Relationship between prehospital time and 24-hour mortality following injury in patients with major trauma in New Zealand

Luisa María Montoya Quesada

School of Population Health

A thesis submitted in partial fulfillment of the requirements for the degree of *Doctor of Philosophy* in Population Health, University of Auckland, 2023.

Abstract

Aim

To explore the relationship between time spent in the prehospital phase and 24-hour mortality following injury in patients with major trauma in New Zealand (NZ).

Methods

Following a systematic review to describe the incidence and characteristics of major trauma in NZ, analysis of routinely collected data from a retrospectively designed prospective cohort study was undertaken. Individuals of any age attended by an Emergency Medical Services (EMS) provider in NZ immediately following major trauma between 1 December 2016 and 30 November 2018 were included. Factors predictive of prehospital mortality were explored using modified Poisson regression. Models were built for total prehospital time and EMS time intervals, and were adjusted by patient sociodemographic, triage and injury characteristics.

Results

A total of 3,334 patients met the eligibility criteria, of which 105 (3.1%) died prehospital and 111 (3.4%) died 24 hours following injury. Median total prehospital time was 74.6 minutes (IQR: 50.6–104.8). Response and transport times were significantly lower for those patients who died 24 hours following` injury ($p<0.05$). In the univariate analysis, total prehospital time greater than 60 minutes was a predictor of survival, reducing the risk of death in 49% (RR: 0.51; 95%CI: 0.35-0.76). Response time greater than 14 minutes, on-scene time between 30-45 minutes and transport times of 10 minutes or more were predictive of less risk of death ($p<0.001$). In the multivariable analysis response time between 5-10 minutes (adjusted RR (aRR): 0.39; 95%CI: 0.18-0.84) or greater than 14 minutes (aRR: 0.37; 95%CI: 0.18-0.80) predicted survival. Other factors increasing the risk of 24-hour mortality in this cohort included age (80-84 years), triage (purple/red), having one or two previous hospital admissions, experiencing non-blunt trauma, and having an injury severity score greater than 24.

Conclusion

Although longer total prehospital times were found to predict reduced 24-hour mortality, analysis of the components of prehospital time was less conclusive and highlighted the importance of factors such as age, triage, and other related-injury factors, namely the severity of trauma. Studies considering 30-day mortality as an outcome and exploring reasons for on-scene and transport delays would be useful extensions to this research.

Acknowledgements

"For I know the plans I have for you, declares the Lord, plans for welfare and not for evil, to give you a future and a hope" ***Jeremiah 29:11***

I would like to thank God for His unconditional love, for giving me the strength to never give up and for helping me to understand that all things work together for good for those who love Him (Romans 8:28).

I would like to thank my family for all their support. Thank you to my mum for being my biggest fan and for encouraging me to do everything I wanted to do in my professional life. Thank you for reminding me that following God is the best decision I can make every single day and thank you for teaching me that love, respect, compassion and education are the most powerful weapons to succeed. I miss you mum, more than you can imagine. This is for you, I know how proud you are of me from heaven. Thank you to my dad and my sister for being there for me. Thank you for always believing in me more than I do.

Thank you to my kiwi mum Lynda Batcheler, you are the most amazing person I have ever met. Thank you for being a great emotional support and for being my angel on Earth. Finishing this PhD would not have been possible without you and your generous heart. Thank you to Timothy Burrell and his family for being such as an extraordinary support during my studies and my time in New Zealand. Thank you to my Colombian friends for our coffee times together, to my friends from church for all your prayers and to my friend Dr Erica D'souza for being an inspiration.

Thank you to my main supervisor Professor Bridget Kool who has patiently supported and guided me through this PhD journey. Thank you for the privilege of learning from you, for the opportunities you have given me to continue with my professional growth, for helping me to support my studies financially through a scholarship, for encouraging me to be a better person and for your permanent motivation. To my co-supervisors Associate Professor Gabrielle Davie and Associate Professor Bridget Dicker, thank you for your patience, wisdom and support. You all are amazing people, and I am very grateful for having the best supervisory team.

Thank to Rebbecca Lilley and Brandon De Graaf from the University of Otago for their help with the data management. I would like to thank St John, Wellington Free Ambulance, the New Zealand National Trauma Network, the National Coronial Information System and the New Zealand Ministry of Health for providing me the necessary data to conduct this research.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AAAM	Advancement of Automotive Medicine
ACC	Accident Compensation Corporation
AIS	Abbreviate Injury Scale
ALS	Advanced Life Support
BLS	Basic Life Support
CI	Confidence Interval
COVID-19	Coronavirus Disease 2019
DALYs	Disability-Adjusted Life Years
DCCM	Department of Critical Care Medicine
ED	Emergency Department
EMS	Emergency Medical Services
EPRF	Electronic Patient Report Form
GBD	Global Burden of Disease
GCH	Geographic Classification for Health
GCS	Glasgow Coma Scale
HEMS	Helicopter Emergency Medical Services
HICs	High Income Countries
HQSC	Health Quality and Safety Commission
HRC	Health Research Council
ICC	Interclass correlation coeficient
ICD	International Classification of Diseases
ICD-10-AM	International Classification of Diseases, 10^{th} Revision, Australian Modification
IQR	Interquartile range
ISS	Injury Severity Score
ICU	Intensive Care Unit
LMICs	Low and Middle-Income Countries
LOS	Length of stay

MAIS	Maximun AIS
MAX	Maximum
MIN	Minumum
MoH	Ministry of Health
MVCs	Motor Vehicle Crashes
NCIS	National Coronial Information System
NHI	National Health Index
NMDS	National Minimum Dataset
NTN	National Trauma Network - Te Hononga Whētuki ā-Motu
NZ	New Zealand
NZDEP	NZ Index of Deprivation
OR	Odds Ratio
PICU	Paediatric Intensive Care Unit
PM	Post-Mortem
RR	Risk Ratio
TBI	Traumatic Brain Injury
TPT	Total Prehospital Time
TR	Trauma Registry
UK	United Kingdom
US	United States
WFA	Wellington Free Ambulance
WHO	World Health Organization

Chapter 1 Introduction

1.1 Injury as a public health issue

Injuries are one of the main causes of disability and death worldwide and remain an important public health issue.[1–9] Injury is defined as "damage to the body produced by energy exchanges that have relatively sudden discernible effects"; they can be intentional or unintentional, and can vary considerably in severity from minor to fatal.[10,11] Unintentional injuries typically comprise motor vehicle crashes (MVCs), falls, poisonings and others, while intentional injuries include self-inflicted injuries, interpersonal violence (homicide and violence) and war injuries.[11,12] Any physical injury that has the potential to cause death or long-term disability is known as major trauma.[13,14] Although an internationally standardised definition of major trauma does not exist, it is commonly defined in terms of injury severity through anatomical scores such as the Injury Severity Score (ISS).[13,15]

There is a huge disparity in the distribution of injury cases around the world, with low and middle-income countries (LMICs) comprising over 50% of the injuries, and different injury patterns between LMICs and high-income countries (HICs).[16] Falls and MVCs are the most common mechanism of injury globally, representing a quarter of all injury deaths and occurring mostly in young males.[17,18] Between 30% and 86% of trauma admissions are due to MVCs, with pedestrians and motorcyclists more commonly affected than car occupants.[18,19] Injuries from catastrophic events such as natural disaster also contribute to morbidity and mortality for short-periods of time.[17]

Some studies have found differences in how trauma occurs and the severity of injuries in both rural and urban populations.[20,21] Different socioeconomic and physical environments surround rural and urban populations, making risk factors of injuries also different between them.[22] A population-based survey conducted in Tanzania in 2002 by Moshiro et al. found that bicycle injuries were predominant in rural areas while in urban areas a large proportion of transport-related injuries were due to motorised vehicles.[21] In terms of hospitalisations, a study conducted in the United States (US) by Coben et al. using the 2004 Nationwide Inpatient data, found that rates for motor vehicle related-injury deaths were higher in rural than urban populations.[23]

Injury does not discriminate and affects all members of society regardless of their economic circumstances or demographic characteristics.[11,24,25] Injury greatly affects children and young adults (under 40 years of age),[3,4] but also older people (≥65 years). This latter group has experienced an increase in major trauma in recent times.[26–28] At both extremes of age, financial and human costs of injuries are significant.[5] However, older patients experience longer hospital stays, extensive recovery periods and higher mortality rates following injury than younger adults.[28,29]

Injury rates globally, independent of age, are generally higher in rural populations compared to urban populations.[20,23,30,31] It has been suggested that this may be due to people in rural areas engaging in more high-risk behaviours and law violations than people residing in urban areas.[31] A study conducted by Mitchell et al. which aimed to compare injury-related morbidity and mortality in rural and urban populations in South West Australia found that despite the low proportion of people living in rural areas and being hospitalised as a result of injury, differences existed in morbidity and mortality rates between these environments, with rural males experiencing the highest rates.[20]

Injuries represent a source of loss of health, impacting social capital and workforce globally.[17] For every injury-related death, there are many people who survived with injuries that result in hospitalisation and that in many cases leave the patient with permanent disabling sequelae, affecting not only the patient's productivity, but the well-being of their families.[11,16] Severe injuries such as limb amputations or spinal cord injuries cause long-term disability. Survivors of injury internationally have to face significant consequences such as permanent disabilities, which impact life expectancy.[32,33] As a result, many years of productivity are lost.[8] According to the Global Burden of Disease (GBD) study, in 2016, MVCs contributed the greatest burden of unintentional injury (1,106/100,000 inhabitants) as measured by Disability-Adjusted Life Years (DALYs).[34] Differences by sex exist with males experiencing more injuries than females, and in consequence more lost DALYs as a result.[17]

Long term sequelae and loss of human capital can also be caused by some common injuries such as upper/lower extremity fracture, concussions or lacerations due to falls or violence.[17] In addition, an important contributor to health loss is traumatic brain injury (TBI), which is a leading cause of trauma-related death.[35,36] Most TBIs are due to unintentional injuries, mainly falls in middle and older adults and MVCs among younger populations.[36] Despite injuries contributing to a significant burden of disability and economic loss, little research attention has given to them.[12]

Injury represents 10% of deaths worldwide, with approximately 5.8 million people dying anually.[13,37,38] LMICs contribute approximately 90% of the worldwide burden of trauma deaths,[4,5,7,39,40] which is associated with the underdevelopment of their public health systems.[9] In rural Europe and LMICs injury mortality rates are above 70%, in part due to challenges in access to advanced treatment facilities.[41]

In New Zealand (NZ), injuries are a significant contributor to morbidity and mortality,[29,42] accounting for more than 1,500 deaths, and 50,000 hospitalisations annually,[43,44] with an estimated overall economic burden of NZ$10.2 billion, or NZ$5.7 million per fatal injury (2010 data).[45] In 2013, unintentional injuries were the second cause of morbidity and mortality among youth (23%) and children (10%), accounting for 8% of total health loss (DALYs).[27,44]

Despite increases in the number of injuries and deaths during the last few decades, some studies have found a decline in the age standardised death rates from injuries. An article published by James et al. based on the results from the GBD Study 2017, showed that age standardised death rates from injuries declined from 1990 to 2017.[17] This could be related to health systems improvements, tighter drinking laws, and other injury prevention efforts.[17] Similar results were found in another study conducted by Molcho et al, who analysed data from 30 countries from 2002 to 2010 to explore trends in injury-related morbidity and mortality among children and adolescents (1-19 years). They found that mortality rates had declined in this group.[46]

Although historically injuries have been seen as “accidents” or “random” events, they can be prevented or mitigated through prevention programmes[47] and strategies that consider social, environmental and behavioural factors.[9,48] The most effective way to reduce the burden of injuries is to prevent injuries occurring in the first place. Many interventions have been proven successful in reducing injuries including: smoke detectors, flame-resistant clothing, swimming pool fences, window bars to prevent falls, traffic speed control, seatbelt use and side-impact protection.[9,11,48,49] However, when primary prevention fails, a secondary prevention approach is needed, which involves the health sector through optimal prehospital and hospital care for injured patients.[11]

1.2 Prehospital trauma care

1.2.1 Trauma systems

It has been reported that most trauma deaths occur during the prehospital phase.[40] In HICs the proportion of deaths that occur prehospital is lower than for LMICs,[9,16] which suggests an inverse relationship between prehospital deaths and economic status.[9,16,19] The study conducted by Mock et al., which included severely injured adult patients from three countries at different economic levels, found that the mortality rate decreased from 63% in a low-income country's hospital, to 55% in a middle-income country's hospital, to 35% in a HIC hospital.[50]

The provision of high quality prehospital care is an important part of a trauma system,[51–56] which is defined as "an organised, coordinated effort in a defined geographic area that delivers the full range of care to all injured patients and is integrated with the local health system".[57] It has been shown that a reduction in the risk of morbidity and mortality can be obtained with the implementation of organised trauma systems,[8,58,59] including planning for emergency medical services (EMS), prehospital triage, transfer criteria and transfer arrangements between hospitals.[12] In the US, a significant decrease in MVC related mortality was observed following the creation of an organised trauma system between the 1960s and 1970s.[60] In Iraq a reduction in injury-related mortality from 40% to 10% was observed following implementation of their national trauma system.[61]

Trauma systems are necessary and have been created to reduce the burden of mortality and disability from injury through the provision of treatment from prehospital care to hospital for injured patients in a defined geographical area,[8] with the aim of providing optimal care in the fastest possible way.[62] Before structured organisations of trauma care were established, patients who suffered trauma were usually attended by general surgeons. Although this practice continues in smaller hospitals, care by different clinical subspecialties in 'trauma centres' - usually located in large hospitals - has become a key aspect of the treatment of trauma patients.[62,63] In remote areas, prehospital care and support can be provided by general practitioners and practice nurses. However, in some countries prehospital services in rural and remote areas rely on volunteer support, and local hospitals are generally small and are mostly run by general practitioners.[63]

Trauma systems are designed to provide coordinated care to injured patients. They involve collaborative efforts by healthcare professionals to deliver comprehensive, effective and timely services to individuals who have experienced traumatic injuries.[64] Coordination of care refers to the integrated management of healthcare services to ensure that a patient's needs are met,[64] which includes not only equipping hospitals with trauma services with the necessary resources, facilities and expertise to provide optimal care,[47,63] but also the adherence of guidelines and/or protocols to transport trauma patients to specific hospitals based on the severity of the injuries sustained, ensuring that patients are taken to the most appropriate facilities for their specific needs.[63] However, variation remains between and within countries in how trauma care is organised, delivered and by whom.[62]

