, 30-49.9yrs, 50-69.9yrs, ≥70yrs as subgroups	TC=812 Non-TC =582	Age <70yrs with age 0-4.9yrs the reference for subgroups	TC=6,104 Non-TC =1,846	OR for TC transport	Age ≥70yrs OR 0.42 (95%CI 0.37-0.48) Age 5.0-14.9yrs OR=0.87 (95%CI 0.66-1.15) Age 15-29.9yrs OR=1.12 (95%CI 0.89-1.41) Age 30-49.9yrs OR=0.99 (95%CI 0.79-1.25) Age 50-69.9yrs OR=0.79 (95%CI 0.63-1.01) Age ≥70yrs OR=0.41 (95%CI 0.33-0.53).	Age 5.0-14.9yrs AOR= 0.74 (95%CI 0.55-0.98) Age 15-29.9yrs AOR=0.69 (95%CI 0.54-0.90) Age 30-49.9yrs AOR=0.65 (95% 0.50-0.84) Age 50-69.9yrs AOR=0.56 (95%CI 0.43-0.72) Age ≥70yrs AOR=0.38 (95%CI 0.29-0.49).	Vital signs, injury criteria, high-risk mechanism, sex, type of incident, treating officer level, time of day, day of week.
Flottemesch et al (2016)	Age ≥65yrs with age 45-64yrs; 65-84yrs; ≥85yrs as subgroups	TC=37,159 Non-TC =44,999	Age 18-64yrs with age 18-44yrs the reference for subgroups	TC=37,473 Non-TC =21,135	OR for initial treatment at a TC	Age ≥65 yrs OR=0.47 (95%CI 0.46-0.48)	Patients with head injuries in 2009: Age 45-64yrs AOR= 0.76 (95%CI 0.71-0.81) Age 65-84yrs AOR=0.61 (95%CI 0.56-0.65) Age ≥85yrs AOR=0.53 (95%CI 0.49-0.57)	Demographic, location of residence, expected payer, injury, clinical complexity, geography,

Study	Exposure Age	Hospital Destination	Comparison Age	Hospital Destination	Measure-ment	Unadjusted	Adjusted	Adjusted for confounders
							Patients with head injuries in 2012: Age 45-64yrs AOR= 0.74 (95%CI 0.69-0.80) Age 65-84yrs AOR=0.59 (95%CI 0.54-0.63) Age ≥85yrs AOR=0.56 (95%CI 0.51-0.60).	
Garwe et al (2017)	Age ≥55yrs	TC=6,086 Non-TC =6,737	Age 17-55yrs	TC=11,696 Non-TC =6,036	OR for EMS transport to TC	Age ≥55yrs OR=0.47 (95%CI 0.45-0.49).	Age ≥55yrs AOR=0.49 (95%CI 0.47-0.52)	Sex, mechanism, injury period, distance to closest TC, distance to closest Level III, systolic blood pressure, EMS intubation, severe injury AIS ≥3, long bone fracture, pelvic fracture, pre-existing comorbidity
Holst et al (2016)	Age ≥65yrs with age 35-49yrs, 50-64yrs as subgroups	TC=487 Non-TC =419	Age 18-64 with age 18-34yrs the reference for subgroups	TC=1,494 Non-TC =901	OR for EMS transport to TC	Age ≥65yrs OR=0.70 (95%CI 0.60-0.82)	Age 35-49yrs AOR= 0.86 (95%CI 0.69-1.07) Age 50-64yrs AOR=0.74 (95%CI 0.59-0.92) Age ≥65yrs AOR=0.78 (95%CI 0.62-1.00)	Sex, median household income, primary payer, weekend arrival, month of arrival, hospital characteristics, mechanism of injury.

Study	Exposure Age	Hospital Destination	Comparison Age	Hospital Destination	Measure-ment	Unadjusted	Adjusted	Adjusted for confounders
Hsia et al (2011)	Age ≥65yrs with age 26-45yrs, 46-65yrs 66-85yrs ≥85yrs as subgroups	TC=3,4155 Non-TC =84,027	Age 18-65yrs with age 18-25yrs the reference for subgroups.	TC=197,120 Non-TC =114,779	OR for admission to TC	Age ≥65yrs OR=0.24 (95%CI 0.23-0.25).	Age >65yrs AOR=0.53 (95%CI 0.45-0.63). Age 26-45yrs AOR=0.75 (95%CI 0.71-0.80) Age 46-65yrs AOR=0.57 (95%CI 0.54-0.60) Age 66-85yrs OR= 0.35 (95%CI 0.30-0.41) Age ≥85yrs AOR=0.30 (95%CI 0.25-0.36)	Sex, insurance, race/ethnicity, income, ISS, type of injury, Elixhauser comorbidities, proximity to TC, availability of TC, metropolitan statistical area.
Lane et al (2003)	Age ≥65yrs	TC=1,144 Non-TC =1,981	Age <65yrs	TC=2,749 Non-TC =3,106	OR for receiving care at TC	Age ≥65yrs OR=0.65 (95%CI 0.60-0.70)	Not stated	Not stated
Ma et al (1998)	Age ≥55yrs	TC=10,684 Non-TC =33,207	Age <55yrs with age 0-14yrs, 15-54yrs, 55-74yrs as subgroups.	TC=8,096 Non-TC =16,270	OR for EMS transport to TC	Age ≥55yrs OR=0.65 (95%CI 0.62-0.67)	Patients meeting major trauma criteria: Age 0-14yrs AOR=1.53 (95%CI 0.87-2.71) Age 15-54yrs AOR=1.43 (95%CI 0.93-2.20) Age 55-74yrs AOR=1.23 (95%CI 0.69-2.20)	Not stated

Study	Exposure Age	Hospital Destination	Comparison Age	Hospital Destination	Measure-ment	Unadjusted	Adjusted	Adjusted for confounders
							Patients meeting mechanism criteria only: Age 0-14yrs AOR=1.71 (95%CI 1.22-2.38) Age 15-54yrs AOR=1.35 (95%CI 1.03-1.77) and: Age 55-74yrs AOR=1.05 (95%CI 0.75-1.48). Patients meeting physiology criteria: Age 0-14 AOR=2.71 (95%CI 2.43-3.02) Age 15-54yrs AOR=1.55 (95%CI 1.43-1.68) and: Age 55-74yrs AOR=1.07 (95%CI 0.96-1.19)	
Nakamura et al (2012)	Age ≥61yrs	TC=16,759 Non-TC =59,498	Age <61yrs	TC=84,880 Non-TC =98,891	EMS transport to TC	Age ≥61yrs OR=0.32 (95%CI 0.32-0.33)	Not stated	Not stated
Scheetz (2004)	Age ≥65yrs	TC=134 Non-TC =88	Age 25-64yrs	TC=467 Non-TC =128	OR for admission to TC	Age ≥65yrs OR=0.42 (95%CI 0.30-0.59).	Not stated	Not stated

Study	Exposure Age	Hospital Destination	Comparison Age	Hospital Destination	Measure-ment	Unadjusted	Adjusted	Adjusted for confounders
Xiang et al (2014)	Age ≥65yrs with age 55-64yrs, 65-74yrs, 75-84yrs, ≥85yrs as subgroups	TC =7,443 Non-TC =7,295	Age 18-64yrs	TC=16,129 Non-TC= 5,523	OR for treatment, admission or death at TC	Age ≥65 OR=0.37 (95%CI 0.35-0.38) Age 55-64yrs OR=0.61 (95%CI 0.54-0.69) Age 65-74yrs OR=0.39 (95%CI 0.33-0.47) Age 75-84yrs OR=0.31 (95%CI 0.25-0.38) Age ≥85yrs OR=0.23 (95%CI 0.18-0.29).	Patients with ISS ≥16; Age 55-64yrs AOR= 0.74 (95%CI 0.66-0.83) 65-74yrs AOR=0.63 (95%CI 0.52-0.76) 75-84yrs AOR=0.58 (95%CI 0.47-0.74) ≥85yrs AOR=0.49 (95%CI 0.38-0.63).	Sex, chronic condition, primary expected payer, median household income, patient location, external cause, admission on weekend.
Zimmer-Gembeck et al (1995)	Age >65	TC =912 Non-TC =316	Age ≤65	TC=1,156 Non-TC =249	OR for admission to TC	Age >65 OR=0.62 (95%CI 0.52-0.74)	Age ≥65 AOR=0.18 (95%CI not available)	Sex, comorbidities, multisystem injury, AIS for all injury regions,

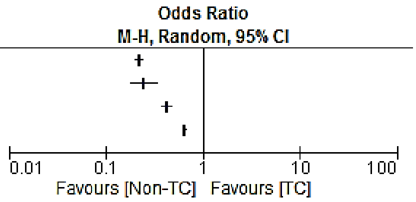
Abbreviations: AIS=Abbreviated Injury Scale, AOR=Adjusted Odds Ratio, CI=Confidence Interval, EMS=Emergency Medical Service, GCS=Glasgow Coma Scale, ISS=Injury Severity Score, Non-TC=Non-Trauma Centre, OR=Odds Ratio, SD=Standard Deviation, TC=Trauma Centre.

Prehospital Trauma Triage Criteria

There was a total of five studies that used the meeting of a prehospital trauma triage criteria (PTTC) to define major trauma. Of these, four compared the likelihood of TC transport between older and younger patients [124, 125, 170, 196] and one study compared the likelihood of Trauma Centre transport between major trauma patients and non-trauma patients.[189] The four studies that used the meeting of a PTTC to define major trauma, all reported a reduced likelihood of TC transport in older patients with major trauma compared to younger patients.[124, 125, 170, 196] The pooled estimate from these four studies showed a decreased odds of EMS TC transport in older patients with major trauma compared to younger patients, however, there was high statistical heterogeneity (I^2=100%) and therefore the pooled result was deemed to be unreliable and therefore not reported (Figure 2).

Figure 2 Summary of the unadjusted odds ratio for EMS transport to a Trauma Centre in older patients compared to younger patients meeting a prehospital trauma triage criteria.

	Older		Younger		Odds Ratio
Study or Subgroup	Events	Total	Events	Total	M-H, Random, 95% CI
Chang 2008	1800	3590	18882	22975	0.22 [0.20, 0.23]
Doumouras 2012	85	300	329	535	0.25 [0.18, 0.34]
Fitzharris 2012	812	1394	6104	7950	0.42 [0.37, 0.48]
Ma 1999	10684	43891	8096	24366	0.65 [0.62, 0.67]



CI=Confidence Interval, M-H=Mantel-Haenszel, TC=Trauma Centre.

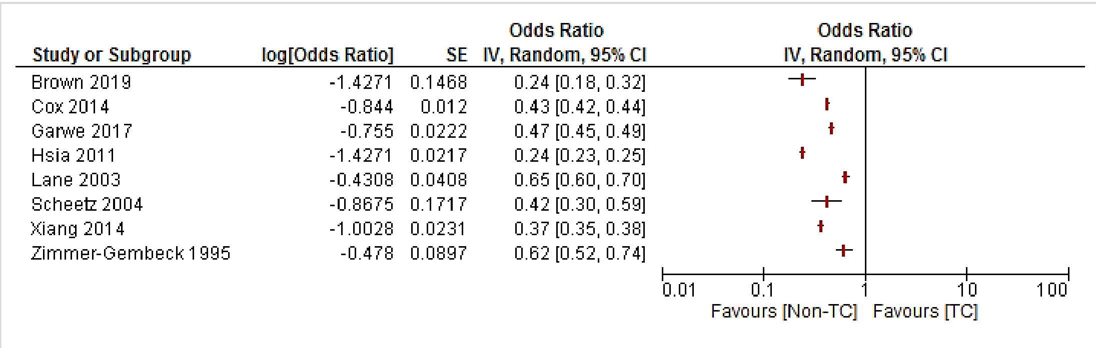
The study undertaken by Davis et al [189] compared patients ≥15yrs with a non-trauma related emergency admission with trauma patients who were retrospectively defined as meeting a PTTC. This study found that, compared to patients with a non-traumatic emergency admission, patients meeting a PTTC aged 15-54 years were almost five times more likely to be transported to a TC (OR=4.86, 95%CI 3.51-6.74) (Table 2). However, compared to patients with a non-trauma related emergency admission, patients meeting a PTTC aged ≥55years had only a 36% increased likelihood of TC transport (OR= 1.36, 95%CI 1.05-1.74). From the reported data we were able to calculate those trauma patients ≥55 years had a 61% reduced likelihood of TC transport (OR=0.39) compared to those 15-54 years. However, this was all trauma patients not specifically those with major trauma.

Beaz et al [188] used the meeting of one element of a PTTC and having an ISS >15 to define major trauma patients. Their study found that the mean age of patients was significantly older in those who were not transported to the TC (63.63 ±16.0 versus 46.62 ±18.54 p<0.001) (Table 2). No raw patient numbers were available to compare older and younger major trauma patients. The authors were contacted for further information but we received no response.

Retrospective Major Trauma Diagnosis

The eight studies using a retrospective diagnosis of major trauma reported a reduced likelihood of TC transport in older patients compared to their younger counterparts.[5, 63, 191, 193, 195, 199-201] The pooled effect of these studies showed a reduced likelihood of TC transport in older major trauma patients in comparison with younger patients. However, there was high statistical heterogeneity (I^2=99%), therefore, the pooled result was deemed to be unreliable and therefore not reported (Figure 3). As only the unadjusted OR was available for the study undertaken by Cox et al,[63] a sensitivity analysis was undertaken excluding this study; however, the results were similar and statistical heterogeneity remained high (I^2=100%) (Appendix 3a).

Figure 3 Summary of the unadjusted odds ratio for EMS transport to a Trauma Centre in older patients compared to younger patients with a retrospective diagnosis of major trauma.



CI=Confidence Interval, IV=Inverse Variance, SE=Standard Error, TC=Trauma Centre.

A sensitivity analysis was undertaken excluding the studies by Hsia et al [193] and Xiang et al [200] as both of these studies included patients who may not have all been primarily transported by EMS (Appendix 3b). The results of this analysis showed a reduction in the likelihood of EMS TC transport in older patients compared to younger patients with major trauma, however, statistical heterogeneity remained high (I^2=96%). As the raw patient numbers reported by Garwe et al [191] included patients who were secondary transfers the authors of this study were contacted for further information, however, no response was received. Therefore a sensitivity analysis was undertaken excluding this study. The results of the sensitivity analysis showed a reduced likelihood of TC transport in older patients in comparison with younger patients, however, there was high statistical heterogeneity (I^2=99%) (Appendix 3c).

There were two studies that analysed specific major trauma subpopulations, these being those with head injuries and those who died in the emergency department. Flottemesch et al [190] included only patients with severe head trauma, defined as being an abbreviated injury scale (AIS) score of ≥4. The study used the initial emergency department presentation as a proxy for prehospital triage decision, however, it was unclear if all included patients were transported by EMS and whilst attempts were made to contact the authors, we were unable to gain further clarification. This study found that compared with patients 18-64 years of age, patients ≥65 years of age had a 53% reduced likelihood of initial treatment at a TC (OR 0.47, 95%CI 0.46-0.48) (Table 2). Holst et al [192] included only trauma patients who died in the emergency department and found that patients ≥65 years had a 30% reduction in the likelihood of TC transport when compared to those aged 18-64 years (OR= 0.70, 95%CI 0.60-0.82) (Table 2).

Davis et al [189] compared the odds of TC transport between trauma patients with an ISS ≥16 and those with a non-trauma related emergency admission. This study found that trauma patients aged 15-54 years had more than six times the odds of TC transport (OR=6.53, 95%CI 4.07-10.47) than those with an emergency classified admission (Table 2). However, for those aged ≥55 years the odds were only 1.67 times (95%CI 1.08-2.58) that of emergency classified admissions.