Another aspect of the coordination of trauma care includes timeliness to definitive care, which involves determining the most suitable mode of transportation (ground and/or helicopter) for trauma patients considering the acuity of the patient's condition and other factors such as the distance to hospital, facilitating the quickest and most effective route to definitive care.[64–66]

Ground EMS transport has been mainly used for the prehospital trauma care of patients,[55,67] but some trauma systems (more often in HICs) have integrated Helicopter Emergency Medical Services (HEMS) as part of prehospital EMS care in order to provide not only rapid transport over long distances but advanced interventions on-scene for improving outcomes.[68,69] Although some studies have shown that transporting the patient by helicopter may be more beneficial compared to ground ambulance transport in specific circumstances,[70,71] others have found that there are no differences in trauma outcomes and that factors for HEMS providers such as time required to request, notify, and respond lead to longer prehospital times,[69,72] resulting in ongoing debate around their benefits.[73,74]

Cooperation of prehospital, in-hospital and rehabilitation facilities defines a trauma care system.[62] Timely access to rehabilitation services is also an important component of an effective trauma care system, in particular for injured older adults and patients with head injuries.[75] A well-integrated trauma system not only encompasses having well-coordinated in-hospital injury care, but also the development of injury prevention strategies, the collection and analysis of injury data, and research.[64]

1.2.2 Emergency Medical Services (EMS)

Due to developments in prehospital trauma care services, prehospital providers have increased their abilities to provide quality care through different life-saving techniques at the scene of trauma.[55,76]

To increase the chances of survival for severely injured patients and prevent long-term morbidity, the provision of optimal EMS prehospital trauma care is required.[24,77] EMS is defined as "a comprehensive system which provides the arrangements of personnel, facilities and equipment for the effective, coordinated and timely delivery of health and safety services to victims of sudden illness or injury",[78] and focuses on providing immediate medical interventions to stabilise patients with life-threatening injuries.[79–83]

Prehospital care can be categorised into four categories: unorganised prehospital care (no formal system to provide pre-hospital care – patients are transported to hospital by public or private vehicles), Basic Life Support (BLS), Advanced Life Support (ALS) and Doc-ALS (physicians go to the scene of injury and provide advanced care to the patient at scene or during transportation).[18,60]

There are two main models of EMS according to the philosophy of pre-hospital care delivery: the Anglo-American and the Franco-German model.[83] However, currently, EMS systems around the world have varied compositions from each model. According to the level of care provided, EMS care is classified as Basic and Advanced Life Support.[60,83]

The Franco-German model runs under the philosophy of "stay and stabilise" (also known as "delay and treat", "stay and play" or "provision of lifesaving interventions at the scene").[55] This model aims to provide primary treatment and the provision of life-saving interventions are initiated at the scene.[83,84] EMS under this model are equipped with advanced medical technology and physicians to provide the advanced care to the patient. This model is mainly implemented in Europe (e.g. Germany, France, Greece, Malta, and Austria) and normally uses helicopters and land ambulances as transportation methods. Emergency physicians are the professionals who normally provide prehospital emergency care in Europe. Patients treated by this model, are usually directly admitted to hospital wards. ALS is associated with this model as its focus is to provide invasive and advanced pre-hospital interventions (endotracheal intubation, fluid replacement, needle-chest decompression and administration of potent medications) at scene before transporting the patient to the hospital.[83,85]

In contrast, the Anglo-American model is based on the "scoop and run" (also known as "load and go" or "rapid transport and treat en route") philosophy.[55] This model seeks for EMS to provide minimal or no interventions at the scene and transport the patient rapidly to a trauma centre.[86,87] Countries with this system (e.g. US and Canada) have trained paramedics and medical technicians who provide the pre-hospital care; the main transportation method is land-transport. Patients treated by this model, are normally initially taken to an emergency department (ED). BLS is associated with this model as its focus is to rapidly transport the patient and only provide non-invasive interventions at scene (cardiopulmonary resuscitation, immobilization, oxygen administration, etc).[83,85] Australia and NZ also follow the Anglo-American model under the "rapid transport and treat en route" philosophy,[83] with a difference in the level of care provided, as these countries not only provide BLS but also ALS care at the scene and en route for injured patients.[88,89] In NZ, the most recent clinical procedures and guidelines (2023) include this strategy, stating that patients need to be rapidly transported to an appropriate hospital, while most treatments are provided en route.[90]

Additional models for the provision of EMS primary health care have been developed by different countries to reduce unnecessary ambulance transport to the ED as well as hospital ED attendances in patients that are not high acuity. The United Kingdom (UK), for example, trialled in 2004 a model called Emergency Care Practitioner Scheme in which it was shown that nearly 50% of patients transported to ED were discharged without a significant treatment.[18,83] In NZ, the Extended Care Paramedic model was introduced in 2009 with the aim of increasing the provision of care and treatment in the community without transporting patients to hospital.[91]

In the mid-1970s the notion of a 'golden hour' of trauma care emerged in the literature.[92] The theory being that trauma patients have better outcomes if they are provided appropriate medical care in a timely manner. The golden hour, the first 60 minutes[51–53,92], is defined as "the immediate time after injury when resuscitation, stabilisation and rapid transport are perceived to be most beneficial to the patient"[1] and is an essential tenet of trauma care.[61] However, in practice, factors such as EMS coverage and geographical location need to be considered. This definition of golden hour has in part driven the focus of EMS trauma care worldwide on shortening prehospital times.[93]

Some studies have demonstrated benefits in cases when the “rapid transport and treat en route” strategy is applied. However, in rural areas with long transport times, the “provision of lifesaving interventions at the scene” approach has shown better results in terms of survival.[54,55,84,86,87,94] Although the evidence is still contradictory, some studies suggest that a balance between rapid transport and the provision of interventions at the scene or en route to hospital is necessary in the management of major trauma patients.[54]

A study analysing trauma systems in high and low income countries by Roudsari et al.[18] found the beneficial use of air ambulances for the delivery of prehospital care for injured patients depends on low population density and inaccessibility of remote areas in countries such as Australia and Canada. However, in Germany and Austria, this type of transport is commonly used as each system has the availability for covering the whole country. In the Netherlands, although distances are short within the country, ALS is provided by HEMS, with units dispatched if there is suspicion of life-threating injuries. In patients with severe blunt trauma, the provision of HEMS instead of EMS seems to reduce mortality.[62,68]

EMS systems which use both ALS and BLS systems, normally use BLS for non-urgent or stable patients and dispatch ALS to the most severe patients. Some studies have shown that for trauma patients, prehospital ALS interventions improve patient outcomes. However, other studies have shown that rapid transport and non-interventions at scene is most beneficial in terms of trauma patient outcomes. The decision of what to do, depends on the providers and patient condition and their severity, so has to be assessed case-by-case.[83]

Although some studies have found that there is a number of DALYs that can be saved through the provision of EMS care,[82] EMS may not be cost-effective in low-income countries due to limited telecommunications and resource restrictions. That is why other strategies to allow the transport of injured patients have included the use of motorbikes, taxis, and minibuses with first-aid training being provided to commercial drivers.[12]

1.2.3 Prehospital care in New Zealand

New Zealand is a high-income island country situated in the South Pacific, with a multicultural population of approximately 4.7 million in 2018.[95] NZ is one of the world's least populous countries,[96] and its widely variable terrain and distances make the provision of optimal prehospital care throughout the country challenging.[42,93,96]

In NZ, prehospital EMS care is delivered by both public and private systems,[97] and can be accessed by a nationwide emergency telephone number (111). The public funding is provided by the Accident Compensation Corporation (ACC) for injury-related issues, and by the Ministry of Health (MoH) for medical emergencies.[98] Private funding is from fundraising activities, donations and sponsorship.[42,98]

Ambulance services are part of the first line of health care.[99] St John is the largest land ambulance services provider with over 90% of resident population coverage across the country;[100] Wellington Free Ambulance (WFA) covers the Greater Wellington and Wairarapa regions.[42,96] In 2015/16, St John attended over 380,000 emergency incidents, of which approximately 2,000 were major trauma patients.[101] In NZ, EMS receive approximately 400,000 calls per year, of which 95% are answered within 15 seconds.[102] According to the NZ MoH, the response target for urban incidents is that EMS should respond (time from the emergency call to scene arrival) to 50% and 95% of life-threating events within 8 minutes and 20 minutes, respectively. For rural incidents, EMS should respond to 50% and 95% of life-threating events within 12 minutes and 30 minutes, respectively.[103]

In the early 2000s, prehospital services in NZ significantly depended on volunteer support, especially in rural areas.[42,98] In 2008, it was estimated that 72% of ambulance personnel in NZ were volunteers,[104] who in most part were not registered as they did not have a tertiary qualification in prehospital care.[98]However, this figure has changed over the years. The study conducted by Beck et al.[105], which aimed to describe the ambulance services in Australia and NZ reported that for 2015 the percentage of volunteer support was 24% for St John and 22% for WFA. Aggregate data from St John in 2021 showed that the proportion of incidents attended by volunteers in urban and rural areas of NZ was 1.2% compared to 98.8% of events that were attended by paid staff (Dr Bridget Dicker, personal communication, December 19, 2023).

Due to the lack of permanent staff during the early 2000s, it was common to see "single crew" ambulances attending emergency cases with some arguing that this negatively impacted on the delivery of quality trauma care in NZ.[42,96,98] However, recent improvements to prehospital services have been significant. St John reported that 96.2% of callouts received during 2018/19 were attended by double-crewed ambulances.[104]

Air ambulance services are also part of prehospital EMS as they support the rapid transfer of those patients who suffered injuries in remote locations (such as rural areas). In NZ, helicopter and fixed-wing aircraft are the types of units used to attend prehospital emergencies.[106] Although the demand for this service has increased in the last decade, the frequency of use is low due to the high cost it incurs.[107]

Effective treatment of traumatically injured patients requires a well-integrated contemporary trauma system, which can be supported by accurate and relevant data.[75,108] The NZ National Trauma Network - Te Hononga Whētuki ā-Motu (NTN), formerly Major Trauma National Clinical Network, was formed in 2012 in order to establish a formal structure in the country and to develop policies and guidelines for managing trauma.[108,109] Since its creation, the NTN and the NZ Trauma Registry (TR) have been providing information annually regarding the number of patients with major trauma admitted to hospitals in NZ and the number of deaths, as well as a description of the main features. This has given the country an overview of the quality of trauma care.[47]

1.3 Prehospital times and mortality

Time is an important determinant of outcomes for individuals following trauma.[1,52,110] The provision of optimal prehospital EMS care and timely transfer to advanced-level hospital care are vital in order to increase the likelihood of survival.[24,111,112] In NZ, a review of prehospital injury death post-mortems between 2009 and 2012 by Kool et al. found that 11% and 28% of the deaths had theoretically survivable and potentially survivable injuries, respectively.[113] This suggests that the chance of survival to hospital for seriously injured people could potentially increase following improvements in access to timely care as part of an effective trauma system.[6,77]

Many health systems around the world, especially those systems in LMICs, place little emphasis on the provision of timely treatment during life-threating emergencies, which increases morbidity and mortality during the first hours after injury.[16,82] In countries where the population density is small, the equitable provision of quality prehospital trauma care is challenging. Additionally, the population distribution between urban and rural areas, resource limitations and the variation in terrain make it difficult to deliver time-critical trauma care.[63] The care of injured patients in rural areas is challenging, as emergency transport to urban centres may be inconvenient or expensive.[114]

1.3.1 Total prehospital time

Trauma is considered a time-sensitive disease.[52,110] Total prehospital time (TPT) is defined as the time spent from the emergency call to arrival at the hospital.[1,115] A TPT of 60 minutes or less is known as the 'golden hour'; as previously discussed this concept suggests that trauma patients should receive definitive care within this time to improve outcomes, encouraging rapid transportation of trauma patients.[53,116] Although this term is well-known, widely accepted among EMS and trauma systems and still used in trauma research, evidence supporting importance of the golden hour is limited.[92] Despite knowing that trauma care is time-dependent, nowadays, trauma systems are focusing on providing optimal care according to the severity of injuries, rather than only provide quick transport.[78,117] The belief is that minimising TPT could have a positive impact on survival in major trauma patients.[110] However, the relationship between TPT and mortality is still unclear.[118]

A study conducted in Nova Scotia by Tansley et al., which reviewed trauma registry data for patients injured as a result of MVCs or penetrating trauma between 2005 and 2014, found the risk of death increased when the TPT was greater than 30 minutes.[58] In a study of 360 patients with severe injuries in Canada, Sampalis et al. found that a TPT of 60 minutes or more was associated with a threefold increase in the odds of death.[119] In contrast, the study published by Ryb et al., which included National Trauma Registry Data of adults who were transported to hospital by ground or helicopter ambulances (2007 data) in the US, reported that for patients with a TPT greater than 60 minutes, the odds of survival were higher.[120] Similar results were found by Clements et al., who evaluated the relationship between total prehospital time and mortality in blunt injured patients in Canada.[121] They found that as total prehospital time increased, mortality decreased.[121] However, the secondary analysis of trauma patients transported by EMS to Level I and II trauma hospitals in North America by Newgard et al.,[118] the study by Báez et al.[122] of injured adult patients transported by an EMS in Pennsylvania and a prospective study of patients with severe injuries in Mumbai conducted by Dharap et al.[52] did not show a significant association between increasing TPT and mortality.

Different factors can influence total prehospital time and its relationship with survival to hospital in trauma patients. Previous studies have shown that although prehospital triage is useful to identify critical patients who require urgent attention, an over or under triage classification, may negatively impact not only on prehospital times, but also on patients' outcomes.[123,124]

TPT can be divided into four intervals:[110,125] activation time, response time, on-scene time and transport time.

1.3.2 Total time to a definitive care hospital

Total time to a definitive care hospital is defined as the time from injury to the time the patient reaches a hospital that provides specialised services relevant to their specific medical conditions.[126] It depends on TPT and its components (EMS response time, on-scene and transport time) as well as the processing time upon arrival at the first hospital where the initial assessment, diagnosis and specialised care takes place, and the transfer time between facilities (if applicable).[65,127]

Time to a definitive care hospital is very important for trauma patients as it can significantly impact their outcomes.[126]

1.3.3 EMS response time (activation and response time)

Activation time is defined as the time from call pick up to dispatch, while response time is calculated as the time from dispatch to scene arrival.[110]

Although some studies have suggested minimising prehospital times in order to improve trauma outcomes, this is not always possible as different approaches are necessary.[110] In the case of activation and response times, coordinated responses through centralised systems[42] and a higher number of EMS units would be necessary to reduce the time spent in these components.