Other Included Studies

Nakamura et al [184] used both a PTTC and/or ISS ≥16 to define major trauma and found that after the age of 60 years the percentage of patients transported to a non-TC increased. The unadjusted odds for TC transport in patients ≥61 years was 0.32 (95%CI 0.32-0.33) compared to those <60 years (Table 2). It is important to note that this refers to all EMS transported trauma patients included in the study, not just those defined prospectively or retrospectively as major trauma. The authors were contacted for further information but we received no response.

Publication Bias

The odds ratios for EMS TC transport in studies included in the pooled analysis were used to construct a funnel plot to investigate the likelihood of publication bias (Figure 4). In the absence of bias, the plot should resemble a symmetric inverted funnel.[185] If a bias exists, the plot will appear asymmetric with the presence of a gap at the right-hand side of the graph.[185] Although the funnel plot does not fully resemble a funnel shape it is not asymmetrical as it would be if a bias existed. [202]

Figure 4 Funnel plot of publication bias using the odds ratio of EMS transport to a Trauma Centre.

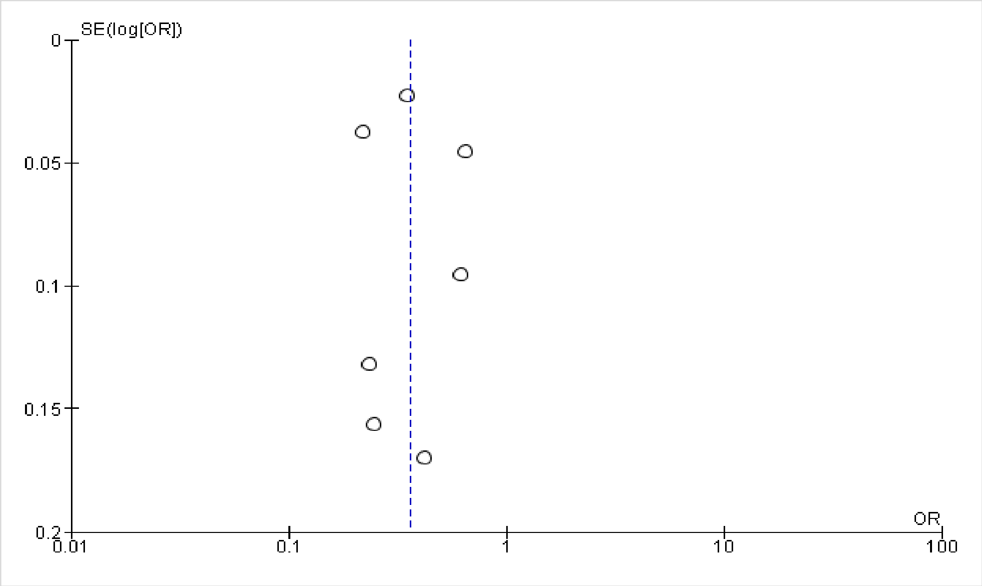


Figure Legend: x-axis= odds ratio (OR); y-axis= standard error of the log odds ratio (SE log OR).

13.6 Discussion

Summary of Evidence

We identified seventeen studies that described the association between age and EMS TC transport, using the definition of major trauma as either patients meeting a PTTC or a retrospective diagnosis. Overall, we found that all studies reported a reduced likelihood of EMS transport to a TC in older patients when compared to younger patients. However, the pooled result of these studies was highly statistically heterogeneous and therefore a meta-analysis could not be performed. To our knowledge, this is the first systematic review undertaken to answer this question. As the results of this study suggest that older patients are unequivocally less likely to be transported to a TC, it is necessary to gain an understanding as to why this undertriaging occurs and how this can be addressed.

There were five studies included in this review that used a PTTC to define their major trauma patients. The reasons for older patients who meet a PTTC not being transported by EMS to TCs are likely to be multifaceted. Suggested reasons for this occurring include, but are not limited to, poor adherence to the triage guidelines,[203] geographic location,[191, 204] ambulance diversion, physician or law enforcement choice [203] and feeling of not being welcome at TCs when transporting older adults with suspected major trauma.[170] However, the most common reason for selecting transport to specific hospitals was found by Newgard et al to be patient or family choice.[203] Furthermore, Newgard et al found that the influence of patient or family choice on the selection of hospitals increases with patient age [203] and this is likely to be due to patients' prior history at local hospitals.[170, 205] It is also plausible that although an older trauma patient may meet a PTTC, EMS providers consider that active trauma care as futile or "not worth it" due to age, injury severity, existing comorbidities and likely prognosis and therefore, choose not to transport older patients to the TC.[5, 170]

It is important to note that the studies that used PTTC alone (without a concurrent retrospective diagnosis), are likely to underestimate the magnitude of the undertriaging of older patients and over triaging of patients who will later be found not to have major trauma on retrospective diagnosis. Standard adult triage criteria have been found to be too restrictive in identifying the need for TC care in older patients.[144, 180, 206] Reasons for this include the ability of older patients to sustain major trauma as a result of low-velocity mechanisms such as falls,[184] which are often not recognised as a mechanism of injury on PTTCs.[180] Furthermore, after trauma, older patients have the ability to appear deceptively uninjured [102] and often have significant comorbidities, polypharmacy, anticoagulation therapy and physiologic changes that can alter their response to a traumatic insult.[184] For example, for the equivalent severity of intracranial injury, the presenting Glasgow Coma Scale score is higher in older patients than their younger counterparts.[120] Similarly, vital signs have been found to be different and less predictive of mortality in older trauma victims than younger patients.[176, 180] Older patients are also more susceptible to occult hypoperfusion, which requires high levels of suspicion to recognise.[184] This lack of overt physiological derangement results in older trauma patients not meeting the physiological criteria of the PTTC.[180]

The studies that use a retrospective diagnosis of major trauma will have produced a better estimate of the undertriaging of older patients with major trauma. However, it is important to consider that these diagnoses are based on information that is not necessarily available prehospital, such as results from imaging. It is, therefore, important to develop ways in which to identify prehospital major trauma in older patients and ensure that these patients receive appropriate care. For example, the adoption of specific PTTC has been shown to significantly improve the detection of older patients requiring this specialised care.[206] However, this increase in sensitivity needs to occur without resulting in unnecessary levels of over triaging (reduced specificity). Similarly, further EMS provider training in regard to older patient response to trauma insults may assist in better identification of major trauma in older patients.[170]

Limitations

Despite searching for grey literature, a limitation of this study could be the non-identification of unpublished literature. Publication bias is thought to occur with the favouring of positive results for publication.[207] Although our funnel plot did not provide evidence of asymmetry, bias cannot be fully excluded.[185] Furthermore, a reporting bias may be present as, although we did not have any language restrictions, studies published in a language other than English may have been missed in our search.[202] The studies included in the review were from three countries, Australia, Canada and the USA, it is not possible to determine whether the findings could be extrapolated to EMS systems in other countries.

13.7 Conclusion

The studies included in this review all showed that older age is associated with a reduced likelihood of EMS TC transport when compared to younger age in major trauma patients. Ensuring that older major trauma patients have access to appropriate hospital care is important. This may be achieved by employing interventions aimed at reducing the rate of undertriaging, including specific PTTCs for older adults and focusing on extended EMS training pertaining to the complexities of major trauma in these patients.

END OF MANUSCRIPT

13.8 Summary

The evidence regarding the association between age and EMS Trauma Centre transport was investigated and synthesised in this systematic review. The aim was to determine if older major trauma patients were more or less likely than younger major trauma patients to be transported by EMS to a Trauma Centre. Seventeen studies [5, 63, 124, 125, 170, 184, 188-193, 195, 196, 199-201] that described the association between age and EMS Trauma Centre transport were identified in the search and included in the review. These studies defined major trauma as either the meeting of a prehospital trauma triage (PTTC) or a retrospective diagnosis. Although all of the included studies showed a decreased likelihood of Trauma Centre transport in older major trauma patients when compared to younger patients, the pooled result of these studies was statistically heterogeneous, therefore, a meta-analysis could not be performed.

After determining that the reduced likelihood of Trauma Centre transport in older major Trauma Centre patients, was present in EMS jurisdictions other than the Perth metropolitan region, the reasons for this occurrence were discussed. The reasons for older patients meeting a PTTC but consequently not being transported to a Trauma Centre are likely to be multifaceted. However, reasons may include, but are not limited to: poor adherence to the triage guidelines, geographic location, ambulance diversion or patient choice. Using a PTTC alone (without a concurrent retrospective diagnosis) was highlighted as being likely to underestimate the magnitude of the undertriaging of older patients.

In regard to patients who were retrospectively diagnosed with major trauma, some of the reasons why older adults were less likely to be transported to a Trauma Centre were discussed. It was highlighted that the standard adult triage criteria are often too restrictive in identifying the need for Trauma Centre care in older patients. Some of the reasons for this that were discussed included, the ability of older patients to sustain major trauma as a result of low falls, the ability of older patients to appear deceptively uninjured confounded by comorbidities, polypharmacy, anticoagulation therapy and physiologic changes altering their response to a traumatic insult.

It was recommended that to address the undertriaging of older adults, specific prehospital trauma triage criteria could be adopted. Furthermore, EMS provider training, in regard to older patient response to trauma insults, may assist in identifying major trauma in older patients.

Chapter 14 Thesis Discussion

The primary purpose of my doctoral research was to examine the epidemiology of trauma patients attended by a paramedic staffed EMS specific to the metropolitan area of Perth, WA, where SJ-WA is the sole provider of road ambulance services.

I begin the discussion with a summary of the key work I have undertaken. I then discuss the findings from my work within the context of recent literature. I discuss the limitations of my research and suggest areas that may benefit from further study. I use the findings from my work to provide a set of recommendations for SJ-WA.

14.1 Summary of Work Undertaken

This thesis comprises six individual studies, of which I was the first author, which have been published in peer-reviewed journals or submitted for publication and a further published study, of which I was a co-author. These seven studies address three of the research aims of this thesis. The final aim to provide recommendations to ensure the optimisation of trauma patient outcomes will be discussed based on the findings of these works.

14.1.1 Retrospective Cohort Study – Epidemiology of Trauma

Aim - Describe the characteristics of all adult patients with trauma, attended by EMS, including prehospital deaths.

Between January 1st 2013 and December 31st 2016 there were 97,724 cases that met the inclusion criteria of the study. I found there was a significant increase in the trauma incidence rate in patients 45-years and over. The highest incident rate was in those 85-years and over with an increase of over 2,300 per 100,000 population-year over the study period. I identified MVCs as being responsible for the most immediate and early deaths. I also found that immediate deaths had the youngest median age at 38-years. Under the current SJ-WA mechanism of injury classification system, there is no specific code for falls from ground level, this meant I could not evaluate the utilisation of ambulances for injuries from this mechanism nor ascertain the number of deaths occurring because of this mechanism of injury.

I found that the majority of patients were deemed to have low acuity injuries (paramedic allocated acuity level 3 to 5), with fewer than three percent reported as being high-acuity (paramedic allocated acuity level 1). This was also demonstrated by the small percentage of patients who received advanced life support, with less than 1 percent of patients receiving this higher level of care.

In the study of which I was a co-author, we examined the incidence, characteristics and demographics of patients who suffered a traumatic aetiology OHCA in Perth, WA, between 1997 and 2014. SJ-WA attended 1,354 traumatic aetiology OHCA, during the study period, with a mean annual crude incidence rate of 6.0 per 100,000. Nearly sixty percent of these were caused by an MVC. The number of resuscitation efforts commenced by paramedics increased over the study period, as did that of bystander CPR, with an average annual increase of 1.2%. Of those who had resuscitation efforts commenced by paramedics, 196 patients (37.2%) were then declared deceased at the scene; 39 (7.4%) were admitted to hospital from the Emergency Department and 9 (1.7%) survived to hospital discharge (discharged from hospital alive).

14.1.2 Retrospective Cohort Study – Demographics, Injury Characteristics and Outcomes of Major Trauma Patients

Aim - Describe the characteristics of all adult patients with trauma, attended by EMS, including prehospital deaths.

Between January 1st 2013 and December 31st 2016 there were 1,625 patients with major trauma, defined as an ISS >15, who were transported to a hospital that submits data to the WA-STR by ambulance in metropolitan Perth, WA. The median age of the patients was 51 years and 71% were male. Falls from standing were the most common mechanism of injury with almost 30 percent of patients injured by this mechanism. Falls from standing were found to be the most common cause of both early (within 24-hours) and late deaths (within 30-days), although there was a concerning number of early deaths in young patients caused by motorbike crashes.

14.1.3 Retrospective Cohort Study – Prehospital Time and Outcomes

Aim - Determine the association between prehospital factors and survival outcomes in major trauma patients.

The first prehospital factor I investigated was prehospital time. I attempted to determine if there was an association between prehospital time and patient outcomes by conducting a retrospective cohort study, consisting of 1,625 major trauma patients. The outcomes of interest were 30-day mortality and 30-day survivor LOS. I used logistic and linear regression models derived with IPTW using the propensity scores to determine the association between these outcomes and prehospital time. No association was found between any individual prehospital time interval and 30-day mortality. Moreover, no association was found between prehospital time ≥60 minutes (the so-called golden hour) and 30-day mortality or hospital LOS (in 30-day survivors) for transported patients. However, an association between longer on-scene time and longer hospital LOS was identified. No association was found between any other individual prehospital time interval and LOS.

14.1.4 Retrospective Cohort Study – Transport Destination for Major Trauma Patients

Aim -Examine and compare the characteristics and outcomes of major trauma patients between transport destinations.

After determining an association between Trauma Centre transport and 30-day mortality in the previous study, I further examined the characteristics and outcomes of those patients transported directly or indirectly to the Trauma Centre and those who never received Trauma Centre transport prior to death or discharge. I included 1,625 major trauma patients in the study. I found a significant difference between the characteristics of the patients in each group. Of specific interest was that the *non-transfers* had the highest proportion of major head injuries, with falls from standing as their mechanism of injury. This group also had the oldest median age. These differences lead me to hypothesise that there was an association between age and Trauma Centre transport, which I investigated further in the following study.

14.1.5 Retrospective Cohort Study – Older Adults and Trauma Centre Transport

Aim - Examine older adults with major trauma transported by EMS as a specific interest group of patients.

To determine whether older age was associated with a reduced likelihood of Trauma Centre transport I undertook a retrospective cohort study consisting 1,625 major trauma patients, of whom, 576 (35%) were ≥65 years of age. Using logistic regression and controlling for predictors of Trauma Centre transport, I identified that the odds of transport to the Trauma Centre in older adults was between 48% and 63% lower than their younger counterparts. Further to this, I attempted to determine whether a mortality benefit was associated with major trauma patients ≥65 years being transported (directly or indirectly) to the Trauma Centre. To determine this, I derived the logistic regression models with IPTW using the propensity scores and found that those older adults not transported to the Trauma Centre, either directly or indirectly, were 1.7 times more likely to die in-hospital.

I found that the association between age and Trauma Centre transport had been previously reported in other studies. However, I was interested to know whether this was a common finding in other EMS jurisdictions which led me to conduct a systematic review of the literature.

14.1.6 Systematic Review – Older Age and Trauma Centre Transport

Aim - Examine older adults with major trauma transported by EMS as a specific interest group of patients.