The relationship between prehospital time components and survival has received some investigation. For activation time, the retrospective study by Kidher et al., which included patients with severe thoracic trauma in London, did not demonstrate a significant impact on mortality.[128] For response time, the retrospective population-based study of trauma patients by Feero et al. found that patients who died had a longer response time compared to the survivors.[129] Gonzalez et al.[130] evaluated the association between prehospital time and mortality in MVC patients, finding that longer response times were associated with higher mortality in the rural setting. However, these results contrast with those found by Esmaeiliranjbar et al.[131] in Iran, who reported that the risk of mortality decreased by increasing one minute in response time. In contrast, Kidher et al. showed that there was no relationship between response time and survival.[128]

In NZ, EMS providers handled 546,721 calls during 2018/19, of which 95.6% were answered within 15 seconds.[104] Although the activation time is fast, response time is affected by reduced ambulance availability. During 2018/19, St John reported they were unable to meet targets (respond to 95% of calls on time) for those life-threatening conditions.[103,104] They achieved 93.9% of life-threating events within 20 minutes in urban areas and 91.1% within 30 minutes in rural areas.[104]

1.3.4 On-scene time

On-scene time is defined as the time from arrival at scene to departure at scene.[110] The international published literature recommends spending less than 10 minutes on-scene when possible ("10-platinum minutes")[132] However, in practice this time is sometimes longer due to the patient's health condition and other non-controllable factors such as rescue procedures, which are different between countries and are influenced by geographical aspects.[114] A secondary analysis of trauma patients presenting to Level I trauma hospitals between 1996 and 2009 in North America by McCoy et al. found that patients with penetrating injuries that had on-scene times greater than 20 minutes had greater odds of mortality.[133] The study published by Brown et al., which included National Trauma Registry Data of adults who were transported to hospital by EMS in Pennsylvania (2000-2013 data), reported that the odds of mortality were higher in patients with prolonged (50% of TPT) on-scene time.[110] In contrast, a systematic review of studies investigating the influence of prehospital time on major trauma patient outcomes conducted by Harmsen et al. found that increasing on-scene-time is beneficial for haemodynamically stable undifferentiated trauma patients.[1] Similar results were found in a Korean study including trauma patients (ISS>9) attended by an EMS by Kim et al.[51] and the study by Esmaeiliranjbar et al.[131] in Iran, which found that mortality was lower when on-scene times were higher.

1.3.5 Transport time

Transport time is defined as the time from departure at scene to arrival at hospital.[110] Rapid transport to the hospital has become the standard of trauma care in the HICs,[52,92,111] with the availability of EMS and HEMS services a key feature in achieving this goal.[134,135] However, due to the lack of infrastructure in many LMICs, rapid transport is not always available.[52] There are inevitable time delays when transporting severely injury patients to definitive care,[63] as there are geographic factors such as the weather conditions (reducing travel speed for land ambulances and restricting flying for HEMS), poor road connectivity, the route taken and traffic jams, that impede rapid transport. Additionally, the hospital coverage and the distance to hospital from the place of incident also affects transport times.[18,62,72] Evidence suggests that in some cases the exposure of patients to unnecessary risk when speeding in transport is not beneficial.[92] The systematic review by Harmsen et al. found that in patients with neurotrauma and haemodynamically unstable penetrating trauma, a shorter transport time may have a positive impact on mortality.[1] In contrast, the retrospective analysis of trauma-related patients by Möller et al.[136] and the review by Kim et al.[51] of trauma registry data in Korea during 2012 did not show a significant association between transport time and mortality.

1.3.6 On-scene and transport time

For scene and transport times, minimal or no interventions in field to the patient[55,132] and a faster transport mode[120,136] could minimise the time spent. However, non-controllable factors such as weather, traffic and distance to the hospital influence transport times.[117]

Although the international recommendation is to have shorter on-scene times and rapid transport to a trauma centre ("rapid transport and treat en route" approach)[83,85], some studies have found greater on-scene times to be beneficial for patients, especially when prehospital interventions have been conducted to treat immediately life-threatening injuries and to improve outcomes. For injured patients in rural areas, transporting times are longer, so patients could benefit for interventions at scene.[54]

There are no recommendations in NZ regarding time spent on-scene and transport time. However, when possible, it is appropriate to stay on-scene to provide immediate treatment and then transport the patient to a suitable hospital. It depends on the individual patient's circumstances, as there could be specific traumatic injuries such as hypovolaemia from uncontrolled bleeding, in which immediate transport might be recommended.[89] The criteria for transporting a patient to a major trauma hospital are defined in a set of prescribed clinical procedures and guidelines established by the NTN and the EMS providers.[137,138] All personnel working in ambulance follow these guidelines, which are updated on average every two to three years.

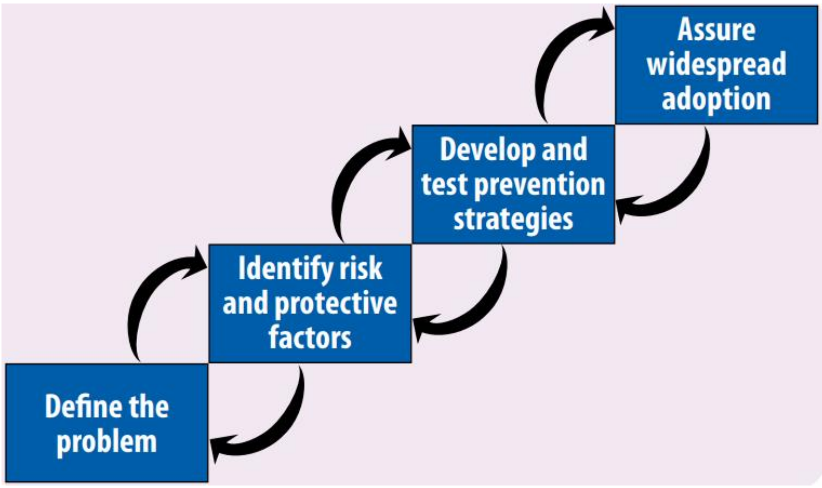
Optimising prehospital trauma systems and care, such as, where appropriate, reducing prehospital times, and ensuring people get to the appropriate receiving facility are necessary in order to reduce serious injury-related mortality and morbidity.[1,9,54,77] This thesis focuses on the distribution of prehospital times and their impact on 24-hour mortality in major trauma patients in NZ.

1.4 The Public Health Model

Public health focuses on improving the health of populations and has an important role in the design and promotion of prevention strategies.[139] Reducing the burden of injuries that have the potential to cause death or long-term disability (major trauma)[13] has been one of the main challenges for public health.[11] The development of research in this area is also crucial to understand the risk and protective factors that will be considered as part of injury prevention programs.

The public health approach to injury prevention is based on a sequence of epidemiological actions that consists of four steps (Figure 1.1).[140]

Figure 1.1 The Public Health Model



Source: National Centre for Injury Prevention and Control[140]

This research, which is aligned with steps 1, 2 and 3 of the public health approach, focuses on identifying the relationship between prehospital times and 24-hour mortality after injury in major trauma patients in NZ.

In this thesis, the review of the published literature from studies investigating the epidemiology of major trauma in NZ was conducted to identify the characteristics of this population (described in Chapter 2) addressing the first step of the Public Health Model.

Data from EMS providers, the NZ-TR and coronial files was analysed in order to explore the relationship between prehospital time spent and prehospital mortality for major trauma cases attended by EMS in NZ. This is described in Chapter 4, and addresses Step 2 of the model.

Opportunities for future strategies are described in Chapter 6 (Step 3 of the model).

1.5 Context and aims of the thesis

The main aim of this research is to explore the relationship between time spent in the prehospital phase (response [includes activation], on-scene and transport) and mortality 24-hour following injury in patients with major trauma in NZ using routinely collected data. The overall goal of the research is to provide opportunities to inform the optimisation of prehospital

EMS, potentially increasing the chances of survival from major trauma. The specific objectives are:

1. To describe the characteristics of major trauma attended by EMS in NZ.
2. To determine the total prehospital time spent and the distribution of total prehospital time (response, on-scene and transport) to first hospital for major trauma cases attended by EMS in NZ.
3. To explore factors predictive of 24-hour mortality following injury in patients with major trauma in NZ.
4. To identify reasons for on-scene delays in the prehospital care of patients with major trauma in NZ.
5. To compare ISS manually derived from the NZ-TR with scores derived using a modified mapping tool.

This research is part of a larger Health Research Council (HRC) funded study (HRC 18/465) titled “Evaluating the impact of prehospital care on mortality following major trauma”, which aims to identify opportunities for improving survival from major trauma in the prehospital phase through to evaluating the relationship between time spent and the type of EMS care received with survival to hospital in patients with major trauma in NZ. The parent study involves the analysis of data from the NZ-TR, NZ’s EMS providers (St John Ambulance Service and WFA) and Coronial case files for the cases attended by EMS that resulted in death either at the scene or before reaching hospital. The study population includes individuals who were attended to by an EMS provider after suffering major trauma between 1 December 2016 and 30 November 2018. Ethics approval for the parent study was obtained from the MoH’s Health and Disability Ethics Committee (Ref 18NTB142), and research approval from the NZ TR, St John, WFA, and National Coronial Information System (NCIS) to access their data for the period of interest. The primary supervisor for this PhD (Associate Professor Bridget Kool) is the principal investigator on that study, the secondary supervisor (Associate Professor Gabrielle Davie), and the PhD advisor (Associate Professor Bridget Dicker) are named investigators on the main study.

For the purpose of this study, the NZ NTN definition of major trauma has been adopted. Major trauma is thus defined as “death following trauma that is principally due to the injuries sustained, or an ISS greater than 12" and it includes only "physical injuries as a result of energy transfer and not internal pathologic processes". Hangings (where only asphyxia occurs without other physical injury), drownings, poisonings, complicated birth, medical and other surgical emergencies are not considered by the NTN as major trauma.[108,109,141] Therefore, these cases are excluded from this study.

1.6 Candidate's role

The candidate joined the "Evaluating the impact of prehospital care on mortality following major trauma" project as Research Fellow during the middle of the first year of the three-year project. The candidate's thesis is focusing on one aspect of the larger study, i.e. the relationship between prehospital time spent and 24-hour mortality following injury in patients with major trauma in NZ.

For the purpose of this thesis, the candidate's main roles included:

- Conducting a literature review of the epidemiology of major trauma in NZ.
- Refining the inferential statistical analysis methods for the PhD aspect of the study.
- Manually estimating the ISS of the patients attended by EMS who died prior to arrival at hospital.
- Participating in the linkage process (EMS providers data with NTN NZ-TR data).
- Cleaning the database.
- Undertaking the descriptive and inferential analyses presented in this thesis.
- Analysing patterns of delays in the prehospital care.
- Comparing ISS derived from ICD-10 codes with those abstracted manually from the injuries described in the patients' report forms.
- Writing the three manuscripts relevant to this thesis and submit them for publication in peer-reviewed journals.

1.7 Personal statement

I was born in Colombia and lived there for the first 27 years of my life. Following high school, I attended university in Colombia where I graduated with a Bachelor's degree in Statistics and a Master of Clinical Epidemiology.

Whilst studying for my Bachelor's degree, I had the opportunity to work in the Surgery Department at the Hospital Universitario del Valle in Cali as a research assistant. As Cali is one of the most violent cities in South America, trauma was one of the areas I became very familiar with. After completing my training as a Statistician, I pursued a career in Clinical Epidemiology. My knowledge, experience and the importance of trauma motivated me to focus on trauma in my master's degree. While I was doing my postgraduate studies, I started working as a lecturer in Epidemiology and Biostatistics.

Once I finished my Master in Clinical Epidemiology, my desire to learn more about research and statistical methods for data analysis increased. At the Fundación Universitaria de Ciencias de la Salud – Hospital San José, I started working with professionals from different medical fields, with a particular focus on the studies related to trauma conducted by the Surgery and ED. My experience as a methodological advisor helped me to improve my skills in research and to understand the importance of having quality data, choosing an appropriate method of analysis and presenting the results in a clear and orderly manner.

My ongoing interest in injury epidemiology and a desire to further develop my research skills motivated me to embark on a PhD. I was interested in pursuing this further study outside of Colombia and decided to explore opportunities in NZ. I connected with Associate Professor Bridget Kool who is an injury epidemiologist with an interest in trauma and trauma outcomes and she agreed to supervise me.

Trauma is an area I am very passionate about. Doing research in this area is gratifying, as the results not only help people in an individual way, but also allow us to create and promote public policies that benefit the community. Comparing the injury epidemiology between Colombia and New Zealand is also of great interest to me.

The opportunity to be involved in the "Evaluating the impact of prehospital care on mortality following major trauma" project and to undertake my PhD has provided me the opportunity to gain an in-depth understanding of the epidemiology of major trauma in NZ and the provision of acute care to these patients. Additionally, working alongside skilled biostatisticians such as Gabrielle Davie (my secondary supervisor) has allowed me to gain additional experience with data linkage and statistical modelling.

I have grown professionally and personally throughout the course of this project. I have enhanced my time and project management skills, refined my academic writing skills, and gained experience through being part of a multidisciplinary research team.

1.8 Structure of the thesis

This thesis consists of six chapters. An overview of each is as follows:

Chapter One provides a description of major trauma as a public health issue and highlights the importance of optimal prehospital EMS care.

Chapter Two reviews the published literature to identify the epidemiology of major trauma in NZ.

Chapter Three outlines the design and methodology of this study.

Chapter Four describes the characteristics of major trauma attended by EMS in NZ and presents the findings of the cohort analysis. Additionally, the reasons for on-scene delays are presented.

In Chapter Five, the agreement between ISS derived manually derived from the NZ-TR with scores derived using a modified mapping tool ISS is presented.

Chapter Six summarises the main findings of the research, discusses strengths and limitations of the study, as well as the implications for policy and future research in the field.

Chapter 2 Epidemology of major trauma in New Zealand: A literature review

2.1 Introduction

In order to reduce rates of morbidity and mortality resulting from major trauma, it is important to understand how major trauma is distributed in terms of time, geographic location and population groups.