I conducted a systematic review that identified and synthesised the evidence regarding the association between major trauma patient age and EMS Trauma Centre transport. To identify studies eligible for review, I performed computerised searches of bibliographic databases. I searched Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Scopus, Cochrane Library and grey literature via Mednar until the 7th of March 2019. This search strategy yielded 3,365 unique citations and one study was identified through other sources (the study that I had previously published). Seventeen studies were included in the review. Major trauma was defined in the studies as either the meeting of a prehospital trauma triage criteria or a retrospective diagnosis. I found that all the included studies showed a decreased likelihood of Trauma Centre transport in older major trauma patients when compared to younger patients. Unfortunately, due to the pooled result of the studies being statistically heterogeneous, I could not perform a meta-analysis.

14.1.7 Recommendations

Aim -To provide recommendations to EMS providers to ensure the optimisation of trauma patient outcomes.

Using the aforementioned findings, I make recommendations for further research and for the provision of prehospital care in the metropolitan area of Perth, Western Australia. These recommendations are detailed after the discussion of the findings in the context of other research and the limitations.

14.2 Discussion of findings in the context of other research

14.2.1 Incidence

The increase in the incidence of trauma in older adults is not unique to the metropolitan region of Perth, WA. A study undertaken in America using data from 29 of the 50 states, found that those aged >65 years were the most common age group attended by EMS, with injury being the most common presentation.[208] In New South Wales (NSW), Australia, studies have shown comparable rises in injury-related presentations of patients over 85-years old [101] and admission rates for patients over 80-years old, disproportionate to population demographic changes.[209] There have also been significant increases in patients transported by EMS to the emergency departments, particularly for those patients over the age of 80.[210] In Melbourne, Victoria, Australia, a study investigating all requests for ambulances found comparable rises in attendance to patients over 85-years of age.[107] Also in Melbourne, a disproportionate increase in the number of patients ≥70 years seeking emergency healthcare from acute public hospitals in the metropolitan area was reported.[211]

In many countries, Australia included, older adults make up the most rapidly increasing section of the population.[68, 121] In 2017 persons 65 years and over made up 15% of the population in Australia and those 85 years and over accounted for 2% of the population.[212] By 2057 the proportion of older adults 85 years and over is predicted to increase to 4.4% of the population.[212] Older adults are often living independently and are more active which may predispose them to the burden of injury.[213] For example, the more active these older adults are, the more risk there is of injury from mechanisms such as falls and road accidents.[60] Furthermore, with the decreased levels of cognition often associated with ageing, comes an increased risk of falls.[214]

Consequently, with an increase in the number of older people in the community, there will be an increase in the demand on EMS and emergency departments by these persons.[171, 209] It is, therefore, paramount that service planning, injury prevention and injury management are undertaken with the consideration of the likelihood of further increasing trauma incidence rates in older adults.[101, 107]

14.2.2 Acuity

The majority of patients with trauma being allocated a low acuity level by paramedics is comparable to the distribution reported in NSW, where hospital triage level was used to define acuity level.[101] The small percentage of patients receiving advanced life support, with less than 1 percent of patients receiving this advanced care, suggests that the majority of patients had no immediate life threats.[215] Although the lack of paramedic exposure to high-acuity patients results in skill decay, decreasing job satisfaction [107] and impacts response times to high-acuity patients,[215] it is important to consider that some of these patients deemed low acuity, were then retrospectively diagnosed as having major trauma. This is evidenced by the number of patients who were deemed to be lower acuity levels when initially transported to hospital but were later found to have an ISS >15. Furthermore, it is important to consider that patients who do not attend a hospital which supplies data to the WA-STR would not have been captured by the study detailed in Chapter 6. It is not known how many patients deemed to be lower acuity in the study undertaken in Chapter 4, were later retrospectively diagnosed as having major trauma.

14.2.3 Trauma Deaths and Traumatic Aetiology OHCA

In the retrospective cohort study of all trauma, detailed in Chapter 4, I reported MVCs as the most common cause of early trauma deaths. Conversely, in the study detailed in Chapter 6, I reported that falls were the most common cause of early deaths. The reason for this disparity is likely to be because of the difference in the categorisation of mechanisms of injury. In the study conducted using solely ePCR data detailed in Chapter 4, I used the paramedic allocated mechanism of injury codes to determine the cause of the trauma. Under this coding system, the category MVCs includes pedestrians, motorcyclist and vehicle occupants. Furthermore, the MVC code may also be used for cyclists and other road users who collide with motor vehicles. In comparison, the WA-STR individually categorise MVCs, pedestrians, cyclists and motorbike riders. Similarly, in the WA-STR falls, are categorised into those from standing, from ≤3 metres and >3 metres, whereas, there is no paramedic allocated mechanism of injury code for falls. It is, therefore, likely that the grouping of MVCs into one category and the lack of coding for falls is the reason for this disparity.

I identified that MVCs caused the majority of these prehospital deaths. With these patients being the youngest of the trauma deaths with a median age of just 38-years of age. Similarly, the majority of patients with a traumatic aetiology OHCA were aged between 16 and 39 years of age. MVCs being the most frequent cause of untimely deaths in a younger cohort of patients has previously been reported in other studies [108, 216, 217] and were the cause of nearly sixty percent of traumatic aetiology OHCA reported in our study.

In comparison with immediate and early deaths, in patients with trauma of all acuities, I reported a significantly older median age of 86 years in those with late deaths (within 30-days). This is similar to the older age reported in a Scottish study (United Kingdom) comparing prehospital and in-hospital deaths.[217] It is likely that the differences in these ages relate to these patients' general state of health as opposed solely to the severity of their injury.[214, 217] Furthermore, it is not known if these deaths resulted solely from the effects of the traumatic insult or from resulting complications, pre-existing comorbidities, or a combination of these.[178]

14.2.4 Prehospital Time

Whilst examining prehospital time and patient outcomes I had expected to find that longer prehospital times would be associated with increased odds of 30-day mortality. However, this was not supported by the data, even when known predictors of mortality were controlled for. Similarly, I could not provide any evidence of a mortality benefit in those with a prehospital time of less than 60 minutes. The only association between time interval and outcome I identified, was those 30-day survivors with a longer on-scene time had a longer hospital LOS. The analysis of specific subgroups of patients (such as those in traumatic aetiology OHCA) also revealed no association between longer prehospital time and mortality.

The inability to demonstrate an association between prehospital time of more than the 'golden hour' and mortality, has also been demonstrated in other studies.[139, 155, 157, 158] Conversely, a decrease in mortality in those with longer prehospital times has also been reported in some studies.[96, 145, 159] A study undertaken in Canada evaluated the relationship between prehospital time and subsequent mortality at Level I Trauma Centres in severely injured trauma patients (ISS ≥12) from blunt mechanisms of injury. This study found that those who were hypotensive on arrival at hospital had a substantially lower risk of mortality when their prehospital time was prolonged.[159]

It is likely that, as opposed to total prehospital time or a specific prehospital time frame, such as the 'golden hour', individual time intervals have more influence on survival outcome.[160] I was unable to determine an association between response time and 30-day mortality. However, it is important to consider this in relation to the setting of this study. In the metropolitan area of Perth, response times are generally not prolonged, with a median time of 10 minutes for those in the <60-minute IPTW cohort and 13 for those in the ≥60-minute IPTW cohort. Furthermore, the metropolitan area of Perth has a relative lack of population density/high-rise dwellings and over 90% of Priority 1 emergency calls were responded to within 15 minutes during the study period.[71, 218] The relatively low occurrence of prolonged response time may, therefore, have precluded the identification of any significant result.

The association between prolonged response time and mortality has been demonstrated in rural Alabama, USA.[146] It has also been suggested that patients who are declared deceased on-scene may be those who have significantly prolonged times until the arrival of EMS [157] with the time after the EMS arrival known to be 60% less hazardous than the time from injury to EMS arrival.[14] It is, therefore, also plausible that my inability to identify any significant result was due to those with prolonged response times being those who were deceased on scene and not captured by the WA-STR.

The on-scene times observed in this study were longer than those reported in previous studies [95, 160] and this prevented further analysis of the 'platinum ten minutes' concept. Despite longer on-scene times, I still could not demonstrate an association between increased time and 30-day mortality. However, it is likely that the paramedics' perception of serious injury and acuity strongly influences the time spent on scene. With minimal time on-scene spent with those with immediate life threats and more time taken with those less severely injured.[95, 96, 155]

Regarding LOS in 30-day survivors, I demonstrated an association between increasing on-scene times and longer LOS. In the two other studies that assessed the relationship between time and LOS, one (conducted in Pennsylvania, USA) determined an association [162] whereas the other (conducted in Scotland, United Kingdom) found no association.[158] It is possible that the finding of an association between longer on-scene times and longer LOS could have occurred because of immediate life threats being corrected in the additional on-scene time and death being prevented. Conversely, these longer scene times could also have been as a result of the high proportion of older adults with falls from standing included in the study. Older patients rarely display any obvious physiological derangement initially [102, 119, 219] and therefore, paramedics may have spent longer on-scene with these patients. However, older adults are also known to have increased susceptibility to in-hospital complications,[123] and requirement for longer recovery times post-injury [101] which may have consequently prolonged their LOS.

Trauma patients are a heterogeneous group, which creates challenges in demonstrating the effect of prehospital time on outcome, especially when a proportion of patients have no time-dependent outcome.[155] Considering that older adults with a fall from standing were overrepresented in the WA cohort of major trauma patients, my inability to find an association between prehospital time and 30-day mortality may be due to a large proportion of the cohort not having a time-dependent condition. It has been shown previously that swift delivery to definitive care is beneficial in unstable patients with penetrating trauma.[95, 160, 161] However, in blunt trauma, of which the majority of this study's cohort consisted, an association has not been so clearly demonstrated.[147] Furthermore, the small number of patients with penetrating injuries prevented the undertaking of any subgroup analysis of this mechanism of injury type.

The findings that I have reported pertaining to prehospital time and major trauma patient outcome suggest that prehospital time is unlikely to be a crucial factor in the management of all major trauma patients. It is feasible to suggest that a balance between the 'stay and play' and 'scoop and run' approaches is necessary to provide optimal prehospital trauma care, as one individual approach will not provide adequate care for all.[32] By acknowledging that those with different mechanisms of injury have inherently different needs, care can also be catered for the individual and a "one size fits all" approach avoided. Furthermore, considering that prehospital time was not associated with mortality, whereas not receiving Trauma Centre care was, suggests that it may be more pertinent to refer to the time from injury to definitive care as being pre-Trauma Centre time and not prehospital time.

14.2.5 Older Age and Trauma

Major trauma has traditionally been viewed as a disease of the young.[205] However, in Australia, an increase in the proportion of major trauma patients aged ≥65 has been observed,[60] an increase that exceeds rates expected from population growth.[205] Age is well known to be an independently significant predictor of mortality in trauma.[123] It has previously been found that for patients aged ≥55 years with low energy transfer mechanisms of injury, such as falls from ground level, for every one year increase in age there was an associated 6% increased risk of mortality.[172] Similarly, for high-energy transfer mechanisms of injury, such as falls from height, MVCs and pedestrians struck by motor vehicle, a 12% increase in mortality for every one-year increase in age was found.[172] Interestingly, a retrospective study, conducted in Sydney over a 10-year period, found that of injured patients admitted to an inner-city Major Trauma Centre after a fall, the proportion of hip fractures, which would not be classified as major trauma, more than halved whilst severe head injuries doubled.[118]

The increase in the incidence rate of trauma, with the highest rate seen in those 85 years and over, combined with the finding of an older median age in major trauma patients is not unique to this study population. This has led many to suggest that trauma is no longer a disease restricted to the young.[60, 101, 121, 170] An older median age and predominance of falls as the cause of major trauma has been reported in the United Kingdom and in Sydney, NSW.[60] Similarly, in the USA, an increasing trend in mortality from falls was observed between 2000 and 2016.[220] This shift in trauma demographic being attributed to increased life expectancy and environmental factors related to improved general health and activity levels of older adults.[60]

Older adults with head injuries and falls from standing as their mechanism of injury were overly represented in the WA cohort of patients who were never transported to the Trauma Centre, either directly or indirectly, prior to death or discharge. When I examined the odds of transport to the Trauma Centre in older adults with major trauma, I found that compared to their younger counterparts, older adults were between 48% and 63% less likely to receive Trauma Centre care. Concurringly, this reduced likelihood of Trauma Centre transport was also reported in all of the studies identified in the systematic review.[63, 124, 125, 170, 184, 188-193, 195, 196, 199-201] Furthermore, those major trauma patients ≥65 years of age who never received care at the Trauma Centre had a 1.7 times increased likelihood of in-hospital mortality than those transported directly or via inter-hospital transfer.

The reasons why older adults have a reduced likelihood of Trauma Centre transport are inherently complex and multifaceted. It is important to remember that the decision as to where to transport a trauma patient must consider the physiological and anatomical injury severity of the patient, distance to the Trauma Centre and traffic conditions.[32] However, some of the reasons for this reduced likelihood include: poor adherence to triage guidelines,[203] the patient's geographic location,[191, 204] ambulance diversion, the choice of the physician or law enforcement [203] and EMS providers not feeling welcome at Trauma Centres when transporting suspected major trauma in an older adult.[170] It has previously been found that patient or family choice also strongly influences the selection of hospital and this increases with patient age.[203] It has been suggested that paramedics do not take into account the effect of age, especially after falls.[102] However, it is also plausible that, even when the severity of the injury is recognised, paramedics may consider Trauma Centre transport as futile due to the severity, patient age, existence of comorbidities and likely prognosis.[170] This may also explain why older adults were not subsequently transferred to the Trauma Centre after initial stabilisation at another hospital, with the assessment that transfer to the Trauma Centre is inappropriate for that patient and a decision made on end of life care.[63, 205] However, death also might have occurred prior to transfer.[205]

Older adults often will not trigger standard adult prehospital trauma triage criteria for major trauma,[144, 180, 206] as many prehospital trauma triage criteria fail to address the physiology and pre-existing conditions of the older adult population.[172] One of the reasons for this is the ability of older adults to sustain major trauma from low-velocity mechanisms such as falls,[184] many attributed to syncopal episodes resulting from medical co-morbidities.[221] Furthermore, cognitive changes may preclude EMS providers from gaining an accurate history of preceding events.[178] Major trauma is normally associated with injuries that result in gross anatomical disruption or external haemorrhage which are both easily recognised.[178] However, in older adults there is frequently minimal evidence of trauma as they often fail to display overt physiological derangement.[102, 119, 219] They are also more susceptible to traumatic intracranial haemorrhage and occult hypoperfusion, which are inherently difficult to recognise,[119, 184] with vital signs being less predictive of mortality.[176, 180] The presence of significant comorbidities, polypharmacy and anticoagulation and antiplatelet therapy may account for this.[184, 222] It has been suggested that the widespread use of anticoagulant and antiplatelet agents predispose older adults to excessive bleeding, which in turn, may be unrecognised due to the absence of hypotension and tachycardia in response to the traumatic insult.[178]

14.3 Limitations

I acknowledge that there are limitations to my doctoral research. These are discussed below.

My study was carried out using data collected from patients with trauma in the metropolitan region of Perth who were attended by SJ-WA paramedics between the 1st January 2013 and 31st December 2016. It is impossible to guarantee that the findings from this study are translatable to other locations or other EMS systems, although similar results have been shown in other studies.

When I examined the epidemiology of trauma, I used SJ-WA data and WA death data from the trauma of all acuities. I used the paramedic allocated mechanism of injury code to identify and group patients. Unfortunately, these codes are broad, subjective and do not identify key subpopulations such as falls. There are no defined codes for specific road trauma subpopulations such as pedestrians and cyclists.

I found that ‘trauma in the home’ was the most common reason for an ambulance attendance, however, this code is generic and ambiguous. Although it is likely that the majority of this type of trauma would be falls from <3 metres, the limited specificity of the paramedic allocated mechanism of injury coding meant that in the absence of a specific code for falls, I could not fully evaluate the utilisation of ambulances for injuries from this mechanism. Using SJ-WA data and WA death data meant that information such as morbidity or length of stay in hospital was not available for the study pertaining to trauma of all acuities, therefore, the long-term injury burden could not be assessed.

Using the WA-STR data I examined the association between outcomes of major trauma patients (defined as an ISS >15) and prehospital factors in two separate studies. Firstly, it is important to consider that these two studies were retrospective and thus inherently at risk of confounding. Although I used IPTW to reduce the risk of confounding in these two studies, there may have been unknown confounders that influenced associations seen in the multivariate analyses. Also, my small sample size may have been prone to type II error.

The classification of major trauma defined as an ISS >15 is a retrospective diagnosis based on information not necessarily available prehospital, such as results from imaging. Therefore, this limits the applicability of my findings to EMS clinical practice.[25] As with all studies using retrospective trauma registry data, the studies are also subject to a potential survivor bias. Patients who exclusively attended a hospital that did not provide data to the WA-STR were not featured in the registry. However, as the Level I Trauma Centre treats approximately 80% of the state’s major trauma,[88] the majority of patients with major trauma would have been transported to a hospital that provided data to the WA-STR.

Despite identifying prehospital deaths in the study of all trauma acuities and further examining these in the study of traumatic aetiology OHCA, these patients were not included in the four studies of major trauma. As those who died prehospital are also not included in the registry, pertinent information such as ISS, AIS and specific mechanism of injury were not available. Another way of determining further information regarding prehospital deaths would be from the National Coronial Information System, however, I, unfortunately, did not have access to those data.

In relation to prehospital time interval, I could not measure exact prehospital times and this is an acknowledged limitation of most time-related prehospital research.[96] I used the time that the call was received by the State Operations Centre and not the actual time the injury was sustained, a time often unknown, to calculate the time variables. Similarly, I used the time that the first emergency vehicle arrived on the scene as the on-scene time, however, this may not have been the time that the crew arrived at the patient. Furthermore, I was unable to ascertain the difference between the time spent extricating the patient from time spent treating the patient. Despite my finding of an association between longer on-scene time and LOS in 30-day survivors, this does not prove causation. Missing prehospital physiological information may have influenced my results, however, this accounted for less than 5% of the data and pertained only to the first tRTS.

Data regarding the decision making of the paramedics were not available. Therefore, in the study investigating transport destination and mortality, it is not known whether the patient's initial transport destination was the Trauma Centre but diversion to a closer hospital for stabilisation of imminent life threats was necessary. This would be influenced by factors such as the location of the incident, time of day and driving conditions. These factors contribute to a selection bias.

In the study that examined older age and Trauma Centre transport, I used the age 65 years to define older adults and this was consistent with previous research.[121, 223] However, it is possible that the association between Trauma Centre transport and age may have been evident at a younger age. Furthermore, there is no existing consensus in the literature as to what age the rate of mortality and morbidity after injury increases.[194]

There was a high proportion of blunt trauma in the cohort of patients with major trauma, therefore, my study will have produced different results to one with a high proportion of penetrating injuries. This may limit the generalisability of the study to different populations. However, this is a recognised limitation of research in major trauma.[166] Generalisability is also limited to road ambulance systems where paramedics (rather than physicians) provide prehospital care.

I used mortality and length of hospital stay as outcomes after trauma in six of the studies undertaken as part of this thesis. These are crude methods of appraising outcome and do not reflect the full burden of injury.[93] The functional outcomes of the survivors were not examined nor was the quality of survival. It is important to consider that an effective trauma system should show a reduction in both mortality and morbidity.[22] It is possible that prehospital time and transport destination decisions had implications for survivors such as complications and post-trauma quality of life, however, these were not explored.

Despite searching for grey literature whilst undertaking my systematic review, publication bias may have occurred, as the studies identified were published and reported a positive result.[207] Although the funnel plot did not show evidence of asymmetry, bias cannot be excluded.[185] Furthermore, although I did not set any restrictions regarding the language that the studies were published in, those published in a language other than English may have been missed in my search, resulting in a reporting bias.[202] As the studies that were included in the review were from three countries, Australia, Canada and the USA, it is not possible for me to determine whether it would be appropriate to extrapolate the findings to other EMS jurisdictions.

In the publication presented in Chapter 12 the results section reads “whereas the majority of patients in the older group were non-major TC transports (n=232 [40%])” however, this should read “whereas most of the patients in the older group were non-major TC transports (n=232 [40%])”.

Despite the aforementioned limitations of my thesis, I have translated the main findings into a set of final recommendations.

14.4 Implications and Recommendations for Future Research

Based on my doctoral research I recommended several areas for future research. I will now discuss the implications of my research followed by the recommendations for further research.

Since the publication of our traumatic aetiology OHCA study, SJ-WA has created a specific clinical practice guidelines for the management of traumatic aetiology OHCA (Thesis Appendix M). This specific clinical practice guidelines de-emphasises the use of chest compressions in traumatic aetiology OHCA and emphasises correction of reversible causes, such as: needle thoracentesis/thoracocentesis for tension pneumothorax, application of tourniquets for external haemorrhage and pelvic splinting for suspected pelvic fractures.[73] The emphasis is placed on rapid extrication and transport to the emergency department. However, if this cannot be achieved within 25 minutes from the arrival of the ambulance on scene, termination of resuscitation is permitted.[73] Although improvement in the provision of care and a priority given to ensuring EMS response times are not unnecessarily delayed, it is likely that the greatest opportunity for reducing the number of untimely deaths in younger persons, will only be achieved by a focus on prevention.[123] In light of this recent change in the management of traumatic aetiology OHCA, comparison of outcomes should be undertaken prior and post change.

The undertriaging of older adults seen in my study is likely to be partly related to the SJ-WA clinical practice guidelines for major trauma. The current guideline does not include a fall <3 metres as a consideration for Trauma Centre transport. Similarly, the major trauma team activation protocol at the Trauma Centre also does not include this mechanism of injury as a trigger for team activation.[35] Therefore, for a patient with a fall from standing to be recognised as potentially having major trauma they would have to meet one of the anatomical criteria in the SJ-WA clinical practice guidelines. Considering that major head injuries, which are highly prevalent in older adults because of increased use of anticoagulation and antiplatelet therapy,[222] are not listed as an anatomical criterion, it is unlikely that a patient with a fall from standing and a concomitant head injury would be considered for Trauma Centre transport.

Given the shift in major trauma to a greater proportion of older adults, trauma systems need to adapt to these changes.[205] Although mortality in older trauma patients is known to be higher than their younger counterparts, with appropriately configured services, good outcomes can be achieved.[224] Developing ways in which to identify major trauma in older patients prehospital is essential to enable these patients to receive appropriate care. It has previously been shown that the adoption of specific prehospital trauma triage criteria can significantly improve the detection of older patients requiring specialised care.[177, 206] However, this increase in sensitivity needs to occur without resulting in unnecessary levels of over triaging (reduced specificity). Similarly, further EMS provider training regarding older adult response to trauma insults may help to better identify major trauma in older patients.[170]

If older adults were included as a special population in the major trauma guideline and paramedics were provided with further education regarding major trauma in older adults, it would be pertinent to repeat the analysis of the association between age and Trauma Centre transport. It would also be important to undertake analysis of the specificity and sensitivity of any new guideline to ensure this has not unnecessarily reduced specificity.

The classification of major trauma is undertaken using diagnoses based on information not necessarily available prehospital, such as results from imaging. It is, therefore, important to develop ways in which to identify older adults with major trauma prehospital and identify those who would benefit from Trauma Centre care to ensure that these patients receive care appropriate to their needs and likely outcome.

As I demonstrated that prehospital time was not associated with an increased probability of 30-day mortality, but no attendance at a Trauma Centre was, it seems imperative that further research ascertains whether prehospital times could safely be extended to enable major trauma patients to directly attend a Trauma Centre.

Improved prehospital care could reduce patient complications resulting in an overall improvement in patient outcomes and this warrants further examination. Therefore, further analysis of the functional outcomes of the survivors and the quality of survival is recommended.

14.5 Recommendations

Based on the findings of my research, I provide the following recommendations:

- The addition of a specific prehospital trauma code, for patients who have a fall as their mechanism of injury, may assist with the early identification and further analysis of this high-risk group.
- The addition of prehospital trauma codes for specific road trauma subpopulations such as pedestrians and cyclists would assist with identification and further analysis of these groups.
- Further efforts are warranted to reduce the undertriaging of older adults with severe injuries, such as redefining the major trauma guideline to include the addition of older adults as a special population that warrant consideration for Trauma Centre transport due to the impact of medication and medical comorbidities.
- The inclusion of a low fall with a potential head strike as a consideration for Trauma Centre transport may assist in the earlier identification of those at risk of major trauma which may not be immediately apparent prehospital.
- Further education should be provided to paramedics in relation to the predominance of falls as a cause of major trauma and the complexities of major trauma in older adults. Paramedics should also be made aware of evidence from the literature that shows older adults have a decreased likelihood of Trauma Centre transport.
- Prehospital trauma care should be delivered in a timely fashion and transport of the patient to hospital should occur reasonably promptly.

14.6 Implementations of Recommendations

This thesis and the recommendations will be submitted to the Clinical Governance General Manager of SJ-WA. Following the submission, the merits of proposal will be considered and discussed by the Clinical Governance General Manager, Medical Director and Clinical

Governance department. If approved, redevelopment of relevant clinical practice guidelines will be undertaken. If there is a significant change or requirement for a new clinical practice guideline or guidelines, this will be tabled and discussed with the Medical Practice Committee. If the Medical Practice Committee approval is received, the new guideline or changed guideline, will be given to education to develop an appropriate education package. It will then be determined if there is a need for inclusion of the information into the paramedic Continuing Education Programme or if online training is appropriate.[225]

14.7 Concluding Remarks

This thesis explored the epidemiology of trauma patients attended by a paramedic staffed EMS specific to the metropolitan area of Western Australia and examined the association between prehospital factors and major trauma patient outcomes. I found that the incidence rate of trauma is increasing especially in older adults, however, the majority of patients attended by paramedics were deemed to be low-acuity with high-acuity patients seen infrequently. In relation to major trauma, more than half of those transported by ambulance were over 51 years old and falls from standing were the most common cause. I could not determine an association between prehospital times longer than the 'golden hour' and 30-day mortality or a specific prehospital time interval that was associated with an increased probability of 30-day mortality. The characteristics of major trauma patients were significantly different between those transported directly or indirectly to the Trauma Centre and those who were never transported to the Trauma Centre. Those who never received Trauma Centre care were significantly older, with high prevalence of major head injuries and falls from standing as the most common mechanism of injury. In regard to older adults with major trauma, I determined that older age was associated with a significantly reduced likelihood of Trauma Centre transport which was consistent with other EMS jurisdictions and older adults had almost twice the risk of 30-day mortality if they did not receive Trauma Centre care.

In light of these findings, I suggest that prehospital trauma care be delivered in a timely fashion and transport of the patient to hospital is reasonably prompt. Furthermore, trauma is not only a disease of the young, therefore, to ensure older adults with major trauma receive transport to an appropriate hospital, specific trauma triage criteria for older patients and focusing on extended EMS training may be required.

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APPENDICES

Appendix A Ethics Approval for Retrospective Cohort Study

Curtin University

Memorandum

To	Professor Ian Jacobs, CHIRI
From	Professor Stephan Millett, Chair, Human Research Ethics Committee
Subject	Protocol Approval **HR 128/2013**
Date	3 September 2013
Copy	

Office of Research and Development
Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for your application submitted to the Human Research Ethics Committee (HREC) for the project titled "*Western Australian Pre-hospital Care Record Linkage Project*". The Committee notes the prior approval by University of Western Australia (UWA) HREC (RA/4/1/2567) and has reviewed your application consistent with Chapter 5.3 of the *National Statement on Ethical Conduct in Human Research*.

- You have ethics clearance to undertake the research as stated in your proposal.
- The approval number for your project is **HR 128/2013.** *Please quote this number in any future correspondence*.
- Approval of this project is for a period of four years **03-09-2013** to **03-09-2017**.
- Annual progress reports on the project must be submitted to the Ethics Office.
- If you are a Higher Degree by Research student, data collection must not begin before your Application for Candidacy is approved by your Faculty Graduate Studies Committee.

- The following standard statement **must be** included in the information sheet to participants:
  This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HR 128/2013). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au.

Applicants should note the following:

It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.

The attached **Progress Report** should be completed and returned to the Secretary, HREC, C/- Office of Research & Development annually.

Our website https://research.curtin.edu.au/guides/ethics/non_low_risk_hrec_forms.cfm contains all other relevant forms including:

- Completion Report (to be completed when a project has ceased)
- Amendment Request (to be completed at any time changes/amendments occur)
- Adverse Event Notification Form (If a serious or unexpected adverse event occurs)

Yours sincerely

Professor Stephan Millett
Chair Human Research Ethics Committee

MEMORANDUM

Curtin University

To:	Professor Judith Finn
	CHIRI
CC:	
From	Dr Karen Heslop, Deputy Chair HREC
Subject	Amendment approval Approval number: HR128/2013
Date	05-May-15

Office of Research and Development
Human Research Ethics Office

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for submitting an amendment to the Human Research Ethics Office for the project:

HR128/2013 Western Australian Pre-hospital Care Record Linkage Project

The Human Research Ethics Office approves the amendment to the project.

Amendment number: HR128/2013/AR2

Approval date: 05-May-15

The following amendments were approved:

Addition of Miss Elizabeth Brown as a co-investigator.

Please ensure that all data are stored in accordance with WAUSDA and Curtin University Policy.

Yours sincerely,

Dr Karen Heslop
Deputy Chair, Human Research Ethics Committee

Appendix B Royal Perth Hospital Human Ethics Committee Approval to use State Trauma Registry Data

Government of Western Australia
Department of Health

Royal Perth Hospital Human Research Ethics Committee

18 September 2017

Professor Judith Finn
Kent Street
Bentley Western Australia 6102

Dear Professor Finn

PRN:	RGS0000000464
Project Title:	The epidemiology of major trauma patients attended by ambulance paramedics in Perth, Western Australia
Protocol Number:	Version 1.1 - 28082017

I am pleased to advise you that the Royal Perth Hospital (RPH) Human Research Ethics Committee (HREC) has granted ethical approval of this research project.

The nominated participating site(s) for this project is/are:
Royal Perth Hospital

If additional sites are recruited prior to the commencement of, or during the research project, the Coordinating Principal Investigator is required to notify the HREC. Notification of withdrawn sites should also be provided to the HREC in a timely fashion.

The approved documents include:

Document	Version	Version Date
State Trauma Registry Data Request 10072017		10/07/2017
State Trauma Registry variables requested	1.00	13/06/2017
Epidemiology of Pre-hospital Major Trauma Protocol Version 1.1 28082017	1.1	28/08/2017

This ethical approval is valid to 18 September 2020 subject to compliance with the 'Conditions of Ethics Approval for a Research Project' (Below).

The following project specific conditions must be met/are noted:

The HREC approved a waiver of consent, noting compliance with Section 2.3.10 of the National Statement (2007).

A copy of this ethical approval letter must be submitted by all site Principal Investigators to the Research Governance Office or equivalent body or individual at each participating institution in a timely manner to enable the institution to authorise the commencement of the project at its site/s.