This chapter presents a review of the epidemiology of major trauma in NZ. Firstly, the aim and the methods used are described, followed by the review results. The chapter closes with a discussion of the findings and implications for future research.

2.2 Aim

In NZ, injury is a leading cause of mortality and morbidity.[1,27,29] Around 50,000 people are hospitalised as a result of injury annually,[43] with an economic cost estimated at NZ$10.2 billion per year.[45] The NZ MoH reported in 2016 that an estimated 8% of total health loss from all causes was attributed to injuries.[27] However, little is known about the incidence of major trauma in the country.

Major trauma is commonly defined in terms of injury severity. The Abbreviated Injury Scale (AIS) is an anatomical scoring system that ranks the severity of individual injuries by body region on a scale of 1 to 6 (1-Minor, 2-Moderate, 3-Serious, 4-Severe, 5-Critical, 6-Maximal or untreatable).[142,143] This system is the basis of the Injury Severity Score (ISS), which is used to predict mortality and morbidity after traumatic multiple injuries.[144,145] The ISS is defined as "the sum of the squares of the highest AIS grade in each of the three most severely injured areas";[146] its minimum score is 1 and its maximum is 75, which is considered as the worst prognosis.[145,146] For example, a patient with cerebral contusion (AIS=3), flail chest (AIS=4) and complex rupture spleen (AIS=5) would have an ISS of 50 ($ISS = 3^2 + 4^2 + 5^2 = 9 + 16 + 25 = 50$). It is important to highlight that ISS is automatically 75 when an injury is an AIS of 6.[147]

Major trauma has been variably defined as:

- An ISS of 15 or more.[148]

- An ISS of 16 or more.[147,149]
- "Death after injury, or admission to an intensive care unit for more than 24 hours requiring mechanical ventilation, or an ISS over 12, or serious injury to two or more body systems".[15]
- The NZ-TR defines major trauma as "death following trauma that is principally due to the injuries sustained, or an ISS greater than 12" and it includes only "physical injuries as a result of energy transfer and not internal pathologic processes".[108,109,150]

According to the NZ-TR, the following patients are not considered to be major trauma cases:[108]

- Injuries secondary to medical procedures.
- Foreign bodies that do not cause injury.
- Hangings, drowning, poisoning.
- Pathology directly resulting in isolated injury.
- Delayed admissions more than seven days after injury.
- Elderly patients (≥65 years) with pre-existing diseases that precipitate injury or death, or those who died as a result of superficial injuries.

The aim of this review was to describe the incidence and characteristics of major trauma in NZ.

2.3 Methods

2.3.1 Inclusion criteria

Studies describing the incidence of major trauma in NZ were included in the review. The following inclusion criteria were required:

- All injury intents.
- All age groups.
- Injuries resulting in admission to hospital.
- Prehospital injury deaths or injury deaths occurring in hospital.

For the purposes of this review, ‘major trauma’ was defined as death or an ISS greater than 12 or greater than 15, depending on the AIS version used at the time the injuries were coded.[108,109,150] In studies where ISS was not provided but the study included fatal and non-fatal cases, the deaths were assumed to be major trauma cases and thus were included.

Studies focusing on treatment injuries were excluded. Non-physical injuries that could not be scored by ISS such as drownings, poisonings and asphyxiations were also excluded (note codes for these three mechanisms were introduced in AIS 2005).[151]

2.3.2 Search strategy

Bibliographic computerised searches based on a MEDLINE search strategy (Appendix 1) were conducted in the following databases: MEDLINE (1950 to September 2021), EMBASE (1980 to September 2021), CINAHL (1982 to September 2021) and Scopus (2004 to September 2021). Medical Subject Headings (MeSH) and keyword search terms used to identify published articles included: “Wounds and Injuries”, “Fatal Injuries”, “Injury Severity Score”, “Major Trauma”, “Severe Trauma”, “Injury Scale”, Epidemiology, Incidence, Prevalence, Mortality and “Vital Statistics”. Searches were adapted, where necessary, for using in other databases.

Additional electronic databases (such as nzresearch.org.nz), the NZ NTN website (https://www.majortrauma.nz/) and the reference lists of all included studies were examined to identify any potentially relevant articles missed by the electronic search.

Limitations of English language, human population and NZ studies were applied. Searches were not restricted by date. LM conducted the initial search, LM and BK independently reviewed the title and abstracts.

2.3.3 Data extraction and appraisal

The search results were collated into an Excel document. Duplicates were identified and removed before the titles and abstracts were screened by LM and BK. Full versions of studies potentially meeting the inclusion criteria were then reviewed, and ineligible studies excluded. Reasons for exclusion were documented. The following information was abstracted from included studies: study design, information sources, study population, case definitions and main findings. The quality of studies was assessed in terms of general strengths and weaknesses of the study design and using the GATE LITE™ critical appraisal form (www.epiq.co.nz).[152]

The PRISMA guidelines were followed during data extraction, analysis and reporting.[153] This information was summarised in a table of included studies.

2.4 Results

The initial search identified 239 studies. Based on the title and abstract, 61 were considered potentially relevant. Of these, 39 studies fulfilled the inclusion criteria (Figure 2.1). The included studies are summarised in Tables 2.1, 2.2 and 2.3.

2.4.1 Study characteristics

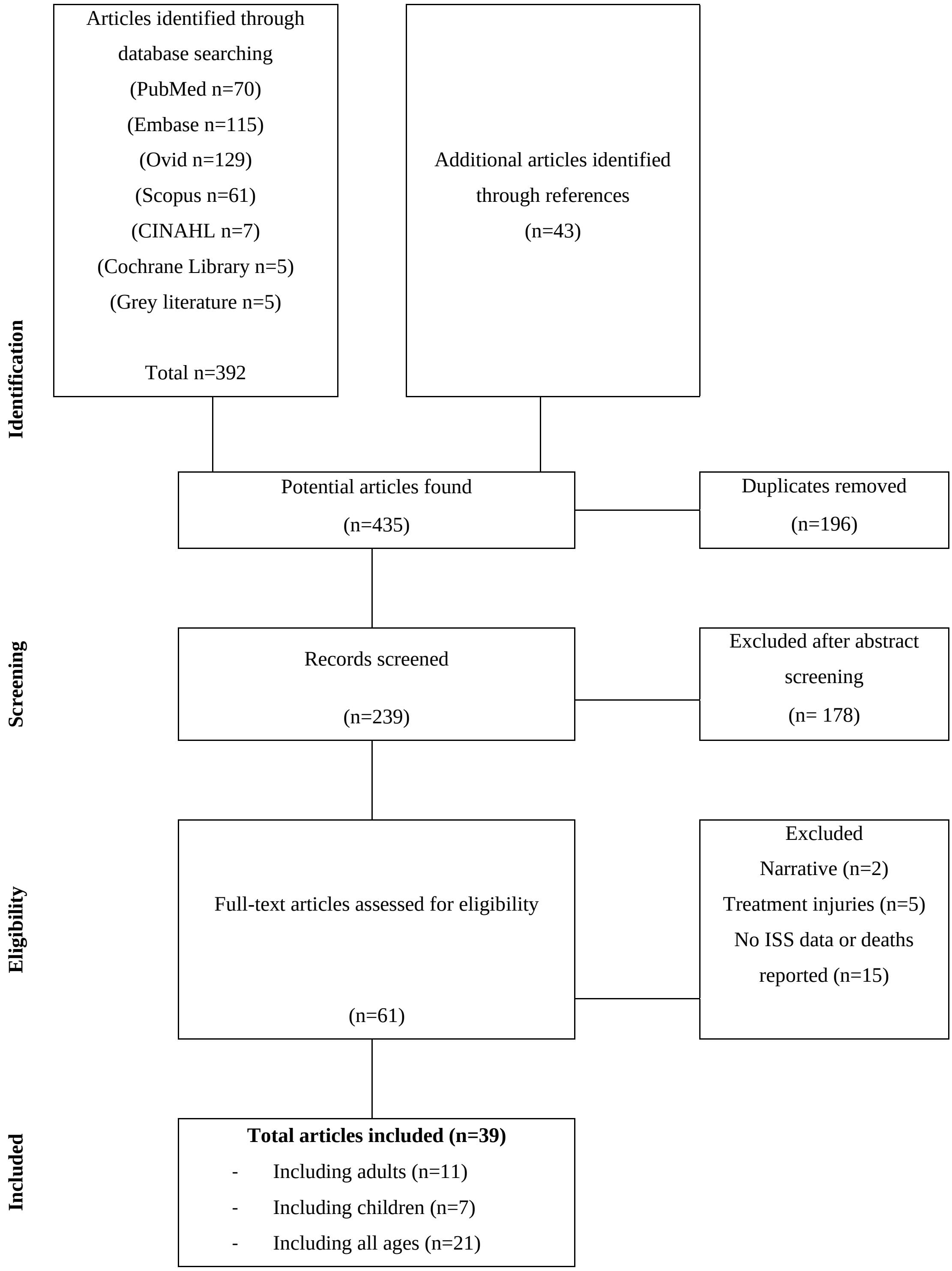
The review period included studies published between 1987 and 2021. Out of the 39 studies included in this review, 19 were based on trauma registry data,[26,154,163–170,155–162] 11 were based on hospital or EMS records[97,171–178] and nine involved routinely collected national morbidity and mortality data from the NZ MoH[179–186]. The majority of studies were descriptive observational studies (n=37), two were population-based cohort studies using prospectively gathered trauma database information from the Auckland region[155,187].

Time periods examined for major trauma-related morbidity were 1998-1993[181], 2000-2006[185] and 2000-2009[186]. For major trauma-related mortality, five studies examined a 10-year period[179,180,183,184,186], ranging from 1978[180] to 2007[186], and two studies considered a 5-year (1988-1992)[181] and 12-year period (1983-1995)[182], respectively.

Twenty-one studies included people of all ages (Table 2.1), adults only in 11 studies (Table 2.2), and children only (under 16 years) in seven studies (Table 2.3). Five of the seven studies focusing on children focused on single mechanisms of injuries.[158,172,176,183,185] The sample sizes ranged from 27[172] to 40,382.[186]

The majority of studies included patients admitted to hospital following injury (n=16)[25,26,187,188,97,155,157,165,171,173,177,178], with two studies describing trauma admissions to the Intensive Care Unit (ICU)[174,175]. Four studies considered trauma due to all-terrain vehicles as a primary focus[158,172,185,189], three studies included injuries occurring at home[183,184,186], three studies limited to a particular injury type,[190–192] two studies considered penetrating trauma[170,193], and two studies described bicycle injuries.[159,179] Other single mechanisms of injury focused studies included pedestrian injuries[176], motorcycle crashes[180], work-related injuries[166], animal-related injuries[168], livestock-related injuries[167], aircraft crashes[181], and river rafting injuries[182].

Figure 2.1 Summary of study selection (PRISMA Flow Diagram)



The definition of major trauma was an ISS > 12 in nine studies[158,165,167,171], an ISS > 15 or death in 16 studies[25,26,176–178,185,187,189,97,155,157,166,168,173–175], and death in 10 studies[170,179,180,182–184,186,188,193] of which seven did not include information of ISS[179,180,182–184,186]. Four studies did not provide a clear definition of major trauma, but reported data on ISS[172,181].

Only 10 studies provide a full description of the characteristics of major trauma[155,171,177,179,180,182–184,187,188]. The remaining studies present information about the incidence of major trauma in trauma populations and the characteristics of trauma in general.

Due to the heterogeneity of included studies, it was not possible to explore trends in the characteristics and incidence of major trauma over the period reviewed.

2.4.2 Incidence of major trauma

2.4.2.1 *Paediatric trauma*

Among studies that described paediatric trauma, the proportion of major trauma cases among studies that focused on single mechanisms of injuries[158,172,176,183,185] ranged from 7%[172] for quad bike injuries to 95%[176] for pedestrian injuries (Table 2.3).

In contrast, the study that included all types of paediatric injuries that resulted in admission to hospital reported a prevalence of major trauma of 63%.[157] Studies that focused on a particular injury type showed a similar proportion of major trauma (5% for liver injury[191] and 6% for pelvic fractures[192]).

The study by Creamer et al. analysed 2004 trauma registry data (all ages) from the Auckland region and reported a major trauma (ISS≥16) rate for children aged less than 15 years of 17/100,000, the lowest rate among all age groups.[155] Kool et al. in their analysis of hospitalisations (2000-2009) and deaths (1999-2008) due to head injury, reported the lowest trauma rates were among children aged 5-9 years (2.3/100,000).[190] However, Collins et al. in their review of pedal bicycle injuries among all ages resulting in death and hospitalisation (1979 - 1988), found that boys aged 10-14 years had the second highest trauma rate (2.3/100,000).[179]

Table 2.1 Epidemiology of major trauma in NZ: summary of included studies (all ages)

Study	Participants	Findings	Comments
Patient hospital/ambulance record-based studies			
Streat SJ (1987)[178]	569 patients who died or were admitted to hospitals in the Auckland Hospital Board region as result of trauma between 15 November and 12 December 1982 Major trauma was defined as ISS≥16	- 9% major trauma - Median ISS=5 (range: 1-75) - MVCs 64% - Head injury 53% - 3% died	- No ethnicity data reported - Only one month of data included in the study
Civil I (1987)[177]	114 patients who presented to the emergency department (ED) of Auckland Hospital following injury between 1 July to 31 December 1983 Major trauma was defined as ISS≥16	- 53% with an ISS of 16-24 - 82% blunt trauma due to falls or MVCs - 30% died	- No ethnicity data reported
Civil I (1988)[97]	602 patients presented to the ED of Auckland Hospital following injury during 1983	- 37% major trauma - MVCs 58% and falls 25%	- Only included information from Auckland Hospital

	Major trauma was defined as ISS≥16	- 10% died	- Injured patients were taken to the closest hospital, which could mean an under representation of the trauma cases - No ethnicity data reported
Safih MS (1999)[175]	2,092 patients with severe trauma admitted to the ICU of Auckland Hospital between January 1987 and December 1996 Major trauma was defined as ISS≥16 or death	- *Older group ≥65 years (n=183; 9%)* Median ISS 25 ; ISS≥16 80% MVCs 57% and falls 34% Mortality 28% - *Younger group <65 years (n=1909; 91%)* Median ISS 26 ; ISS≥16 89% MVCs 67% and falls 13% Mortality 14%	- Information of ethnicity was available from 1989
Mittal A (2001)[173]	75 patients admitted to Auckland Hospital following trauma between December 1999 and January 2000	- 22% <50 years had major trauma - 14% ≥50 years had major trauma - Length of stay (LOS) 19 days for patients with no co-morbidities	- Information of ethnicity and sex was not reported