This letter constitutes ethical approval only. This project cannot proceed at any site until separate site authorisation has been obtained from the Chief Executive or Delegate of the site under whose auspices the research will be conducted at that site.

Should you have any queries about the HREC's consideration of your project, please contact the Ethics Office at EMHS.REG@health.wa.gov.au or on 08 9224 2292. The HREC's Terms of Reference, Standard Operating Procedures and membership are available from the Ethics Office or from http://ww2.health.wa.gov.au/About-us/East-Metropolitan-Health-Service/About/Human-Research-Ethics-and-Governance.

The HREC wishes you every success with this project.

Yours sincerely

DR RAMIN GHARBI
Chairman | Royal Perth Hospital Human Research Ethics Committee

CONDITIONS OF ETHICS APPROVAL FOR A RESEARCH PROJECT

The following general conditions apply to the research project approved by the Human Research Ethics Committee (HREC) and acceptance of ethical approval will be deemed to be an acceptance of these conditions by all project investigators:

1. The responsibility for the conduct of this project lies with the Coordinating Principal Investigator (CPI).
2. The investigators recognise the reviewing HREC is registered with the National Health and Medical Research Council and that it complies with the current version of the National Statement on Ethical Conduct in Human Research.
3. A list of HREC member attendance at a specific meeting is available on request, but no voting records will be provided.
4. The CPI will immediately report anything that might warrant review of ethical approval of the project.
5. The CPI will notify the HREC of any event that requires a modification to the protocol or other project documents and submit any required amendments to approved documents, or any new documents, for ethics approval. Amendments cannot be implemented at any participating site until ethics approval is given.
6. The CPI will submit any necessary reports related to the safety of research participants in accordance with the WA Health Research Governance Standard Operating Procedures.
7. Where a project requires a Data Safety Monitoring Board (DSMB), the CPI's will ensure this is in place before the commencement of the project and notify the HREC. All relevant reports from the DSMB should be submitted to HREC.
8. For investigator-initiated and collaborative research group projects the CPI may take on the role of the sponsor. In this case, the CPI is responsible for reporting to the Therapeutic Goods Administration (TGA) any unexpected serious drug or device adverse reactions, and significant safety issues in accordance with the TGA guidelines.
9. If the project involves the use of an implantable device, the CPI will ensure a properly monitored and up to date system for tracking participants is maintained for the life of the device.
10. The CPI will submit a progress report to the HREC annually from the ethics approval date and notify the HREC when the project is completed at all sites. The HREC can request additional reporting requirements as a special condition of a research project. Ethics approvals are subject to the receipt of these reports and approval may be suspended if the report is not received.
11. The CPI will notify the HREC of his or her inability to continue as CPI and will provide the name and contact information of their replacement. Failure to notify the HREC can result approval for the project being suspended or withdrawn.
12. The CPI will notify the HREC of any changes in investigators and/or new sites that will utilise the ethics approval.
13. The HREC has the authority to audit the conduct of any project without notice if some irregularity has occurred, a complaint is received from a third party or the HREC decides to undertake an audit for quality improvement purposes.
14. The HREC may conduct random monitoring of any project. The CPI will be notified if their project has been selected. The CPI will be given a copy of the monitor's report along with the HREC and Research Governance (RG) Office at the site/s.
15. Complaints relating to the conduct of a project should be directed to the HREC Chair and will be promptly investigated according to the WA Health's complaints procedures.
16. The CPI should ensure participant information and consent forms are stored within the participant's medical record in accordance with the WA Health's RecordKeeping Plan.
17. The CPI will notify the HREC of any plan to extend the duration of the project past the expiry date listed above and will submit any associated required documentation. A request for an extension should be submitted prior to the expiry date. One extension of 5 years may be granted but approval beyond this time period may necessitate further review by the HREC.
18. Once the approval period has expired or the project is closed, the CPI will submit a final report. If the report is not received within 30 days the project will be closed and archived.
19. Projects that do not commence within 12 months of the approval date may have their approval withdrawn and the project closed. The CPI must outline why the project approval should remain.
20. The CPI will notify the HREC if the project is temporarily halted or prematurely terminated at a participating site before the expected completion date, with reasons provided. Such notification should include information as to what procedures are in place to safeguard participants.
21. If a project fails to meet these conditions the HREC will contact the CPI to address the identified issues. If, after being contacted by the HREC, the issues are not addressed, the ethics approval will be withdrawn. The HREC will notify the RG Office at each site within WA Health that the project procedures must discontinue, except for those directly related to participant's safety.

Government of Western Australia
East Metropolitan Health Service

18 October 2017

Prof Judith Finn
Curtin University
Bentley WA
6102

Dear Judith

Project Title: **The epidemiology of major trauma patients attended by ambulance paramedics in Perth, Western Australia**

PRN: **RGS 00000000464**

On behalf of Royal Perth Hospital, East Metropolitan Health Service, I give authorisation for your Access Request for access to participants data at the following site(s):

- **Royal Perth Hospital**

This authorisation is based on the approval from the Royal Perth Hospital Human Research Ethics Committee and the review from the Research Governance Office.

If you have any queries, please contact the Research Governance Office on (08) 9224 8791 or EMHS.REG@health.wa.gov.au.

Yours sincerely

Dr Aresh Anwar
EXECUTIVE DIRECTOR

Research Ethics & Governance
Level 3 Colonial House, Royal Perth Hospital, GPO Box X2213 Perth WA 6847
Telephone: (08) 9224 2260 / (08) 9224 2292
Email: EMHS.REG@health.wa.gov.au

Appendix C St John Western Australia – Dispatch/Problem Codes

DISPATCH/PROBLEM CODES (reviewed June 2014)

01	**TRAUMA**
010	Other
011	Domestic
012	MVA
013	Sporting/Recreational
014	Industrial
015	Assault
016	Hanging
017	Sexual Assault
018	Shooting
019	Stabbing
20	**ABDOMINAL**
201	Pain
202	Hematemesis
203	Melena
204	Aneurysm
205	GIT Bleed
206	Vomiting +/- Diarrhoea
21	**OBST/GYNY**
211	Vaginal Bleed
212	Pre-Eclampsia
213	Ectopic Pregnancy
214	Miscarriage
215	Normal Labour
216	Comp. Labour
217	Baby Born
218	Neonatal Resus
219	Other
22	**ALLERGY**
221	Anaphylaxis
222	Localised
223	Medication Reaction
24	**RESPIRATORY**
240	Pulmonary Embolism
241	Asthma
242	APO (Non Cardiac)
243	CAL/COAD
244	Pneumothorax
245	Respiratory Tract Infection
246	Aspiration/Regurgitation.
247	Obstruction Upper Airway
248	Resp Arrest
249	Other
25	**EAR/NOSE/THROAT**
250	ENT
251	Epistaxis
26	**INFECTION**
261	Significant risk to AO
262	Septicaemia
263	Localised Infection
264	Pyrexia Unknown Origin
27	**GERIATRIC/ DEBILITY**
271	Generalised Debility
273	Vertigo/Dizziness
274	GP Hospital Referral
275	Mobility Assistance only
28	**ILLNESS**
281	Unspecified (text explanation)
282	Flulike Illness
29	**ENDOCRINE/ METABOLIC**
291	Ketoacidosis
292	Hypoglycaemia
293	Hyperglycaemia
30	**MUSCULO/SKELETAL**
301	Pain/Inflammatory
302	Quad/Para
303	Amputee
31	**NEUROLOGICAL**
310	Convulsions Other
311	Altered Conscious State
312	CVA/Stroke
313	Headaches
314	Convulsions - Febrile
315	Convulsions - Epileptic
316	Status Epilepticus
317	Syncope
318	Unconscious Unknown
319	TIA (Recovered)
32	**POISONING**
321	Ingested
322	Absorbed
323	Gaseous
33	**DRUG/ALCOHOL INDUCED**
331	Drug Induced Mental Illness
332	O/dose intent harm
333	Alcohol Intoxication
334	Overdose (Unintentional)
335	Narcotic OD
34	**UROLOGY**
341	Haematuria
342	Retention
343	Renal Colic
344	Incontinence
345	Renal Failure (Renal Dialysis)
346	Urinary Tract Infection
35	**ENVIRONMENT**
351	Hypothermia
352	Hyperthermia
353	Barotrauma/DCS
354	Near Drowning
355	Electric Shock
356	Burns
357	Bites & Stings
358	Dehydration
36	**MALIGNANCY**
361	Malignancy
37	**PSYCHO/SOCIAL**
371	Psychiatric Illness
372	On Forms
373	Social Problem
41	**CARDIAC**
410	APO (Cardiac)
411	Chest Pain / ACS
412	Angina Diagnosed
413	AMI diagnosed
414	CCF
415	Cardio Shock
416	Pacemaker Fail
417	Cardiac Dysrhythmia
418	Cardiac Arrest
419	Post Cardiac Arrest
44	**NEO NATAL**
440	Neo Natal
50	**PR VISIT**
500	PR Visit
59	**STANDBY**
591	Wait for other amb
592	Major Incident
593	Dangerous Incident
594	Disaster Exercise
60	**SPORTING STAND BY**
602	Sporting Fixture
80	**TRANSFERS**
801	Trauma
802	Abdominal/Renal
803	Obstetrics/Gynaecology
804	Respiratory
805	Endocrine/Environmental
806	Drug/Alcohol
807	Psychological
808	Cardiac
809	Other

TRANSMISSION CODES

62	Ambulance Not
73	On an Errand
79	Arrive at Scene
80	Mobile
81	Arrived Destination
82	Cleared
83	At Station
84	Police
85	Petrol
86	Spare
87	Workshops
88	Belmont HQ
89	Return to Station
90	Patient Deceased
99	Meal Break

AMBULANCE NOT REQUIRED

The codes for non transport are as follows:

1	No Emergency care
2	Patient refused
3	Patient assessed – no Problem found
4	Patient assessed – Seek further treatment
5	Transported by another Ambulance
6	Transported by another Means
7	Doctor in attendance
8	Call Cancelled
9	Stood down
10	Patient not ready – to Rebooked
11	Clinic appointment
12	Unable to locate scene
13	Patient absconded
14	Hoax
15	Care given. Transport Declined
16	Patient Deceased

Problem Urgency

Australasian Triage Scale	Treatment Acuity	Numeric Code	Example of Diagnosis
Resuscitation	Immediate	1	Shock, Cardiac Arrest, Unconscious
Emergency	Within 10 Minutes	2	Chest Pain, Severe Dyspnoea
Urgent	Within 30 Minutes	3	Moderate Trauma- Ankle Wrist Fracture
Semi Urgent	Within 60 Minutes	4	Acute Abdominal Pain, Sprained Ankle
Non Urgent	Within 120 Minutes	5	Chronic Disorder, Rash, Back Pain
Non-ATS case	Not Applicable	6	Transfer to NH, Transport Home, Clinic Run

Appendix D St John Western Australia Clinical Practice Guideline for Treatment of Major Trauma

GENERAL

1.1E MAJOR TRAUMA GUIDELINE

July 2016

MAJOR TRAUMA GUIDELINE:

In accordance with the trauma services plan developed by the Department of Health, patients suffering major trauma should be taken to hospitals designated as Major Trauma Centres. Within the plan Royal Perth Hospital (RPH) is designated the **State Major Adult Trauma** centre and Princess Margaret Hospital (PMH) the **State Major Paediatric Trauma centre**. Sir Charles Gairdner (SCGH) and Fiona Stanley Hospital (FSH) are designated metropolitan trauma services.

Major trauma is any injury that has the potential to cause prolonged disability or death. There are many causes of major trauma, blunt and penetrating, including falls, motor vehicle collisions, and gunshot wounds. Depending on the severity of injury, quick management and transport to the appropriate Trauma Centre may be necessary to prevent loss of life or limb.

The following should be followed in regards to patients with suspected major trauma:

Adult:

1. All patients with major trauma should be taken directly to **RPH where possible.**

2. Where the patient's condition appears **imminently** life threatening, diversion to thenearest appropriate emergency department for stabilisation should be undertaken.

3. Trauma patients with obvious spinal injuries, who are pregnant or have major pelvic injuries, should always be taken to **RPH** except in imminent life threatening situations where stabilisation is required prior to transfer to RPH.

4. Burns: Patients should be taken to **FSH** where possible. Should significant major trauma also be present, they should be taken to **RPH**.

5. All country hospital transfers of major adult trauma should be taken to RPH. RFDS transfers will have a designated receiving hospital and crews should follow this.

Paediatrics:

6. All major paediatric (patients age less than 14 years) trauma (including burns) should be taken to PMH unless urgent stabilisation is required at the nearest appropriate emergency department prior to transfer to PMH.

Patients not suffering major trauma as defined in this guideline are to be transported to the hospital designated by the ANC. Should the patient need specialised care, as defined by the current Transport Circular; Ambulance Distribution to Hospitals and the Clinical Matrix, the ANC should be contacted to inform them of the change of destination.

Clinical Matrix is located at Clinical Governance Aide Memoire.

MAJOR TRAUMA CRITERIA

In accordance with the trauma services plan developed by the Department of Health, patients suffering major trauma should be taken to hospitals designated as Major Trauma Centres.

Major Trauma should be considered in any one of the following criteria:

MECHANISM

- MBA > 30 km/h with injuries.
- MVA > 60 km/h with injuries.
- Ejection from vehicle
- Penetrating injury to head, neck, torso or proximal extremities.
- Fall > 3m
- Fatality on scene whereby the patient was in the same vehicle.
- Pedestrian or cyclist with speed impact > 25km/h

ANATOMICAL CRITERIA

- Flail Chest
- Pelvic Fractures
- Amputation / crush Injury proximal to hand and foot.
- 2 or more long bone fractures
- Suspected Spinal Injury
- Polytrauma
- Open or depressed skull fracture
- De-gloving or mangled extremity proximal to hand and foot.

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Appendix F Manuscript – Trends in Traumatic Out-of-Hospital Cardiac Arrest in Perth, Western Australia from 1997-2014

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Clinical paper

Trends in traumatic out-of-hospital cardiac arrest in Perth, Western Australia from 1997 to 2014☆

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ABSTRACT

Aim: This study aims to describe and compare traumatic and medical out-of-hospital cardiac arrest (OHCA) occurring in Perth, Western Australia, between 1997 and 2014.

Methods: The St John Ambulance Western Australia (SJA-WA) OHCA Database was used to identify all adult (≥16 years) cases. We calculated annual crude and age-sex standardised incidence rates (ASIRs) for traumatic and medical OHCA and investigated trends over time.

Results: Over the study period, SJA-WA attended 1,354 traumatic OHCA and 16,076 medical OHCA cases. The mean annual crude incidence rate of traumatic OHCA in adults attended by SJA-WA was 6.0 per 100,000 (73.9 per 100,000 for medical cases), with the majority resulting from motor vehicle collisions (56.7%). We noted no change to either incidence or mechanism of injury over the study period ($p > 0.05$). Compared to medical OHCA, traumatic OHCA cases were less likely to receive bystander cardiopulmonary resuscitation (CPR) (20.4% vs. 24.5%, $p = 0.001$) or have resuscitation commenced by paramedics (38.9% vs. 44.8%, $p < 0.001$). However, rates of bystander CPR and resuscitation commenced by paramedics increased significantly over time in traumatic OHCA ($p < 0.001$). In cases where resuscitation was commenced by paramedics there was no difference in the proportion who died at the scene (37.2% traumatic vs. 34.3% medical, $p = 0.17$), however, fewer traumatic OHCAs survived to hospital discharge (1.7% vs. 8.7%, $p < 0.001$).