	Major trauma was defined as ISS>15	- LOS 24.5 days for patients with co-morbidities	
Wakeman C (2003)[191]	93 patients with liver injuries admitted to Christchurch Hospital over a five-year period (1996-2000) NB. 'major trauma' not defined. ISS is reported	- *Paediatric population 0-17 (n=22; 23.7%)* Median ISS 17.5 (range 4 - 59) LOS 4 days (range 1 – 12) Mortality 5% - *Adult population ≥18 (n=71; 76.3%)* Median ISS 17.0 (range 5 - 50) LOS 8 days (range 1 – 52) Mortality 13% (ISS 32)	- Information of ethnicity and sex was not reported
National morbidity/mortality data-based studies			
Collins BA (1993)[179]	238 cases of pedal cycle injuries resulting in death between 1979 and 1988 NB. ISS not reported but injury-related deaths	- 88% collisions with motor vehicles - 60% had head injuries - 39% of fatalities aged 5-14 years - Mortality rate 0.8/100,000 persons/year	- No ethnicity data reported - The nature of injury was not specified for a small proportion of the deaths

Langley JD (1994)[180]	1,175 cases of motorcycle crashes resulting in death between 1978 and 1987 NB. ISS not reported but injury-related deaths	- 96% MVCs - Mortality rate 3.5/100,000 persons/year	- The body regions injured were not specified
Chalmers DJ (2000)[181]	224 cases of aircraft crashes and related events in civil aviation, resulting in hospitalisations (1988-1993) and death (1988-1992) NB. 'major trauma' not defined. ISS by groups is reported	- Hospitalisations (n=120; 54%): ○ ISS≥20 3.3% ○ 38% involved fixed-wing aircraft - Fatalities (n=104; 46%): ○ ISS≥20 82% ○ 53% involved fixed -wing aircraft	- No ethnicity data reported - ISS could not be calculated in 17 cases of death - A clear definition of major trauma was not provided
Kool B (2013)[190]	51,912 people (all ages) admitted to hospital between 2000 and 2009 or who died between 1999 and 2008 as result of head injuries NB. ISS not reported but injury-related deaths	- Hospitalisations (n=47,565; 92%): ○ Incidence rate 118.1/100,000 ○ Higher incidence rates in males ○ Highest incidence rates for Māori ○ Mortality 2%	- Under-estimation of head injuries due to the inclusion of cases with a principal diagnosis of head injury

		- Fatalities (n=4,347; 8%): ○ Mortality rate 10.8/100,000 ○ Mortality rate in aged ≥65 21/100,000 ○ Mortality rate in aged 15-24 17.3/100,000 ○ Highest mortality rates for Māori	
Trauma registry-based studies			
Pang JM (2008)[188]	186 trauma deaths (all ages) occurred between 1 January 2004 and 31 December 2004 in the Auckland region NB. ISS not reported but injury-related deaths	- Median ISS=25 (range: 1-75) - MVCs 32% - Hanging 36%	- No ethnicity data reported - Inclusion of hanging could affect the median ISS
Creamer GL (2008)[155]	448 patients (all ages) with severe injuries (ISS>15 or death) admitted to hospital during 2004	- Injury rate 33.6/100,000 - MVCs 50% and falls 19% - Hangings 15% (all resulted in death) - Mortality rate 14.4/100,000	- No ethnicity data reported

Creamer GL (2010)[187]	448 trauma patients (all ages) admitted to one of the four hospitals in Auckland region, with an ISS>15 or who died as result of injury during 2004	- Māori (n=95; 21%): ○ MVCs 45% ○ Hanging 25% ○ Assault 18% ○ Injury rate 61.4/100,000 ○ Mortality rate 28.4/100,000 - Pacific (n=66; 15%): ○ MVCs 44% and falls 23% ○ Assault 14% ○ Injury rate 38.6/100,000 ○ Mortality rate 16.4/100,000 - Other (n=287; 64%): ○ MVCs 52% ○ Hanging 22% ○ Assault 12% ○ Injury rate 28.5/100,000 ○ Mortality rate 11.9/100,000	- The data used to calculate the rates were projections

Wood A (2013)[189]	101 trauma patients (all ages) admitted to Waikato Hospital between February 2007 and March 2001 as result of quad bike-related injuries Major trauma was defined as ISS>15 or death	- 27% major trauma ○ 37% rollovers ○ 26% collisions ○ 29% head injury - 1 death (traumatic brain injury)	- Single-centre study - Information of rural hospitals in the Waikato region was not included, which could cause an underestimation of the quad bike injuries
Tosswill M (2018)[167]	168 trauma patients (all ages) admitted to a Midland hospital with livestock-related injury from 2012 to 2015 Major trauma was defined as ISS>12	- 5% major trauma - Mean ISS=3.6 (highest ISS=22) - 76% cattle-related - 7% head injuries - 40% upper/lower extremity injuries - Mean LOS=2.3 days	- Injuries treated in the community were not included
Burstow M (2019)[26]	26,882 patients (all ages) admitted to Auckland hospital between 1995 and 2014 following trauma Major trauma was defined as ISS≥16	- <65 years (n=22,454; 84%) ○ 18% major trauma ○ Median ISS=4 (IQR*: 4-10) ○ 37% falls	- No ethnicity data reported

		○ 2% died (13% with an ISS≥16) - ≥65 years (n=4,428; 16%) ○ 15% major trauma ○ Median ISS=4 (IQR*: 4-9) ○ 72% falls ○ 6% died (28% with an ISS≥16)	
Singh N (2019)[159]	998 patients (all ages) admitted to hospital between 1 June 2012 and 31 July 2016 as a result of cycling-related injuries in the Midland Region Major trauma was defined as ISS≥13	- 8% major trauma - 15% Māori - 62% occurred in road - 52% upper/lower extremity injuries - Injury rate 21.1/100,000 in males aged≥20 years (2013-2014) - Injury rate 9.4/100,000 in females aged≥20 years (2015-2016)	- Injury patients who died prehospital were not included
Christey G (2020)[163]	195 trauma patients (all ages) admitted to a level one trauma centre between March 5-18 2020 and March 26 to April 8 2020	- Pre-lockdown (n=124; 64%): ○ Major trauma 18% ○ 68% male ○ 29% Māori	- Single centre experience

	Major trauma was defined as ISS>12	○ 37% falls ○ 33% home injuries - During lockdown (n=71; 36%): ○ Major trauma 15% ○ 59% male ○ 31% Māori ○ 34% falls ○ 48% home injuries	
Kandelaki T (2021)[160]	702 patients (all ages) with major trauma admitted to Christchurch Hospital between 1 June 2016 and 31 May 2018 Major trauma was defined as ISS≥13	- Māori (n=63; 9%): ○ 75% male ○ 44% MVCs ○ 22% falls ○ 5% mortality - Other (n=639; 91%): ○ 69% male ○ 45% MVCs ○ 30% falls ○ 11% mortality	- Possibility of incorrect ethnicity data in the Waikato trauma registry
McGuinness MJ (2021)[194]	286 patients (all ages) with major trauma admitted to hospitals in the Northern Region between 16	- 2020 (n=123; 43%): ○ 31% falls ; 30% MVCs	- Small sample size - No ethnicity data reported

	March to 8 June 2019 and the same period but in 2020 Major trauma was defined as ISS>12 or death	○ 97% blunt trauma ○ Mean ISS 20±8.6 ○ 14% mortality - 2019 (n=163; 57%): ○ 25% falls ; 36% MVCs ○ 91% blunt trauma ○ Mean ISS 20±8.5 ○ 12% mortality	
Fan D (2021)[195]	83 patients (all ages) with major trauma admitted to Christchurch Hospital between 22 February 2020 and 30 May 2020 Major trauma was defined as ISS≥13	- Pre-lockdown (n=36; 44%): ○ Mean ISS 21±9.1 ○ 89% male ○ 31% falls ○ 50% transport-related injuries - During lockdown (n=21; 25%): ○ Mean ISS 22±6.1 ○ 81% male ○ 48% falls ○ 38% transport-related injuries - Post-lockdown (n=26; 31%): ○ Mean ISS 21±9.1 (level 3)	- Single centre experience - No ethnicity data reported - Small sample size

	○ Mean ISS 19±7.5 (level 2) ○ 85% male ○ 31% falls ○ 46% transport-related injuries

Abbreviations: *IQR: Interquartile range; ISS: Injury Severity Score; MVCs: Motor Vehicle Crashes; ED: Emergency Department; LOS: Length of Hospital Stay; ICU: Intensive Care Unit

Table 2.2 Epidemiology of major trauma in NZ: summary of included studies (adults)

Study	Participants	Findings	Comments
Patient hospital/ambulance record-based studies			
Gardiner JP (2000)[174]	2,305 trauma admissions to the ICU of Auckland Hospital from 1 January 1988 to 31 December 1997 Major trauma was defined as ISS≥16	- 89% major trauma - Median ISS 26 (range: 1-75) ; ISS≥25 64% - MVCs 66% - 63% of critical injuries were the head and neck region	- Information of ethnicity was available from 1989
Czuba KJ (2019)[171]	112 injured patients≥18 years old with an ISS>12 admitted to one of the two trauma centres in Auckland between 15 June 2015 and 14 December 2016	- 24% with an ISS of 12-15 - 36% with an ISS of 16-20 - MVCs 30% and falls 28% - Median LOS greater in patients with higher ISS: ○ ISS 12-20: 7 days ○ ISS 21-25: 10 days ○ ISS 26-30: 22 days ○ ISS>30: 25 days	- Only 54% of the eligible population was included

National morbidity/mortality data-based studies			
O'Hare D (2002)[182]	33 cases of injuries associated with white water and other recreational river rafting resulting in death between 1983 and 1995 NB. ISS not reported but injury-related deaths	- Drowning 94% - 36% due to the raft capsizing	- No ethnicity data reported - Small sample
Kool B (2007)[184]	73 people aged 25-59 years who died as a result of an unintentional fall-related injury occurring at home between 1993 and 2002 NB. ISS not reported but injury-related deaths	- Falls from buildings or structures 26% - Falls involving stairs or steps 19% - Fatality rate for males 0.63/100,000 - Fatality rate for females 0.20/100,000	- No ethnicity data reported - The type of fall was not specified for 25% of the fatalities
Kool B (2011)[186]	40,986 people aged 20-64 discharged from hospital between 2000 and 2009 or who died between 1998 and 2007 as result of unintentional injuries occurring at home	- Hospitalisations (n=40,382; 99%): ○ 0.6% major trauma ○ Falls 45% ○ Cutting/piercing 17% - Deaths (n=604; 1%): ○ Falls 21%	- Overestimation of injury incidence due to the inclusion of cases without a diagnosis code and because the no compensation of the cases admitted and discharged in a reference year

	NB. ISS not reported but injury-related deaths	○ Burns 12% ○ Poisoning 38% (Drug-related 78%)	
Trauma registry-based studies			
Civil I (1998)[193]	96 patients aged≥16 years admitted to Auckland Hospital following penetrating trauma in 1995 NB. ISS not reported but injury-related deaths	- 4.2% major trauma - 75% of major trauma intentional - Median ISS=22 (range: 9-75)	- The body regions injured were not specified - No ethnicity data reported
Johns E (2004)[168]	167 adult (≥15 years of age) admissions to Auckland Hospital for animal-related injury from December 1994 to April 2001 Major trauma was defined as ISS>15 or death	- 14% major trauma (including 2 deaths) - Median ISS=4 (range: 1-32) - 86% associated with horses - 49% involved the extremities - LOS influenced by the ISS (Mean=4 days; range: 1-62)	- No ethnicity data reported

Tan C-P (2004)[25]	105 trauma patients aged≥40 years admitted to Auckland Hospital between 1 January and 3 March 2003 Major trauma was defined as ISS>15	- 15% major trauma - 5% died due to head injury	- No mechanism of injury and ethnicity data reported
Hsee L (2008)[170]	56 trauma patients aged≥15 years admitted to hospital or who died as a result of gunshot injuries between 1995 and 2006 NB. ISS not reported but injury-related deaths	- 7% major trauma due to brain trauma (ISS range: 25-75) - Median ISS 10 (range: 1-75) - 52% unintentional injuries - Extremities injuries 38%	- No ethnicity data reported
O'Leary K (2017)[165]	2,278 trauma patients aged ≥65 years admitted to hospital in the Midland region between 1 January 2012 and 31 December 2014	- 10% major trauma ○ 98% unintentional injury ○ Falls 39% ○ Transport related injury 43% ○ Chest injuries 22%	- Information of ethnicity was obtained directly from the patients

	Major trauma was defined as ISS>12	○ Head or neck injuries 22% ○ LOS≥10 days: 31%	
Kool B (2017)[166]	2,169 trauma patients ≥15 years old admitted to a Midland hospital with work-related injuries between 1 January 2012 and 31 December 2015 Major trauma was defined as ISS>15	- 4% major trauma - Median ISS=2 (IQR*: 1-4) - Falls 19% - Injury caused by contact with machinery: 26% - Extremities injuries 48%	- Pre-hospital deaths were not included

Abbreviations: *IQR: Interquartile range; ISS: Injury Severity Score; MVCs: Motor Vehicle Crashes; LOS: Length of Hospital Stay; ICU: Intensive Care Unit

Table 2.3 Epidemiology of major trauma in NZ: summary of included studies (paediatric population)

Study	Participants	Findings	Comments
Patient hospital/ambulance record-based studies			
Roberts I (1991)[176]	64 children under 15 years of age injured as pedestrians and admitted to the Department of Critical Care Medicine (DCCM) of Auckland Hospital between 1986 and 1989 Major trauma was defined as ISS≥16	- 95% major trauma - Median ISS=29 (range: 4-75) - 83% of critical and severe injuries were in the head region - 14% died (all from brain injuries)	- Information of ethnicity (census and hospital data) was based on parent report ethnicity
Pearce R (2015)[172]	27 children under 16 years of age with confirmed quad bike injuries and admitted to Starship Children's Hospital from January 2007 to July 2014 NB. 'major trauma' not defined. ISS by age groups is reported	- Mean ISS 14 (range: 1-75) - ISS 33.8 (range: 9-75) for PICU admissions - 26% head injury (Mean ISS 19.4; range: 5-43) - 7% died	- Only 59.2% had information about the quad bikes - A clear definition of major trauma was not provided - Small sample

Bajaj M (2018)[192]	179 children with a pelvic fracture admitted to Starship Hospital between July 1995 and May 2015 NB. 'major trauma' not defined. ISS is reported	- Mean ISS 9 (IQR: 4-22) - Severe traumatic brain injury 19% - Pedestrian struck by a vehicle 46% - MVCs 23% - Mortality 6% (ISS 36.5; range 17-59)	- No ethnicity data reported
National morbidity/mortality data-based studies			
Gulliver P (2005)[183]	355 deaths in children under 5 years occurring in the home between 1989 and 1998 NB. ISS not reported but injury-related deaths	- Suffocation 36% - Homicide rate 2/100,000 children per year	- No ethnicity data reported
Anson K (2009)[185]	218 children under 16 years old hospitalised because of ATV-related injury between 2000-2006 Major trauma was defined as ISS>15 or death	- Median ISS 9 (range: 4-9) ; ISS>15 8% - Falls from vehicles 49% - 6 admissions to PICU - 8% died	- Data related to ethnicity was not available for 7 patients - Limited information about deaths

Trauma registry-based studies			
Couch L (2010)[157]	82 children aged <15 years admitted to hospital as result of trauma between 1 May 2003 and 30 April 2004 Major trauma was defined as ISS>15	- Starship Hospital (n=40; 49%) ○ 63% major trauma ○ MVCs 48% and falls 38% ○ 80% head injury - KidzFirst (n=42; 51%) ○ 62% major trauma ○ MVCs 60% and falls 31% ○ 77% head injury - 1 death (ISS=38)	- Small sample size, which affected statistical power. - Not all injury presentations were included - Problems in defining moderate trauma
Scott A (2011)[158]	146 children under 15 years old admitted or died in Starship Children Hospital between 1 November 1999 and 31 December 2008 as result of motorcycle trauma Major trauma was defined as ISS>12	- Motorbikes (n=123; 84%) ○ 9% major trauma ○ Median ISS=3.1 (range: 1-35) ○ 2 deaths due to head injuries - All-terrain vehicles (n=23; 16%) ○ 26% major trauma ○ Median ISS=4 (range: 1-25)	- The lethality of motorcycles is likely to be underestimated because coroner's records for deaths outside hospital were not searched

Abbreviations: *IQR: Interquartile range; ISS: Injury Severity Score; MVCs: Motor Vehicle Crashes; PICU: Paediatric Intensive Care Unit; DCCM: Department of Critical Care Medicine

The studies reviewed showed that boys had higher incidence rates of major trauma than girls.[157,158,172,176,183,185] The review of national morbidity and mortality data by Collins et al. found that boys aged 5-9 years and those aged 10-14 years had a higher incidence of major trauma (2.0/100,000 and 2.3/100,000 person-years respectively) than girls (0.6/100,000 and 1.3/100,000 respectively).[179] Similar results were found by Kool et al., where the incidence of major trauma was higher in boys than in girls aged 5-9 years (2.7/100,000 cf. 1.9/100,000) and among those aged 10-14 years (4.3/100,000 cf. 2.6/100,000).[190] Additionally, Creamer et al. found that injury rates among boys aged 0-14 years were approximately twice that of girls (23/100,000 cf. 12/100,000).[155]

2.4.2.2 *Adult trauma*

The proportion of major trauma cases among the total trauma cases reported in the adult population ranged from 4%[166] to 89%[174] in the studies reviewed (Table 2.2). A review of trauma registry data from the Auckland region (2004 data) by Creamer et al., reported an overall major trauma (ISS≥16) incidence rate of 34/100,000 per year, with rates highest among young adults (15-29 years; 60/100,000) and older adults (≥75 years; 50/100,000).[155]

The studies reviewed showed that major trauma occurs most commonly among males.[25,165,166,170,171,174,182] The study by Gardiner et al. of adult ICU trauma admissions to Auckland Hospital over a 10-year period (1988-1997), found that males had a significantly higher incidence of trauma than females (53.8 cf. 16.7 per 100,000 person-years).[174] These findings are consistent with a review of trauma registry records of work-related injuries in the Midland region (2012-2015) by Kool et al., where rates among male workers were approximately five times greater (238/100,000 workers) than among females (44/100,000 workers).[166]

Additionally, the review of pedal bicycle injuries among all ages resulting in death and hospitalisation by Collins et al. found that males aged 80 years or more had the highest trauma rate (3.5/100,000). However, the authors recommended treating this finding with caution because of the small number of fatalities in this group.[179]

2.4.2.3 *Trauma among Māori*

Although more than 35% of paediatric major trauma cases occurred among children of European origin[158,172,176,185] (range from 38%[176] to 89%[158]), Māori experienced the highest trauma rates (Table 2.3).[176,187] The review of trauma registry data of injured child pedestrians (<15 years) admitted to Auckland Hospital (1986 - 1989) by Roberts et al. reported higher trauma rates among Māori children (13.2/100,000) than children of European origin (4.2/100,000).[176] These findings are consistent with the population-based study of trauma registry data by Creamer et al., where injury rates among Māori males aged 0-14 years were higher (50/100,000 per year) than among other ethnicities combined (12/100,000 per year).[187] However, the same study showed that for females aged 0-14 years, the incidence rate among non-Māori Pacific children was almost double the rate among Māori children (35/100,000 cf. 19/100,000).[187]

Adult trauma rates were higher among Māori than other ethnicities.[174,179,187] The population-based study by Creamer et al. of trauma registry data reported higher major trauma (ISS≥16) rates among Māori (61.4/100,000 per year) and Pacific people (39/100,000 per year) compared to people of NZ European and other ethnicities combined (29/100,000 per year).[187] Gardiner et al. found similar results among adult ICU trauma admissions, where the rates for Māori and Pacific patients were greater (123/100,000 and 70/100,000 respectively) than for NZ European patients (36/100,000).[174]

For all age groups, the review of major trauma admissions for Māori in the Canterbury region (2006 - 2018) by Kandelaki et al. showed that 9% of major trauma cases occurred among Māori, with Māori males the most affected (75%).[160] It also reported similar incidence rates among Māori and other ethnicities (57.9/100,000 cf. 57.3/100,000).[160]

Although trauma incidence rates among males[25,165,166,170,171,174,182] and Māori[174,179,187] were highest in the majority of studies reviewed, a review by O'Leary et al. of older adult (≥65 years) trauma cases from the Midland Trauma Registry between 2012 and 2014 found that, injury rates were higher among females (608/100,000) than males (557/100,000), and non-Māori compared to Māori (594/100,000 cf. 460/100,000).[165]

2.4.3 Mechanism of injury

Blunt trauma accounted for more than 80% of all trauma-related admissions among all ages in the studies reviewed (Table 2.1).[97,157,167,174,177,178] MVCs and falls were the most common mechanism of injury among trauma patients across all age groups.[97,157,163,165,171,174,180,187,194,195] The review of Midland trauma registry data by Kool et al. reported that contact with machinery (26%) and falls (19%) were the most common cause of work-related injuries.[166] Couch's review of trauma records of 82 children (<15 years of age) admitted to two Child Emergency Departments ED over one-year period, found that MVCs accounted for 57% of all trauma, of which 61% involved pedestrians. Additionally, falls and other mechanisms in this age group (including non-accidental injury) accounted for 34% and 12% of injuries, respectively.[157]

This review found that although major trauma due to falls is common across all age groups in NZ, the incidence is highest in older adults (≥65 years).[165,175,196] The review of older adult trauma cases in the Midland trauma registry published by O'Leary et al. found that among older major trauma (ISS≥13) patients, the prevalence of MVCs was higher than the prevalence of falls in this age group (43% cf. 39%).[165]

Among the studies that analysed trauma due to pedal cycles, motorbikes or all-terrain vehicles, the main mechanisms of injury were falls from the vehicle and collisions with motor vehicles.[172,179,185,189] Wood et al. reviewed data from the Waikato Hospital trauma registry on major trauma patients (ISS>15) with quad-bike related injuries between 2007 and 2011 and found that the main mechanism of injury was rollovers (37%).[189]

Studies analysing animal and livestock-related injuries reported that falls from horses (81%) and being hit by cattle, sheep, pigs or goats were the most common cause of injuries, respectively.[167,168] Penetrating injuries were uncommon.[170,193]

2.4.4 Severity

The head was the most commonly injured body region in major trauma patients in the studies included in this review.[157,165,172,174,176,178,179,189,190] The prevalence of head injuries ranged from 26%[172] in a review of quad bike injuries in children to 100%[190] in a study of incidence and mortality due to head injury. Pearce's review of Paediatric ICU (PICU) records, found that in children under 16 years of age admitted to Starship Children's Hospital between 2007 and 2014 with head injuries due to a quad bike incident, the mean ISS was 19.4 (range 5-43), which was slightly higher in those who were not wearing helmet at the time of the injury (mean ISS 21.8; range 9-43).[172]

Upper and lower extremity injuries were common among major trauma cases. However, these did not represent life threatening injuries.[158,159,166–168] Singh et al. found that 52% of cycling-related injuries involved extremities.[159] A study of major work-related trauma by Kool et al.[166] and a study of injuries due to animals by Johns et al.[168], which reviewed trauma registry data, found similar proportion of extremity injuries (48%[166] and 49%[168] respectively).

A study by Civil et al. of 114 patient hospital records over a six-month period, found 40% of patients with major injuries admitted to hospital had an ISS between 16 and 24, and that no patients with an ISS≥50 survived.[177] Safih et al. in their review of Auckland Hospital ICU records, found no difference in the mean ISS between younger (<65 years) and older adult (≥65 years) patients (26 cf. 25).[175] Similar results were reported by Wakeman et al. in patients with liver injuries, who did not find difference in the mean ISS (17.5 cf. 17.0) between paediatric (0-17 years) and adult population (≥18 years).[191] However, the study of Starship PICU records by Pearce et al. found that ISS was higher in children under 5 years of age (mean ISS 22.3) compared to children aged 5-10 years of age (mean ISS 10.5).[172]

In terms of ethnicity, the study by Wood et al. that examined data from 101 Waikato Hospital trauma registry cases with quad-bike related injuries, found that Māori had a significantly higher mean ISS compared to their NZ European counterparts (16.8 cf. 10).[189]

Three of the studies reviewed reported an association between length of hospital stay (LOS) and ISS.[168,171,173] Czuba et al. in a cohort of 112 patients with major trauma (ISS≥12) from two hospitals in Auckland, found that the median LOS was greater in patients with higher ISS. The results of this study showed that patients with an ISS≤25 stayed in hospital for a maximum 10 days, while patients with an ISS>25 were in hospital between 22 and 25 days.[171]

2.4.5 Death ocurring among major trauma patients

The proportion of deaths among major trauma patients in the studies reviewed ranged from 1%[189] to 30%[177]. An age gradient was evident in some studies, with an in-hospital case fatality rate approximately twice as high in older patients (≥65 years) compared to younger (<65 years) patients (28% cf. 13%; $p<0.001$).[26,175] The review of national morbidity and mortality data (1989 to 1998) by Gulliver et al. examining injuries sustained in the home among young children (<5 years of age), found that mortality rates reduced as age increased. Annualised mortality rates among children aged 0-11 months were 28/100,000 compared with 5/100,000 among children aged 48-59 months.[183] Collins et al. in their review of pedal bicycle injuries resulting in death and hospitalisation (1979 - 1988), found that 39% of the fatalities occurred in children between 5 and 14 years old.[179] However, Kool et al. in their review of head injuries resulting in death (1999-2008) and hospitalisation (2000-2009), found that only 4% of the fatalities occurred in children between 5 and 14 years old.[190]

The study by Langley et al. which reviewed national mortality data relating to motorcycle crashes (1978 -1987), reported a mortality rate of 3.5/100,000 persons per year for all age groups, with males experiencing higher rates than females in those aged 15-24 years (3.4/100,000 cf. 2.0/100,000).[180] Similarly, Kool et al. in their study of people aged 25-59 years who died as a result of unintentional falls at home, found the fatality rate for males was three times higher than the female rate (0.63/100,000 cf. 0.20/100,000).[184]

Mortality rates in the studied reviewed also varied by ethnicity. Māori accounted for less than 30% of all trauma-related deaths[180,186,187] (range from 9%[180] to 25%[186]) and had the highest fatality rates. The Auckland regional study by Creamer et al. of trauma registry data (ISS>15), reported higher injury mortality rates among Māori (28.4/100,000 per year) and Pacific (16.4/100,000 per year) compared to NZ European and other ethnicities combined (11.9/100,000 per year).[187] Kool et al. found similar results in patients aged 20-64 years for unintentional injuries that occurred at home, with fatality rates of 5.4/100,000 among Māori and 3.0/100,000 for NZ European.[186] However, the review of major trauma admissions for Māori conducted by Kandelaki at al. showed that the proportion of deaths was lower for Māori compared to other ethnicities (5% cf. 11%).[160]

The main causes of death in major trauma patients in the studies reviewed were MVCs[155,179,187,188] (range 32%[188] to 88%[179]) and falls[155,184,186–188] (range 10%[188] to 23%[187]). The study of unintentional injuries occurring at home resulting in death (1998-2007) or hospitalisation (2000-2009) conducted by Kool et al. found that over a 10-year period burns were one of the main mechanisms of injury resulting in death (12%).[186]

In relation to the nature of injuries sustained, head injuries were common (60% - 100%) among fatal injury cases.[179,190]

2.4.6 Impact of Covid-19 in major trauma admissions

Coronavirus disease 2019 (COVID-19) has changed the lives and daily routine of many people around the world. Due to its rapid spreading, the World Health Organization (WHO) declared it as a global pandemic on March 11, 2020.[197] Two weeks later, on March 25 at 11:59pm, NZ moved to level 4 (lockdown), the highest level of a four-level alert system announced by the NZ Government in order to eradicate the virus, avoiding an overburdening of the healthcare systems.[194,195,198] Although the effects of the lockdown are yet unknown, some studies conducted in NZ have shown a significant impact on the number of major trauma admissions.[163,194,195]

The study conducted by Christey et al. of trauma patients admitted to a level one trauma centre in NZ pre-lockdown (March 5 to 18, 2020) and during lockdown (March 26 to April 8, 2020) showed a reduction of 50% in all major trauma admissions.[163] This study also found that there was a decrease in the number of trauma admissions for males (50% reduction), children aged 0-14 years (48% reduction) and Māori (39% reduction). Although it was a significant reduction in the number of trauma admissions due to falls and MVCs (48% and 74%, respectively), these continue being the most common mechanism of injury during lockdown in NZ.[163] Similarly, Fan et al. in their study of major trauma patients admitted to Christchurch hospital before (February 22 to March 25), during (March 26 to April 27) and after lockdown (April 28 to May 30), found a 42% reduction in the number of major trauma admissions during lockdown in all sex and age groups.[195] The most common mechanism of injury before and after lockdown was transport-related injuries. However, during lockdown falls were the most common injury (48%). Road and home were the most common places of injury across all periods.[195]

The study by McGuinness et al. which reviewed major trauma registry data in the Northern Region (16 March to 8 June 2020 and the same period in 2019), reported a decreased in major trauma admissions of 25% in 2020 compared to 2019. Although there was a reduction in age, gender, mechanism of injury, type of injury and injury intent, there was no evidence of statistically significant differences. An increase in the number of injuries occurring at home was observed in 2020 compared to 2019 (35% cf. 20%).[194]
utcome

2.5 Discussion

The aim of this review of the published literature was to describe the incidence and characteristics of major trauma in NZ. Thirty-nine studies met the review eligibility criteria. The studies included were mainly descriptive observational studies that had analysed routinely collected data from trauma registries, hospital records, or national morbidity and mortality data. The proportion of major trauma reported in the studies reviewed was variable, ranging from 4%[166] to 95%[176]. This in part reflects the heterogeneous case definitions used, and the different populations studied (e.g. trauma registry data cf. MoH morbidity and mortality data).