Conclusions: Despite temporal increases in rates of bystander CPR and paramedic resuscitation, traumatic OHCA survival remains poor with only nine patients surviving from traumatic OHCA over the 18-year period.

Introduction

Historically, the resuscitation of patients with trauma related out-of-hospital cardiac arrest (OHCA) was considered futile, particularly when compared to outcomes achieved in OHCA of medical aetiology.[1,2] However, recent evidence suggests survival in traumatic OHCA has improved, with rates of survival reported as high as 5 to 9%.[3–7] The reasons for this increase in survival from traumatic OHCA are not clear. It is known that survival from non-traumatic OHCA is enhanced through improving each component of the 'chain of survival'.[9,10] The chain of survival consists of early: recognition of cardiac arrest, CPR, defibrillation and advanced post-resuscitation care.[11] Variations in the application and effectiveness of these key components may explain the differences in survival between medical and traumatic OHCAs.[6,12] Additionally, there is currently insufficient evidence of temporal trends in traumatic OHCA, such as incidence and aetiology, that may explain these recent increases in survival.

This study aims to describe and compare traumatic and medical OHCA in metropolitan Perth, Western Australia, between 1997

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and 2014. Specifically, we aim to investigate temporal trends in the incidence, characteristics and outcomes of traumatic OHCA, and compare these against medical OHCA.

Methods

Perth is the capital city of the state of Western Australia, with a population of 2.0 million and a land area of 5300 square kilometres.[13] St John Ambulance Western Australia (SJA-WA) is the sole provider of emergency road ambulance services in WA, with a single tiered service of advanced life support paramedics in the Perth metropolitan area.[14] The management of OHCA by SJA-WA paramedics, including the commencement and termination of resuscitation in the field, is directed by the SJA-WA cardiac arrest clinical practice guideline (CPG), which is based on the Australian Resuscitation Council guidelines.[15] Specifically, resuscitation can be withheld by paramedics in the following situations: where death has clearly occurred, where major injuries are incompatible with life, in palliative care patients where death was expected and imminent, and where an Advanced Directive is in place. Termination of resuscitation by paramedics is appropriate in cases in which all of the following apply: no response to maximal directed resuscitation by SJA-WA for at least 20 min, the arrest was not witnessed by a paramedic, the patient is asystolic and no defibrillation was delivered at any stage during the resuscitation.

Data collection

Cases were extracted from the SJA-WA OHCA database, which is maintained by the Prehospital, Resuscitation and Emergency Care Research Unit (PRECRU) located at Curtin University. Patient outcomes such as admission to hospital, survival to hospital discharge and cerebral performance score[16,17] on hospital discharge are determined through medical record review by a research nurse. All cases of OHCA with either a traumatic or medical aetiology were included for analysis. As per the recent Utstein guidelines, medical OHCA is defined as "cases where the cause of the cardiac arrest is presumed to be cardiac, other medical (e.g. anaphylaxis, asthma, GI bleed), and where there is no obvious cause of the cardiac arrest".[18] Traumatic OHCA is defined as "cardiac arrest directly caused by blunt, penetrating, or burn injury".[18] Patients aged <16 years and those with a mechanism of hanging or drowning were excluded. Arrests were classified as being unwitnessed when listed as such or when there was insufficient evidence on the witness status. Paramedic industrial action during 2008 and a migration from paper to electronic patient care records (e-PCR) in 2011 resulted in missing cases for those years; therefore cardiac arrest rates for 2008 and 2011 were estimated by averaging the preceding and subsequent years (2007 and 2009, and 2010 and 2012, respectively).

Ethics approval

The collection of SJA-WA cardiac arrest data during the study period was approved by the University of Western Australia Human Research Ethics Committee (HREC) (#RA/4/1/1004); which in 2013 was replaced by the Curtin University HREC (#128/2013). An ethics exemption was approved by Monash University HREC (#CF15/1570-2015000780), since all patient-level data analysis was undertaken at Curtin University by one of the authors (HT).

Data analysis

Annual crude and age-sex standardised incidence rates (ASIRs) were calculated. Annual rates were calculated using the Australian Bureau of Statistics population data for each year for the Perth Statistical Division[19] as denominators. ASIRs were calculated using the direct method[20] whereby annual age-sex specific incidence rates were calculated across 5-year age-groups by sex using the number of traumatic and medical OHCAs for each age-group and sex as numerators. Rates were standardised by 5-year age groups using the 2011 Australian population as the population standard.[19] As the study excluded cases with age <16 years, all population data for the 15–19 age group were adjusted to reflect a 16–19 age group by assuming an equal distribution of age (population data for the 15–19 age group was multiplied by 0.8). Temporal trends in crude incidence, ASIR, rates of bystander CPR and paramedic resuscitation, and the mechanism of injury in traumatic OHCA were assessed with linear regression using the calendar year as the independent variable. A sensitivity analysis was performed excluding data from 2008 and 2011, when the number of traumatic and medical OHCAs were estimated.

Comparisons of the patient cohort, arrest characteristics and outcomes between traumatic and medical OHCA were conducted using the chi-square test for categorical variables and the Mann-Whitney test for continuous variables. Years were grouped relative to resuscitation guideline updates in 2005[21,22] and 2010,[23,24] which were similarly reflected in ARC guidelines. The location of the arrest was grouped into those occurring in a public place and others (place of residence, nursing home and other). The mechanism of injury was grouped into motor vehicle collisions, falls from height, penetrating injuries and others (assault, work-related, train accident, electric shock, burn, fall on the same level and other). Factors affecting initiation of bystander CPR were analysed using multivariable logistic regression. Included variables were those known to influence the initiation of bystander CPR.[25] Paramedic-witnessed arrests were included in all analyses with the exception of those related to bystander CPR. Data analysis was performed using Stata (Version 13.1, StataCorp, College Station, TX) and SPSS (Version 21.0, IBM, Armonk, NY). A p-value <0.05 was considered statistically significant.

Results

From 1997 to 2014 in metropolitan Perth (Western Australia) SJA-WA attended 21,071 cases of OHCA. The aetiology of arrests remained stable over time, with 16,076 (74%) medical cases and 1354 (6%) traumatic events.

Temporal trends and characteristics of traumatic and medical OHCA

The mean annual crude incidence rate of OHCA attended by SJA-WA was 6.0 per 100,000 for traumatic cases and 73.9 per 100,000 for medical cases. These were similar to the mean annual age-sex standardised rates of 6.0 per 100,000 for traumatic cases and 87.6 per 100,000 for medical cases (Fig. 1). The incidence of medical OHCA was not linear over time ($p = 0.06$); however, we observed an early decline from 1997 to 2002 (16% reduction in incidence), a stabilization period from 2002 to 2009, followed by a 17% increase in incidence from 2009 to 2014. The incidence of traumatic OHCA for both crude ($p = 0.99$) and standardised ($p = 0.98$) rates showed no significant trend over time. The trend in standardised incidence of traumatic OHCA remained non-significant when stratified by the following age groups: 16–39 ($p = 0.11$), 40–64 ($p = 0.07$), 65–79 ($p = 0.20$) and 80 years and older ($p = 0.25$). The majority of traumatic OHCAs were due to motor vehicle collisions (MVC = 56.7%), penetrating injuries (16.7%) and falls from a height (7.5%). We noted no trends in the mechanism of injury over time ($p > 0.05$ for all) (Fig. 2).

Compared to the medical group, traumatic OHCA cases were more likely to be younger, male, occur in a public place and

Table 1
Comparison of traumatic and medical cases of OHCA in metropolitan Perth, Western Australia from 1997 to 2014.

Characteristic	OHCA aetiology		*p* Value
	Traumatic	Medical	
Number of cases	1,354	16,076	
Year, *n* (%)			0.007
1997–2005	566 (41.8%)	7,162 (44.6%)	
2006–2010	433 (32.0%)	4,498 (28.0%)	
2011–2014	355 (26.2%)	4,416 (27.5%)	
Age group, *n* (%)			<0.001
16–39	716 (52.9%)	915 (5.7%)	
40–64	427 (31.5%)	4,713 (29.3%)	
65–79	134 (9.9%)	5,719 (35.6%)	
80 and older	77 (5.7%)	4,729 (29.4%)	
Male sex, *n* (%)	1,067 (78.8%)	10,597 (65.9%)	<0.001
Initial arresting rhythm, *n* (%)			<0.001
VF/VT	45 (3.3%)	2,756 (17.1%)	
PEA	231 (17.7%)	1,530 (9.5%)	
Asystole	855 (63.1%)	10,180 (63.3%)	
Unknown	223 (16.5%)	1,610 (10.0%)	
Location of arrest, *n* (%)			<0.001
Public place	1,007 (74.4%)	1,867 (11.6%)	
Other	347 (25.6%)	14,209 (88.4%)	
Arrest witnessed by, *n* (%)			<0.001
Bystander	475 (35.1%)	3,787 (23.6%)	
Paramedic	42 (3.1%)	779 (4.8%)	
Unwitnessed	837 (61.8%)	11,510 (71.6%)	
Bystander CPR initiated, *n* (%)	276 (20.4%)	3,931 (24.5%)	0.001
Resuscitation commenced by paramedics, *n* (%)	527 (38.9%)	7,199 (44.8%)	<0.001
Response time, median (IQR) min	9.0 (6.4–12.0)	9.0 (6.4–11.5)	0.03
Mechanism of injury, *n* (%)			
Motor vehicle collision	768 (56.7%)	–	
Penetrating injury	226 (16.7%)	–	
Fall from height	101 (7.5%)	–	
Other	259 (19.1%)	–	
Outcome where resuscitation was commenced by paramedics, *n* (%)			
Died at scene	196 (37.2%)	2,466 (34.3%)	0.17
Admitted to hospital from emergency department	39 (7.4%)	1,151 (16.0%)	<0.001
Survived to hospital discharge	9 (1.7%)	628 (8.7%)	<0.001

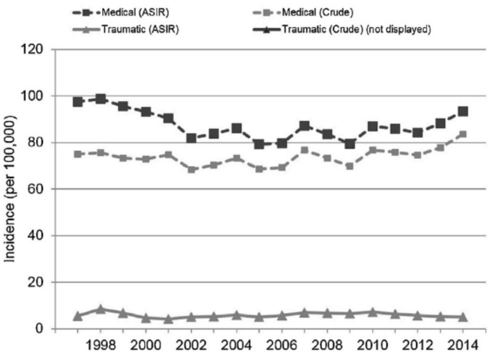

Fig. 1. Temporal trends in crude and age-sex standardised incidence rates of OHCA of medical and traumatic aetiologies attended by paramedics in Perth between 1997 and 2014. Note that the crude incidence rate for traumatic OHCA is not displayed as it overlays the age-sex standardised curve.

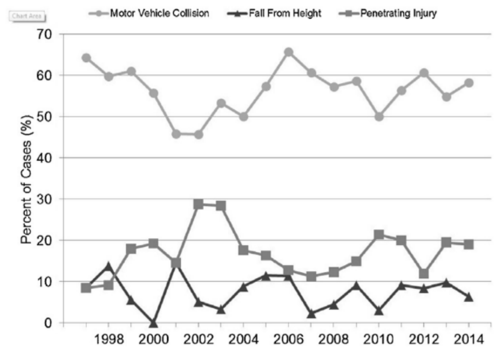

Fig. 2. Temporal trends in the mechanism of injury for traumatic OHCA cases (excluding the 'others' group).

present in a non-shockable rhythm (VF/VT: 3.3% vs. 17.1%, Table 1). Although traumatic OHCA cases were more likely to be witnessed by a bystander (35.1% vs. 23.6%, $p < 0.001$), they were less likely to receive bystander CPR (20.4% vs. 24.5%, $p = 0.001$) or have resuscitation commenced by paramedics (38.9% vs. 44.8%, $p < 0.001$).

Rates of bystander CPR significantly increased over time in traumatic OHCA, with an average annual increase of 1.2% (95% CI: 0.7–1.7, $p < 0.001$), and medical OHCA, with an average annual increase of 0.8% (95% CI: 0.5–1.0, $p < 0.001$). A significant increase was also observed in the percentage of traumatic OHCA with resuscitation commenced by paramedics, with an average annual increase of 1.0% (95% CI: 0.5–1.6, $p < 0.05$). As seen in Fig. 3, rates of paramedic commencement of resuscitation in traumatic OHCA substantially rose during the periods of 1997–2001 (21.7%) and 2010–2014 (20.3%). This increase from 2010 to 2014 was also observed for rates of bystander CPR (21.4%). For cases of medical OHCA, there was no significant overall trend in paramedic

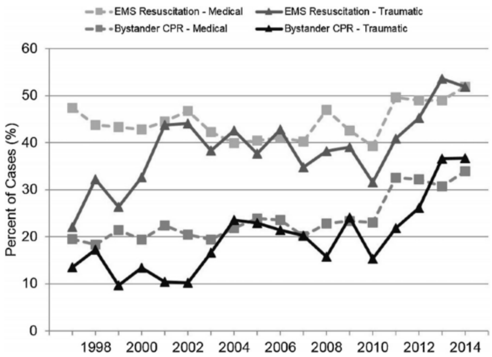

Fig. 3. Temporal trends in the percentage of cases with bystander CPR and paramedic resuscitation segregated by medical and traumatic aetiologies. This data includes paramedic-witnessed arrests.

Table 2
Multivariable logistic regression models for the initiation of bystander CPR, stratified by traumatic and medical aetiologies. Arrests were those not witnessed by paramedics.

Covariate	Traumatic OHCA OR (95% CI)	Medical OHCA OR (95% CI)
Year		
1997–2005	1	1
2006–2010	1.02 (0.72–1.45)	1.25 (1.13–1.38)
2011–2014	1.73 (1.22–2.44)	2.60 (2.36–2.87)
Age group		
16–39	1	1
40–64	1.37 (1.00–1.86)	0.88 (0.74–1.04)
65–79	0.89 (0.53–1.47)	0.55 (0.47–0.65)
80 and older	1.37 (0.73–2.57)	0.33 (0.28–0.39)
Sex		
Male	0.88 (0.63–1.23)	1.03 (0.94–1.13)
Mechanism of injury		
MVC	1	–
Fall from height	1.04 (0.59–1.83)	–
Penetrating injury	1.55 (0.88–2.72)	–
Other	1.05 (0.70–1.58)	–
Location of arrest		
Other	1	1
Public place	1.32 (0.81–2.15)	2.92 (2.60–3.28)
Witnessed by a bystander		
Yes	3.29 (2.41–4.49)	4.83 (4.42–5.28)

commencement of resuscitation ($p = 0.14$), however there was a substantial increase from 2010 to 2014 (12.6%).

Factors in bystander CPR

Multivariable logistic regression showed an increased odds of receiving bystander CPR in 2011–2014 relative to 1997–2005 for both traumatic (OR = 1.73, 95%CI: 1.22–2.44) and medical OHCA (OR = 2.60, 95%CI: 2.36–2.87) (Table 2). In medical OHCA, older age groups had lower odds of receiving bystander CPR than the 16–39 age group. In traumatic OHCA, the odds of receiving bystander CPR were not associated with age group ($p > 0.05$) or with the mechanism of injury ($p > 0.05$).