The results demonstrate that differences in trauma rates exist in NZ by sex, ethnicity, and age. This review found rates of major trauma are highest among young adults (15-29 years) and older people (≥75 years), and lowest among children aged 0-14 years.[155,179] These findings are consistent with a review of Japan's Trauma Registry data by Kojima et al., which found that moderate to major trauma (ISS≥9) occurs most commonly among elderly people aged 60 years or older (53%), and less common among children (9%).[199]

This review also showed that in both the paediatric and adult populations, males[25,157,182,183,185,158,165,166,170–172,174,176] and Māori[174,176,179,187] are the subgroups most affected by major trauma in NZ. These results are consistent with data from NZ's TR 2018-19 report, which showed the incidence of major trauma was higher among males in all age groups, and that Māori experienced higher major trauma rates (56/100,000) than non-Māori (43/100,000).[141]

Blunt trauma due to MVCs and falls were the main mechanisms of trauma resulting in hospitalisation and death in NZ in this review.[97,155,180,184,186–188,194,195,157,163,165,167,171,174,178,179] For the paediatric population, these findings are consistent with a review of 5 years of data from a Swiss trauma registry which found blunt trauma represented 92% of all admissions and that 42% of the patients had major injuries (ISS>15), of which 76% were males with injuries primarily due to falls (40%) and MVCs (34%).[200]

Chico-Fernández et al. reported that 79% of the trauma patients admitted to ICU in Spain (2012-2015) were young men, and the main mechanism of injury was falls (37%).[201] A study conducted in Australia by Harris et al., which included 355 patients with major trauma, found that 63% of the cases were due to MVCs and that males were more overrepresented (72%).[3]

Similar results were found by Alberdi et al. in another Spanish study investigating the epidemiology of severe trauma in all age groups, where the main cause of trauma among patients aged 15-25 years was road traffic related injury, and that older patients (>65 years) had a greater mortality rate than younger people (35% cf. 15%).[4]

Major trauma studies in Australia have found that males aged between 15 and 24 years account for the majority of all trauma admissions, with blunt trauma from MVCs being the main cause of injury.[29,96] However, the 2017-18 annual report published by the NZ NTN showed that there are three age peaks (15-29, 45-60 and 85+), being the 15-29 age group the one with the greatest burden of injury.[202] Although patterns of trauma are similar between Australia and NZ, incidence rates differ.[96] According to the Victorian State Trauma System the incidence of major trauma in 2016-17 was 55/100,000[203] which was greater than that reported by the NZ NTN in 2018-19 (48/100,000).[141]

In the current review, among major trauma patients the head was the most common body region injured. [157,165,172,174,176,178,179,189,190] A Spanish study conducted by Rastogi et al. of 748 patients (all ages) admitted to a major trauma centre in India, reported 57% of patients had sustained head injuries.[204] Alberdi et al. in their study of the epidemiology of severe trauma in Spain found a lower prevalence (33%-47%).[4] The Spanish studies both identified a statistically significant association between ISS and mortality.[4,201] The studies included in this review suggest that length of stay in hospital is influenced by ISS.[168,171,173] However, the relationship between ISS and mortality could not be examined in this review because seven of the 10 included studies defined major trauma as death and did not include information about ISS.[179,180,182–184,186,190]

Trauma admissions in NZ decreased during the COVID-19 pandemic[163,194,195,205], mainly due to the restrictions on the free movement orchestrated by different Governments around the world, reinforcing the notion that trauma is a social disease. The studies reviewed reveal a reduction of more than 40% in major trauma admissions during lockdown, with the greatest reductions observed in males, children aged 0-14 years and MVCs[194,195]. The NZ's TR 2019-20 report showed the incidence of major trauma was lower in 2019/20 than in 2018/19 (44/100,000 cf. 48/100,000) and reported a 50% reduction in major trauma admissions across the country during the initiation of level 4 (lockdown), mainly due to changes in transport injuries.[206] Similar results were found in a study conducted in South Australia by Harris et al., which reported a 33% reduction in major trauma admissions, especially for those aged 40 years or older and for transport-related trauma (45% reduction in each case).[207]

2.5.1 Strengths and limitations

This review provides a useful summary of studies of major trauma in NZ that have been published up until September 2021, providing historical context for those working in the trauma or injury prevention fields. The strength of this review includes a rigorous methodology to identify relevant studies through an exhaustive search of the current data in multiple electronic databases. Two independent reviewers (LM and BK) performed the literature search, selected, and evaluated the quality of the articles, which enhanced validity and reliability. Results have been reported following the PRISMA guidelines.[153]

The strengths of studies included in this review that analysed data from the MoH[179–186,190] include the ability to explore trends over time, and the population-based nature of the data. However, MoH morbidity databases do not include trauma-specific injury severity indices,[179] which explains why information related to ISS was not reported in some articles or had to be calculated in others using the AIS. Comparisons of findings between studies were difficult due to the differences in sample sizes, population groups and major trauma definitions.

The review findings need to be considered in light of some limitations. The review period included studies from 1987 to 2021, a time during which there were a number of AIS revisions,[143,151] resulting in potential differences in how major trauma is defined and having a potential impact on injury research. Since the development of AIS in 1971 by the Association for the Advancement of Automotive Medicine (AAAM), there have been some updates,[151,208,209] the most recent being the AIS 2015.[143,210] The AIS 2005 update brought significant changes in scores for some body regions, in particular for the thorax and head regions.[208,209] The 2008 update provided further refinements to the classification deficits.[151,211] The AIS 2015 update improved brain injury and spinal cord coding.[210] Palmer et al. noted that there is a significant decrease in the number of patients classified as major trauma when converting AIS98-coded data to AIS08.[212] From the information provided, 48% of the studies included in this review used the AIS98 or previous versions, and the remaining studies used the AIS05/08 versions. Based on the findings of Palmer at al. this may mean the earlier studies in this review may have overestimated the severity of injury reported.

Another limitation is the ability to calculate an overall estimate of the incidence of major trauma in NZ; this is challenging due to the lack of a clear definition of major trauma in included studies, and difficulties in comparing trauma registry studies with non-trauma registry studies due to the exclusion of non-physical trauma in the former (e.g. poisoning, asphyxiation, and drownings). Although ISS has been recognised as the "gold standard" scoring system for trauma, it has substantial limitations.[148,213–215] Firstly, ISS scoring is expensive as a significant amount of time and effort is required for AIS collection.[216,217] Moreover, the scored injuries are often not even the three most severe injuries as the ISS only considers at most only three of a given patient's injuries, one per body region.[214,215] Additionally, it does not take account for contextual information such as comorbidities and issues relating to the event itself that may have contributed to patient outcomes.[217] A study of the accuracy of injury coding in NZ by Davie et al. found in a random sample of public hospital discharges that 14% of the principal injury diagnosis and 26% of the external cause codes had inaccuracies, which were identified on the first, second or third characters.[218] This is likely to have affected the completeness of case ascertainment in the studies reviewed.

Only half of the studies reviewed reported ethnicity. Previous NZ research has highlighted that Māori are disproportionally represented in national injury data.[219,220] Additionally, it has been found that ethnicity reported on the national systems can differ to what patient identifies. The study of Scott et al. evaluated the quality of ethnicity data (self-reported compared to that recorded by the Waikato Hospital Trauma registry) and found the percentage of self-identified ethnicity that mismatched Trauma Registry ethnicity was 21% for Māori compared to 4% for non-Māori.[221]

There was limited South Island data included in the published studies reviewed. The majority of studies found were conducted or included data from the North Island, especially from Auckland and the Waikato region. Trends over time were unable to be described due to the heterogeneity of the included studies.

There is a scarcity of data relating to ethnicity, and major trauma among children in the international published literature which makes it difficult to compare the findings of this review with those from other countries.

2.6 Summary

The findings confirm that major trauma is a significant contributor to morbidity and mortality in NZ. The incidence rate of fatal major trauma is highest among older Māori males with head injuries due to MVCs and falls. Non-fatal major trauma incidence rate is highest among young Māori males. The review findings highlight the need for further analytical studies that can explore factors that may impact on survival from major trauma such as access to effective and timely emergency medical services and advanced level trauma care. Changes in major trauma admissions during the COVID-19 pandemic as part of public health interventions, reinforce the notion that trauma is a social disease.

Chapter 3 Methods

3.1 Introduction

The literature review described in Chapter 2, revealed the high incidence of major trauma in NZ, confirming the need for well-designed analytical studies to explore factors that may have an impact on survival from major trauma. This chapter describes the methods used to address the following research questions:

1. What are the characteristics of major trauma patients attended by EMS in NZ?
2. How is total prehospital time distributed between response time, on-scene and transport time?
3. What are the factors associated with prehospital mortality in patients with major trauma in NZ?
4. What is the relationship between EMS prehospital time and 24-hour mortality after injury in patients with major trauma in NZ?
5. What are the reasons for on-scene delays in the prehospital care of patients with major trauma in NZ?

This research forms part of a larger HRC of NZ funded project “Evaluating the impact of prehospital care on mortality following major trauma”[222]. The overall aim of this project was to identify opportunities for improving survival from major trauma in NZ in the prehospital phase. The candidate’s primary supervisor (Professor Kool) is the project’s principal investigator and Associate Professor Dicker, and Associate Professor Davie are two of the named investigators. As described in Chapter 1, the candidate’s role in this project included reviewing the relevant literature, data cleaning, consistency checking, deriving key variables, ISS scoring, conducting a descriptive analysis of the cohort, leading the development of the prehospital deaths model, and contributing to the interpretation of the project’s findings.

3.2 Study design

The “Evaluating the impact of prehospital care on mortality following major trauma” project is a retrospectively designed prospective cohort study, analysing routinely collected data related to injury attendances by NZ’s EMS providers (St John and WFA) for the period 1

December 2016 to 30 November 2018. Outcome data was obtained from NZ Coronial case files (from the Australasian NCIS) which included cases with a primary cause of death as injury who were attended by EMS and who died before reaching hospital and from the NZ-TR for those that survived to hospital.

3.3 Identifying the cohort of interest

3.3.1 Eligibility criteria

Eligible records included those from individuals of any age who were attended by an EMS provider in NZ immediately following major trauma during the period of interest. The NZ-TR definition of major trauma was used in this study, that is "ISS greater than 12 (based on AIS 2005 Update 2008) or death following trauma that is principally due to the injuries sustained"[108,109,141,223]. Only physical injuries as a result of energy transfer and not internal pathologic processes are included, and therefore the following injury cases were excluded[108,109,223]:

- Injuries secondary to medical procedures.
- Foreign bodies that did not cause injury.
- Hangings (where only asphyxia occurs without other physical injury).
- Poisonings or drug ingestion that did not cause injury.
- Drownings.
- Pathology directly resulting in isolated injury.
- Isolated neck of femur fracture.
- Delayed admissions (more than seven days after injury).
- Elderly patients with pre-existing diseases that precipitate injury or death, or those who died as a result of superficial injuries.

Additionally, those patients who self-presented or arrived at hospital more than 24 hours after the receipt of EMS care were excluded. For those cases with more than one presentation to hospital due to major trauma within the study period, the most recent injury episode was selected. The rationale for this was made because for the last injury episode it was not possible to know, a priori, whether the patients survived or not, whereas with earlier injury episodes it was known that the patient had survived.

3.3.2 Data sources

Although the primary sources of information on major trauma cases were NZ's EMS providers, NZ-TR and NCIS, additional information from other sources was required to supplement and/or validate the data obtained. The information sources used in this study are briefly described below.

3.3.2.1 *Primary sources of information*

EMS Patient Report Forms

Electronic Patient Report Forms (ePRFs) allow EMS providers to record patient information into a structured form using a tablet device instead of completing a paper-based form. They were introduced in NZ by St John in October 2015 and nearly three years later, WFA moved to ePRFs (March 2018). The use of ePRF improves data quality and completeness, and can contribute to a better-integrated acute care health system in NZ[224,225]. An ePRF is generated whenever an ambulance is assigned to an incident, so for a given incident there can be multiple rows for one injured patient. For example, in a rural road traffic crash a patient may initially be seen by a volunteer staffed ambulance (ePRF #1) and if the injuries are sufficiently severe a rescue helicopter team may be called (ePRF #2), then following transfer by helicopter to a major centre an ambulance may be required to transfer the patient from the heliport to the hospital (ePRF #3). The transfer of an ePRF from one provider to other is ideal when dealing with multiple patients per incident. However, it does not happen in many cases and multiple ePRFs end up being created for a single patient.