Traumatic OHCA survival

Comparisons between traumatic and medical OHCA over the entire study period (Table 1) revealed that, of cases where resuscitation was commenced by paramedics, there was no difference in the proportion of patients who died at the scene (37.2% vs. 34.3%, $p = 0.16$). However fewer traumatic OHCAs were admitted to hospital from the emergency department (7.4% vs. 16.0%, $p < 0.001$) and survived to hospital discharge (1.7% vs 8.7%, $p < 0.001$). Of the nine traumatic OHCA patients who survived to hospital discharge (Table 3), the majority were due to motor vehicle collisions ($n = 4$), aged <65 ($n = 6$), presented with an initial rhythm of pulseless electrical activity (PEA) ($n = 7$), were witnessed by paramedics ($n = 4$) or bystanders ($n = 3$), and occurred in the most recent time period (2011–2014; $n = 6$). Of the survivors whose arrest was not paramedic-witnessed ($n = 5$), bystander CPR was not performed on any patient. Neurological outcomes at discharge measured by Cerebral Performance Category (CPC) revealed that of the nine survivors, six had good neurological outcome (CPC ≤ 2) and three had severe cerebral disability (CPC = 3).

Table 3
Characteristics of survivors of traumatic OHCA in Perth, Western Australia, from 1997 to 2014 ($n = 9$).

Characteristic	Traumatic OHCA survivors
Number of cases	9
Year, *n* (%)	
1997–2005	1 (11.1%)
2006–2010	2 (22.2%)
2011–2014	6 (66.7%)
Age group, *n* (%)	
16–64	6 (66.7%)
65 and older	3 (33.3%)
Male sex, *n* (%)	6 (66.7%)
Initial arresting rhythm, *n* (%)	
VF/VT	1 (11.1%)
PEA	7 (77.8%)
Asystole	1 (11.1%)
Location of arrest, *n* (%)	
Public place	6 (66.7%)
Other	3 (33.3%)
Arrest witnessed by, *n* (%)	
Bystander	3 (33.3%)
Paramedic	4 (44.4%)
Unwitnessed	2 (22.2%)
Bystander CPR initiated, *n* (%)	0 (0.0%)
Response time, median (IQR) min	5.0 (4.6–8.7)
Mechanism of injury, *n* (%)	
Motor vehicle collision	4 (44.4%)
Other	5 (55.6%)
Cerebral performance category, *n* (%)	
CPC ≤ 2	6 (66.7%)
CPC = 3	3 (33.3%)

Sensitivity analysis

No changes in the statistical significance of trends were seen with the exclusion of the years 2008 and 2011; where rates were estimated due to missing data.

Discussion

This is the first study to investigate temporal trends in the incidence, mechanism of injury and rates of bystander CPR and commencement of resuscitation by paramedics in traumatic OHCA. We observed no trend in the incidence or mechanism of injury for traumatic OHCA between 1997 and 2014. Although we observed an increase in rates of bystander CPR and commencement of resuscitation by paramedics over time, survival from traumatic OHCA was rare with only nine survivors in 18 years.

We found the incidence of traumatic OHCA to be far lower than medical OHCA. Our study extends the work of Bray et al.,[26] who reported a significant decline in ASIR of medical OHCA over the period 1997 to 2002, followed by a period of stabilization between

2003 and 2010. The data from our present study shows a rapid recent increase in the ASIR of medical OHCA–which is approaching the rates recorded in the late 1990s. However, the reasons for this increase are not clear. It may, at least in part, be explained by the introduction of electronic patient care records in 2011 and subsequent improved case capture, or may simply be natural variation in incidence. Future work is warranted to observe whether this recent increasing trend in ASIR of medical OHCA continues and is present in other regions.

Australian data on traumatic injury deaths from 1999 to 2008 demonstrated decreasing trends in road traffic accident and homicide fatalities,[27] however we did not observe a temporal trend in the mechanism of injury of traumatic OHCA in the SJA-WA data. In our study, motor vehicle collisions, which generally result in blunt injury, were the most common mechanism of injury and this is consistent with European studies.[4,7] Further work is required to understand the association between specific injuries and survival.

Bystander CPR rates increased significantly in both traumatic and medical OHCA, however the rate of increase was greater in traumatic OHCA and increased to the point where bystander CPR rates were greater in traumatic OHCA relative to medical OHCA in 2013 and 2014. The substantial rise in rates of bystander CPR from 2010 to 2014 may be explained in part by the introduction of a Medical Priority Dispatch System (MPDS) in 2011,[28] which has been shown to increase the detection of cardiac arrest in the emergency call[29] and subsequently increase the provision of dispatcher-assisted CPR instructions.[30] Despite this increase in bystander CPR rates, survival in our study was low. While bystander CPR has been associated with survival in medical OHCA,[31] the evidence in support of chest compressions for traumatic OHCA is limited. Furthermore, no survivors in our study received bystander CPR. It is thought that in hypovolaemic patients, chest compressions are ineffective due to incomplete cardiac filling and subsequent low cardiac output, although this has only been demonstrated in a single animal model.[32] In these cases, haemorrhage control and fluid replacement are critical.[12] Depending upon the mechanism of injury, chest compressions may aid in circulating oxygenated blood in normovolaemic patients. However, the evidence in support of this is scant. Despite this, chest compressions remain the recommended treatment of traumatic OHCA patients in the American Heart Association[33] and European Resuscitation Council[8] guidelines, noting that the delivery of chest compressions should not delay the treatment of reversible causes, such as a tension pneumothorax or cardiac tamponade. Further work is required to understand in which situations chest compressions are effective and to identify novel/invasive interventions in the treatment of traumatic OHCA, such as prehospital thoracotomy[34] or resuscitative endovascular balloon occlusion of the aorta (REBOA).[35]

Survival in our study was much lower than recent reports.[3,4,6,7,36,37] This difference may be explained by the cohort studied. Other reports have excluded cases, such as those: with obvious signs of irreversible OHCA or injuries incompatible with life,[36] confirmed dead at the scene,[4] where resuscitation was terminated in less than 10 min after commencement,[7] or the inclusion of only those patients who were transported to hospital.[3,37] Of those appropriate for comparison with our study, Deasy et al.[6] reported an overall survival to discharge of 1.3%; and 5.1% of those in which resuscitation was attempted by paramedics. These survival rates are higher than those reported in our study (0.7% and 1.7%, respectively). The variation in survival of those in whom resuscitation was attempted by paramedics is likely explained by differences in the commencement and termination guidelines of the two ambulance services. This is demonstrated by differences in the proportion of traumatic OHCA cases that were transported to hospital; 62.8% of cases were transported by SJA-WA, in contrast to the 35.0% of cases transported in the study by Deasy et al.[6]

It is also important to note that seven of the nine survivors presented with a rhythm of PEA. Cases of PEA in medical OHCA have low survival rates and resuscitative efforts on these patients have been questioned.[38] In medical OHCA, PEA is reported to occur from aortic dissection or rupture, acute myocardial infarction or pulmonary embolism.[39] This is in contrast to traumatic OHCA where pathophysiological events, such as hypovolemia or cardiac tamponade, restrict the ability of the cardiovascular system to generate palpable cardiac output. In these cases, addressing reversible causes is key to enhancing survival.[24] The results of our study demonstrate that cases of PEA resulting from traumatic OHCA are not futile.

There is limited data on the neurological outcomes of traumatic OHCA patients. A recent systematic review reported good neurological outcome (CPC ≤ 2) in 57% of survivors of traumatic OHCA.[40] This outcome rate is similar to that observed in our study (66.7%, $n = 6$), however the included papers in this systematic review are similarly limited by the low number of survivors with neurological outcome data (median = 4). Further work is required to understand neurological outcomes in traumatic OHCA.

Limitations

Our study covers the metropolitan region of Perth and thus does not include rural cases. Our study does not include deaths where SJA-WA were not called; however, SJA-WA attend most unexpected out-of-hospital deaths in Perth. The impact of missing cases in 2008 and 2011 on the distribution of mechanisms of injury and rates of bystander CPR and paramedic resuscitation is likely to be minimal given that we have estimated data loss of less than 20%. The sensitivity analysis supported this assertion as there were no changes in the statistical significance of trends. Predictors of survival in traumatic OHCA could not be assessed in this study as there were too few survivors ($n = 9$).

Conclusions

This study of OHCA in Perth, Western Australia, found no trends in the crude and age-sex standardised incidence of traumatic OHCA over an 18 year period. Similarly, there were no trends in the mechanism of injury of traumatic OHCA. Rates of bystander CPR and paramedic resuscitation in traumatic OHCA significantly increased over the study period to levels similar to medical OHCA. Despite these increases, survival was poor with only nine survivors of traumatic OHCA from 1997 to 2014. Further studies are required to identify those traumatic OHCA patients most likely to benefit from commencement of resuscitation by ambulance paramedics.

Conflict of interest statement

There are no conflicts of interest.

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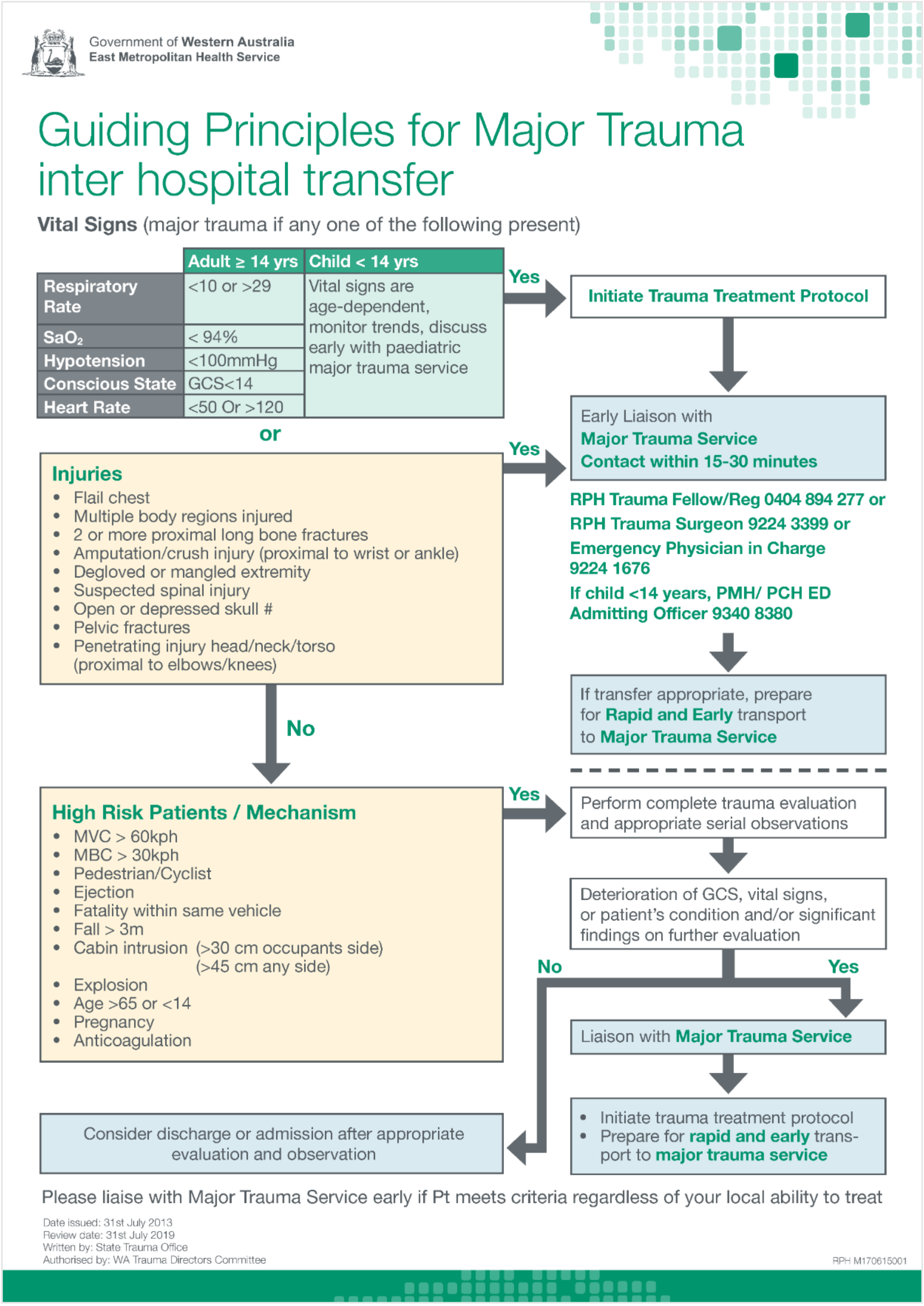
Appendix H Guiding Principles for Major Trauma Inter Hospital Transfer



Government of **Western Australia**
East Metropolitan Health Service

Guiding Principles for Major Trauma inter hospital transfer

Vital Signs (major trauma if any one of the following present)

	Adult ≥ 14 yrs	Child < 14 yrs
Respiratory Rate	<10 or >29	Vital signs are age-dependent, monitor trends, discuss early with paediatric major trauma service
SaO_2	< 94%	
Hypotension	<100mmHg	
Conscious State	GCS<14	
Heart Rate	<50 Or >120	

Yes → **Initiate Trauma Treatment Protocol**

or

Injuries
- Flail chest
- Multiple body regions injured
- 2 or more proximal long bone fractures
- Amputation/crush injury (proximal to wrist or ankle)
- Degloved or mangled extremity
- Suspected spinal injury
- Open or depressed skull #
- Pelvic fractures
- Penetrating injury head/neck/torso (proximal to elbows/knees)

Yes → Early Liaison with **Major Trauma Service Contact within 15-30 minutes**

RPH Trauma Fellow/Reg 0404 894 277 or
RPH Trauma Surgeon 9224 3399 or
Emergency Physician in Charge 9224 1676
If child <14 years, PMH/ PCH ED Admitting Officer 9340 8380

If transfer appropriate, prepare for **Rapid and Early** transport to **Major Trauma Service**

No ↓

High Risk Patients / Mechanism
- MVC > 60kph
- MBC > 30kph
- Pedestrian/Cyclist
- Ejection
- Fatality within same vehicle
- Fall > 3m
- Cabin intrusion (>30 cm occupants side) (>45 cm any side)
- Explosion
- Age >65 or <14
- Pregnancy
- Anticoagulation

Yes → Perform complete trauma evaluation and appropriate serial observations

Deterioration of GCS, vital signs, or patient's condition and/or significant findings on further evaluation

Yes → Liaison with **Major Trauma Service**
- Initiate trauma treatment protocol
- Prepare for **rapid and early** transport to **major trauma service**

No → Consider discharge or admission after appropriate evaluation and observation

Please liaise with Major Trauma Service early if Pt meets criteria regardless of your local ability to treat

Date issued: 31st July 2013
Review date: 31st July 2019
Written by: State Trauma Office
Authorised by: WA Trauma Directors Committee

RPH M170615001

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Appendix K PROSPERO Registration

A systematic review of the association between older age compared to younger age and transport to a trauma centre by emergency medical services in patients with major trauma

Elizabeth Brown, Hideo Tohira, Paul Bailey, Judith Finn

Citation

Elizabeth Brown, Hideo Tohira, Paul Bailey, Judith Finn. A systematic review of the association between older age compared to younger age and transport to a trauma centre by emergency medical services in patients with major trauma. PROSPERO 2018 CRD42018115532 Available from: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018115532

Review question

Are older patients with major trauma more or less likely to be transported to a trauma centre by emergency medical services than younger patients?

Searches

The following electronic databases will be searched: MEDLINE (via Ovid), EMBASE (via Ovid), CINAHL (via EBSCO), Scopus, Cochrane Library and grey literature via Mednar.
The search strategy will include only terms relating to or describing the population of interest. The search terms will be adapted for use with specific database filters, where available.

Review articles may be used to find other relevant articles. Reference lists from relevant articles will be used to identify additional studies.

No publication date or language restriction will be placed on the studies included in the review.

Types of study to be included

The following types of studies will be included: randomised control trials, cohort studies, cross-sectional studies and case-control studies and any other type of comparative study.
Studies that will be excluded: reviews, letters, editorials, case studies and all other commentaries.

Condition or domain being studied

Patients with major trauma who are transported to hospital by an emergency medical service.

Participants/population

Patients with major trauma
Inclusion:

Adults and children (no age restriction) with major trauma who were transported by ambulance/emergency medical services. All emergency medical service transport types (e.g. ambulance or air) will be included in the definition of emergency medical service transport.

Exclusion:

Studies that do not investigate the primary transport (i.e. from the accident scene) of patients with major trauma (i.e. inter-facility transfer).

Studies only investigating the triage of patients with major trauma once the patient has arrived at hospital.

Studies only including patients not transported by emergency medical services (i.e. transported by taxi or private vehicle).

Studies that do not report the patient age (in years or age group).

Intervention(s), exposure(s)

Older patient age.

Comparator(s)/control
Younger patient age.

Context
Patients with traumatic injuries that occurred outside of the hospital and attended by an emergency medical service (e.g. ambulance service)

Main outcome(s)
Emergency medical service transport to a major trauma centre

Additional outcome(s)
Not applicable

Data extraction (selection and coding)
Titles and abstracts will be reviewed by EB to identify potentially relevant studies. Full-text articles will be independently reviewed by EB and HT to ensure the eligibility criteria are met using pre-determined forms. Results will be discussed at a team meeting with EB, HT, PB and JF. Differences will be resolved by consensus.

Risk of bias (quality) assessment
Methodological quality of the studies will be independently assessed by two authors (EB and HT) The checklist developed by GRADE for methodological assessment of observational studies which can be found in table 5.5 of the GRADE handbook will be used for the assessment of the methodological quality of studies included in this review. The consensus will be reached by discussion. Findings from the quality assessment may be used to conduct a sensitivity analysis to test the effect of removing poor-quality studies.

Strategy for data synthesis
The I^2 statistic will assess the statistical heterogeneity of the data from individual studies. Results will be combined using RevMan v5.3. and presented as random effects odds ratios if the I^2 statistics is below 50% and studies are deemed appropriate to be combined (clinical heterogeneity).

Analysis of subgroups or subsets
Subgroup analysis will be considered for the following groups:
Older adult age groups - >65 years >85 years

Mechanism of injury groups – for example falls or motor vehicle crashes.

Contact details for further information
Elizabeth Brown
Elizabeth.E.Brown@postgrad.curtin.edu.au

Organisational affiliation of the review
Prehospital, Resuscitation and Emergency Care Research Unit (PRECRU)

Review team members and their organisational affiliations
Miss Elizabeth Brown. Prehospital, Resuscitation and Emergency Care Research Unit (PRECRU)
Dr Hideo Tohira. Prehospital, Resuscitation and Emergency Care Research Unit (PRECRU)
Assistant/Associate Professor Paul Bailey. St John Ambulance Western Australia
Professor Judith Finn. Prehospital, Resuscitation & Emergency Care Research Unit (PRECRU)

Type and method of review
Meta-analysis, Systematic review

Anticipated or actual start date
05 November 2018

Anticipated completion date

01 March 2019

Funding sources/sponsors

National Health and Medical Research Council (NHMRC) Centre for Research Excellence in Prehospital Emergency Care grant GNT1116453.

Conflicts of interest

Elizabeth Brown is an employee of St John Ambulance WA.
Prof Judith Finn receives a partial salary from St John Ambulance WA.

Yes

Language

English

Country

Australia

Stage of review

Review Completed not published

Subject index terms status

Subject indexing assigned by CRD

Subject index terms

Air Ambulances; Emergency Medical Services; Humans; Trauma Centers

Date of registration in PROSPERO

12 December 2018

Date of publication of this version

13 May 2019

Details of any existing review of the same topic by the same authors

Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	Yes

Versions

12 December 2018
13 May 2019

associated files or external websites.

Appendix L Supplementary Information for the Systematic Review

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	

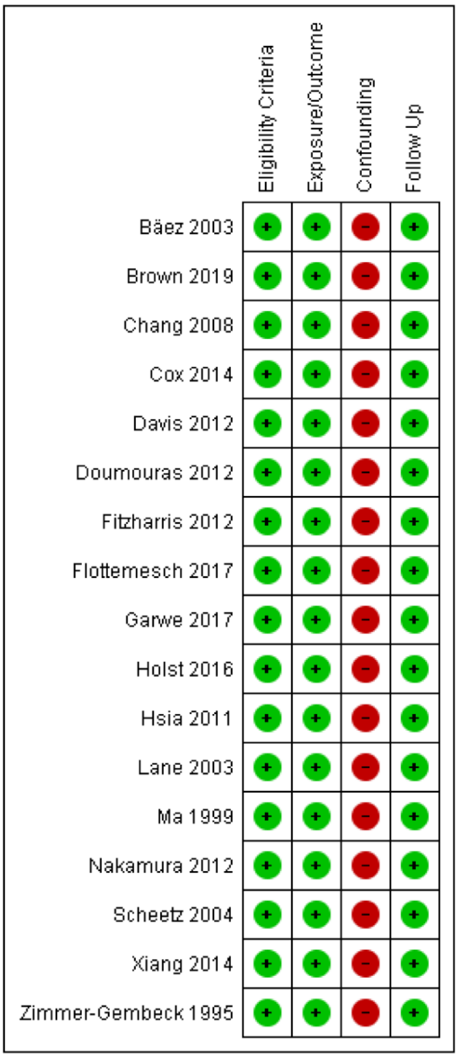
From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

Appendix 1. Search strategy (Medline)

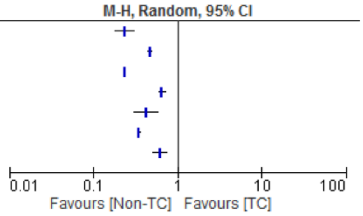
#	Medline terms	Results
1	(Major trauma or injury severity score or traum* or injur*).mp	1,27,624
2	(multiple trauma or "wounds and injuries" or injury severity score).sh.	93,892
3	1 or 2	1,27,624
4	(older adult or older age or elderly or advanc* age or old* or age*).mp.	11,116,811
5	(aged or adult).sh.	5,826,220
6	4 or 5	11,116,811
7	(young*).mp.	1,233,006
8	(young adult or middle aged).sh	4,302,937
9	7 or 8	4,734,633
10	(emergency medical service* or paramedic* or ambulance* or transport* or pre hospital or prehospital or pre-hospital or emergency medical technician).mp	742,110
11	(Emergency medical services or ambulances or emergency health service or emergency service, hospital).sh.	99,432
12	10 or 11	796,169
13	(trauma centre or trauma center or trauma cent* or trauma unit or hospital or accident and emergency or emergency department or casualty).mp	125,051
14	(Trauma centers or Trauma unit).sh.	9,354
15	13 or 14	131,281
16	(triage or triage protocol* or protocol* or triage guideline* or guideline* field triage or field medicine or undertriage OR under?triage).mp.	532,232
17	(triage or "transportation of patients").sh.	18,735
18	16 or 17	540,297
19	3 and 6 and 9 and 12 and 15 and 18	1,263
20	Limit to humans	1,249

Appendix 2. Risk of bias summary: review authors' judgments about each risk of bias item for each included study.



Appendix 3a. Sensitivity Analysis - Summary of the unadjusted odds ratio for Emergency Medical Service Transport to a Trauma Centre in older patients compared to younger patients with a retrospective diagnosis of major trauma, excluding study by Cox et al.

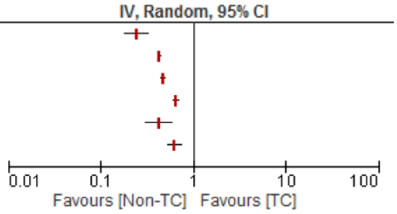
Study or Subgroup	Older Events	Older Total	Younger Events	Younger Total	Odds Ratio M-H, Random, 95% CI
Brown 2019	188	420	578	746	0.24 [0.18, 0.30]
Garwe 2017	6086	12823	11696	17732	0.47 [0.45, 0.49]
Hsia 2011	34155	118182	197120	311899	0.24 [0.23, 0.24]
Lane 2003	1144	3125	2749	5855	0.65 [0.60, 0.71]
Scheetz 2004	134	222	467	595	0.42 [0.30, 0.58]
Xiang 2014	7443	14738	16129	21652	0.35 [0.33, 0.37]
Zimmer-Gembeck 1995	912	1228	1156	1405	0.62 [0.52, 0.75]



CI=Confidence Interval, M-H=Mantel-Haenszel, TC=Trauma Centre

Appendix 3b. Sensitivity Analysis - Summary of the unadjusted odds ratio for Emergency Medical Service Transport to a Trauma Centre in older patients compared to younger patients with a retrospective diagnosis of major trauma, excluding studies by Hsia et al and Xiang et al.

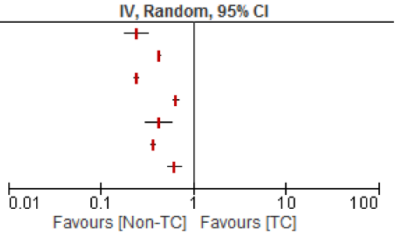
Study or Subgroup	log[Odds Ratio]	SE	Odds Ratio IV, Random, 95% CI
Brown 2019	-1.4271	0.1468	0.24 [0.18, 0.32]
Cox 2014	-0.844	0.012	0.43 [0.42, 0.44]
Garwe 2017	-0.755	0.0222	0.47 [0.45, 0.49]
Lane 2003	-0.4308	0.0408	0.65 [0.60, 0.70]
Scheetz 2004	-0.8675	0.1717	0.42 [0.30, 0.59]
Zimmer-Gembeck 1995	-0.478	0.0897	0.62 [0.52, 0.74]



CI=Confidence Interval, IV=Inverse Variance, SE=Standard Error, TC=Trauma Centre

Appendix 3c. Sensitivity Analysis - Summary of the unadjusted odds ratio for Emergency Medical Service Transport to a Trauma Centre in older patients compared to younger patients with a retrospective diagnosis of major trauma, excluding study by Garwe et al.

Study or Subgroup	log[Odds Ratio]	SE	Odds Ratio IV, Random, 95% CI
Brown 2019	-1.4271	0.1468	0.24 [0.18, 0.32]
Cox 2014	-0.844	0.012	0.43 [0.42, 0.44]
Hsia 2011	-1.4271	0.0217	0.24 [0.23, 0.25]
Lane 2003	-0.4308	0.0408	0.65 [0.60, 0.70]
Scheetz 2004	-0.8675	0.1717	0.42 [0.30, 0.59]
Xiang 2014	-0.9943	0.0284	0.37 [0.35, 0.39]
Zimmer-Gembeck 1995	-0.478	0.0897	0.62 [0.52, 0.74]



CI=Confidence Interval, IV=Inverse Variance, SE=Standard Error, TC=Trauma Centre

Appendix M Clinical Decision Making Tool for Traumatic Cardiac Arrest

CLINICAL DECISION MAKING TOOL FOR TRAUMATIC CARDIAC ARREST / PERI ARREST

OBJECTIVE:

Clinical assist tool to aid on scene times and manage patients to an extent that allows rapid transport to a tertiary facility. Rapid transport of traumatic cardiac arrest or peri arrest patients to definitive care whereby bloods, surgery and trauma surgeons are available allows for a higher and improved recovery rate.

PROCEDURE:

The attached time lined guide assist to highlight skills which are appropriate to traumatic cardiac arrest cases. The skills are limited but prove to be rapid and effective. Using the timeline to establish which skill has to be performed within that proposed time will assist with on scene times of less than 10 minutes. Failure to perform the skill should not prevent delayed on scene times, i.e.: failure to secure an IV within the allocated 5 minute mark should not delay extrication.

PRECAUTIONS / NOTES:

Cardiac arrest caused by catastrophic haemorrhage or of trauma related aetiology is seldom rectified in the prehospital environment. Key interventions are surgical in nature and or the administration of blood products, neither of which are available pre-hospital. The best possible outcome for these patients is rapid transport to these facilities.

In accordance with the trauma services plan developed by the Department of Health, patients suffering major trauma should be taken to hospitals designated as Major Trauma Centres**.** Within this plan; Royal Perth Hospital (RPH) is designated the State Major Adult Trauma Centre.

Hospital notification ideally occurs once the decision is made that the patient will be transported under priority conditions. Consider State Trauma Unit (STU) if within 20 minutes from Royal Perth Hospital (RPH) on priority driving conditions.

REFERENCES / AUTHORITY:

Director of Trauma Services Royal Perth Hospital / State Director of Trauma (WA).

European Resuscitation Council Guidelines for Resuscitation 2015, Section 4. Cardiac arrest in special circumstances.

Luna GK, Pavlin EG, Kirkman T, Copass MK, Rice CL. Hemodynamic effects ofexternal cardiac massage in trauma shock. J Trauma 1989;29:1430–3.170. Willis CD, Cameron PA, Bernard SA, Fitzgerald M. Cardiopulmonary resuscita-tion after traumatic cardiac arrest is not always futile. Injury 2006;37:448–54.171. Lockey D, Crewdson K, Davies G. Traumatic cardiac arrest: who are the sur-vivors? Ann Emerg Med 2006;48:240–4.172. Crewdson K, Lockey D, Davies G. Outcome from paediatric cardiac arrest asso-ciated with trauma. Resuscitation 2007;75:29–34.

Identify Trauma

ELAPSED TIME

Obvious non -reversible Cause – Do not resuscitate

Non Traumatic Cause- Universal ALS algorithm

DAMAGE CONTROL AND MANAGEMENT OF REVERSIBLE CAUSES

ARRIVAL

A: Insert OPA / NPA / LMA with c-spine control (Time allows for basic interventions only)

B: BVM Ventilations x2. Maximize Oxygenation (Skill 314)
Bilateral chest decompression **in suspected pneumothorax / chest trauma**. (Clinical Skill 808)

C: Stop any life threatening haemorrhage.
Consider CAT (Clinical Skill 915)
Consider T-Pod (Clinical Skill 913)
Establish IV / IO Access (Limited to 1 attempt).

5 MIN — **TREATMENT**

D: Apply Defib Pads. Only 7.5% of traumatic cardiac arrest are initially in VF or VT

Compressions- *Chest compressions should not delay the treatment of reversible causes listed above or transportation. In cardiac arrest caused by hypovolaemia, cardiac tamponade or tension pneumothorax, chest compressions are unlikely to be as effective as in normovolaemia patients.*

PREPARE FOR EXTRICATION
Prepare for **IMMEDIATE** rapid extrication. Secure patient to scoop or load onto stretcher

7 MIN — **PREPARE**

NOTIFY RECEIVING HOSPITAL

9 MIN — **NOTIFY HOSPITAL**

TRANSPORT
Perform only lifesaving interventions.
(e.g.: CPR, IV access, Fluids, and Adrenaline)
Immediate transport to appropriate hospital.

10 MIN — **TRANSPORT**

BLUNT TRAUMA
Prolonged CPR in **BLUNT** trauma cardiac arrest after reversible causes have been addressed is almost never associated with a good outcome. If delivery to an Emergency Department cannot be achieved within 25 minutes from arrival on scene, it is reasonable to terminate resuscitation if no ROSC after 10 minutes of resuscitation post correction of reversible causes / damage control measures and termination criteria are met (CPG 4.6D).