Information is entered on-scene by paramedics and is able to be shared with other health care providers involved in patient's care[226,227]. The record can be electronically accessed through a secure HealthLink sent by the EMS provider.

ePRFs recorded as trauma from St John and WFA for the study period were used to identify the cohort of interest. In case EMS underestimated patient status all triage statuses were included (status 1: immediate threat to life, status 2: potential threat to life, status 3: unlikely threat to life, status 4: no threat to life). Additionally, ePRFs of patients who died prehospital or ended up in the NZ TR but were not recorded as major trauma by EMS were included.

WFA's paper-based PRFs were used for the period before ePRFs were introduced by WFA (1 December 2016 and 5 March 2018); for this period, relevant data was extracted manually and entered into the study database. EMS data (St John and WFA) collected and used in this thesis contains information related to demographic characteristics of the patients (e.g. age, gender), patient status (e.g. blood pressure, Glasgow coma scale [GCS]), incident details (e.g. incident number, date and time of injury, place of injury), pre-hospital information (e.g. provider type [air/land], interval data [response time, time at scene, transport time]), reasons for delays in the prehospital setting (only available for St John's ePRFs), destination (e.g. trauma hospital, morgue) and treatment provided.

New Zealand Trauma Registry

The NZ TR is a prospectively maintained database containing information related to all major trauma cases admitted to hospitals in NZ[108,228]. The data collected includes[228]:

- **Demographic characteristics:** Date of birth, age, sex, ethnicity, weight
- **Incident details:** Incident number, date and time of injury, injury cause, dominant injury type, mechanism of injury, place of injury, injury description
- **On-scene information:** Date and time of observations at scene, pulse, systolic blood pressure, spontaneous respiratory rate, GCS eye, GCS voice, GCS motor, total GCS, mode of transport from scene
- **Referral information:** Referring hospitals, pulse, systolic blood pressure, respiratory rate, temperature, GCS eye, GCS voice, GCS motor, total GCS, vital sign qualifiers, date and time of observations at referring hospital, date and time of observations from referring hospital, date and time of departure from referring hospital, mode of transport to definitive care hospital
- **Definitive hospital:** definitive care hospital, date and time of observations at definitive care hospital, pulse, systolic blood pressure, respiratory rate, temperature, GCS eye, GCS voice, GCS motor, total GCS, vital sign qualifiers, blood alcohol concentration on arrival, first measured venous base excess, first measured INR (International Normalised Ratio), date and time index computed tomography performed, discharge date and time, disposition after ED, patient intubated, date and time patient intubated, emergency operative procedures, date and time for each emergency procedure, ISS, number of hours on ventilator, total length of stay, length of ICU stay, diagnosis made

>48 hours after arrival, discharged destination from acute care, date and time discharged from definitive care

- **Outcomes:** Type of death
- **Others:** National Health Index (NHI)

NZ-TR data used in this thesis contains information related to demographic characteristics (age, sex, ethnicity); incident details (incident number, date and time of injury, dominant injury type, mechanism of injury, place of injury); on-scene information (pulse, systolic blood pressure, spontaneous respiratory rate, mode of transport from scene); definitive hospital (definitive care hospital, pulse, systolic blood pressure, respiratory rate, temperature, blood alcohol concentration on arrival, discharge date and time, patient intubated, date and time patient intubated, ISS, number of hours on ventilator, total length of stay, length of ICU stay, date and time discharged from definitive care); outcomes (type of death) and NHI.

The NZ-TR dataset obtained for this project contains one row for every hospital a patient was assessed at or admitted to, which means that for some patients there could be multiple rows if they had, for example, been assessed at an initial hospital, then be transferred to a definitive care hospital.

National Coronial Information System

The decision to conduct a post-mortem (PM) in NZ is a decision made by a coroner, usually to confirm the cause of a person's death. In NZ, the family has the right to object to a PM, but it is the coroner who will make the final decision taking into consideration the factors cited by the family. However, if a person has died in suspicious circumstances (e.g. a crime), a PM should be done without any objections[229].

Electronic copies of PM reports were requested from NCIS for cases seen by EMS but who died prior to arrival at hospital. PM files contain a detailed report of the injuries sustained and for some cases, a brief description of the circumstances of death; a copy of pathology and toxicology reports can be sometimes available[230]. Information abstracted from these files included: date and time of death, mechanism of injury, involvement of alcohol (if available) and all injuries sustained.

3.3.2.2 *Secondary sources of information*

National Health Index

Every person in NZ (independent of their migratory status) who accesses health services is assigned a unique identifier number, known as the National Health Index (NHI). The NHI database contains a person's NHI number with the information related to their demographic characteristics (first name, last name, date of birth, gender, ethnicity)[231]. The access to this dataset was key to obtain the gold standard for ethnicity and the date of death of the individuals included in this study.

National Minimum Dataset of hospital discharges

The Ministry of Health's (MoH's) National Minimum Dataset (NMDS) is a national collection of hospital discharge information that includes clinical information for inpatients and day patients from public and private hospitals. The dataset includes information regarding diagnosis and external causes codes, inpatient procedures and admission/discharge dates[232]. This information was helpful not only to confirm the cohort of major trauma cases but also to validate the information obtained from EMS records and NZ-TR data. Due to the fact that the diagnosis codes are assigned according to the International Classification of Diseases, 10th Revision (ICD-10), this database was also accessed in order to enable a comparison of algorithm derived ISS from ICD-10 coding of injuries contained in the NMDS, with ISS data contained in the NZ-TR (see Chapter 5), which is manually derived by trauma nurses.

Geographic Classification for Health

The Geographic Classification for Health (GCH) is a modification of StatsNZ's Urban Accessibility (UA) Classification designed for use in health research and policy. It provides a 5-level and binary rural-urban classification for all geographical areas of NZ as at the 2018 Census[233]. The GCH 2018 was used to explore possible geographic disparities in timely access to health services for those patients who suffered major trauma in NZ.

New Zealand Index of Deprivation

The NZ Index of Deprivation (NZDep) is a small area level estimate of socioeconomic deprivation in NZ[234]. For its calculation nine Census variables are used and the information is displayed in deciles. The 10% of small areas with scores representing the highest levels of deprivation are classified as NZDep10, while areas with scores representing the lowest levels of deprivation are classified as NZDep1[234,235]. Data from NZDep based on Census 2018 (NZDep2018) was included in this study[236].

Health Quality and Safety Commission

The Health Quality and Safety Commission (HQSC) focuses on improving health and disability support services in NZ[237]. HQSC monitors, reports and publishes information about improvements in safety and quality, through identifying key health and safety indicators[237,238]. Variables related to acute and total admissions to hospital during the last 12 months and Charlson Comorbidity Index for the cohort were obtained from HQSC and used in this study to explore a possible relationship with mortality.

3.3.3 Sample size

According to the NZ-TR data[150], around 3,300 fatal and non-fatal major trauma cases during the study period were expected to meet the eligibility criteria. Assuming a proportion of fatalities of 9%[202], a confidence level of 95% and an error of 1%, the minimum sample size estimated for this study was 3,146.

3.4 Creating the analytical dataset

3.4.1 Outcomes

There were two outcomes of interest in this thesis:

1. ***Prehospital mortality:*** Individuals who had a record in the NZ-TR that linked to an earlier EMS record were considered to have survived to hospital. Those who died prehospital (on-scene or during transfer to hospital) were identified through the EMS provider's records and considered as prehospital deaths.

The outcome variable was created as a binary variable. If the patient was a prehospital death, it was coded as “1”; otherwise, the code was “0”.

2. ***24 hour-mortality after injury:*** As previously discussed, individuals who had a record in the NZ-TR that linked to an earlier EMS record were considered to have survived to hospital. To identify the patients who died 24 hours after injury, both EMS and NZ-TR data were used to calculate the difference between the date/time the patient was discharged from hospital and the date/time of injury. This information, combined with the discharge status from hospital (death or alive) was used to create the outcome variable. If the patient died in hospital within 24 hours after injury, it was coded as “1”; otherwise, the code was “0”. In this case, prehospital deaths were not considered, and therefore excluded as part of the outcome.

3.4.2 Data linkage

St John and WFA ePRFs were accessed electronically via a secure server. A copy of the WFA paper-based forms was obtained, and relevant information was extracted into an Excel database. Supplementary electronic files were also provided with information regarding dates and times of the incident, earliest prehospital times, crew head count, prehospital care provided, etc.

Data from both EMS providers (St John and WFA - ePRFs and paper-based forms) were combined into one EMS dataset. A unique identifier for every record was created. The dataset was restricted to those records where ‘transporting vehicle=1’, as multiple vehicles can provide attention to the patient but not necessarily be the vehicle that transports the patient to the hospital. Using the rurality, the NZDep of usual residence and the geographic co-ordinates of the injury incident in EMS data, the GCH and NZDep was assigned.

Before linkage was undertaken with the NZTR database, the EMS dataset was reshaped into a wide dataset reflecting a patient-incident; each contains all transfers (if there were more than one) involved in getting the patient to the hospital. As mentioned before, for those cases with more than one presentation to hospital due to major trauma within the study period, the last injury episode was selected.

The EMS dataset was probabilistically linked to the NZTR dataset using the incident number, first name, last name, sex, date of birth, date of injury and NHI (where available), in order to restrict the cases to those who sustained major trauma and were admitted to hospital. The linkage purpose was to find the best possible match.

The linked EMS-NZ-TR dataset previously obtained was then deterministically linked to the data provided by HQSC to obtain variables related to acute and total admissions to hospital during the last 12 months and the Charlson Comorbidity Index. Subsequently, this dataset was linked to the NMDS using NHI and variables such as name, last name, age, sex, dates of admission and discharge. This was done as patients can, on occasion, end up with two or more NHIs, so confirming the identification of major trauma cases attended by an EMS that were admitted to hospital was necessary. In addition, relevant hospitalisation related information was obtained and the validation of injury information (e.g. injury intent, mechanism of injury) was possible. The ICD-10 diagnosis codes were obtained from this database to enable a comparison of NZ-TR ISS with ISS derived from ICD-10 coding of injuries (see Chapter 5).

EMS clinical status at arrival at scene and at arrival to hospital were used to identify those cases who died prehospital. A list of patients with 'status=0' (death) at scene and 'status=0" at arrival to hospital was obtained from the EMS dataset and it was used to identify the reports available on the NCIS system. Coronial files were reviewed to determine eligibility and electronic copies of PMs of those individuals who died prehospital were accessed. Injury data was extracted into a REDCap database and then ISS was calculated.

EMS-attended major trauma cases and EMS-attended prehospital deaths with coronial post-mortems were collated to generate the final EMS cohort. A de-identified dataset for analysis was created. Variables were named according to the source of data they came from (Figure 3.1).

3.4.3 Data abstraction

Variables of interest were obtained from EMS records and the NZ-TR database for major trauma cases who survived to hospital. For those patients who died prehospital, relevant information was obtained from EMS data and PMs via NCIS. The Candidate undertook training as part of her thesis in AIS coding and she reviewed the PMs for the prehospital deaths. Where available, the injury information contained in these records was used by the Candidate to code each injury using the AIS 2005/08 system and manually estimate the ISS of these patients considering the three most severely injured body regions. A sample of the Candidate's coding was checked by an experienced coder to verify the data reported. This information was entered in a REDCap database.

Variables extracted from the data sources and used in this thesis are described in section 3.2.2.

3.4.4 Quality process/Data cleaning

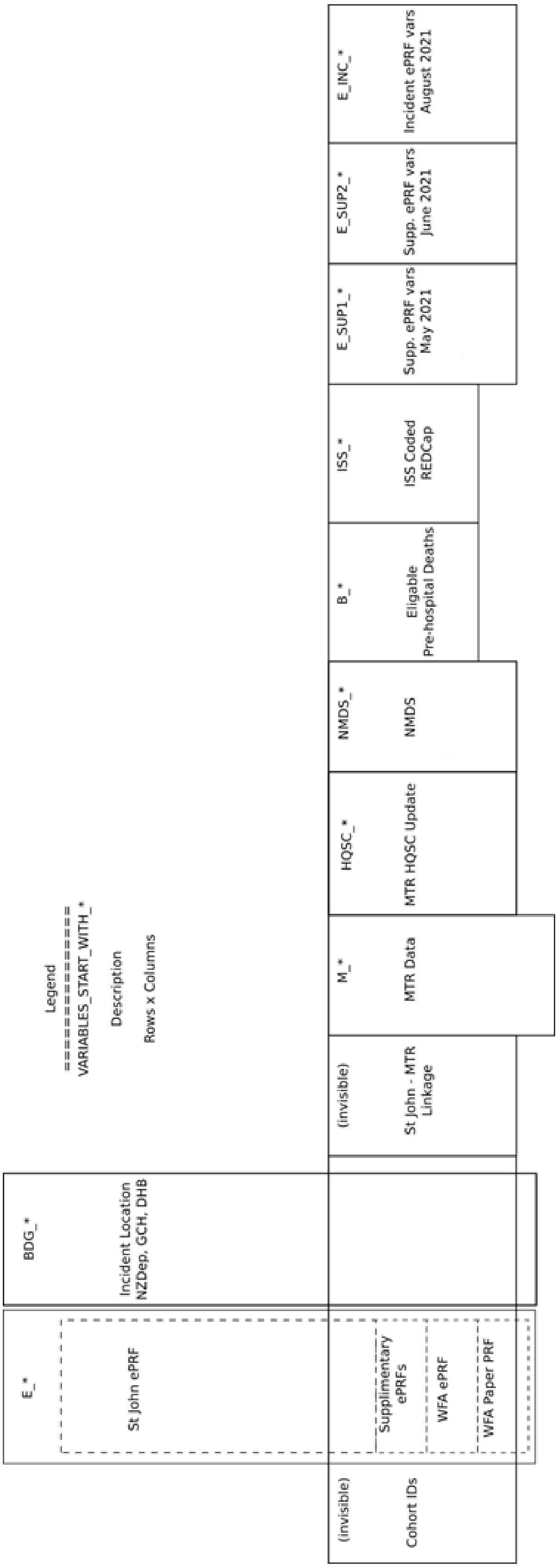
Duplicate rows in the final database were identified using the incident number, NHI (where available), name, last name, and sex, and then removed from the dataset. Possible typing errors or erroneously reported information in the categories of the variables used were identified by making frequency tables for the qualitative variables. When an "error" was found, it was verified by looking at related variables in the original data (before linkage).

Reported times by EMS providers were checked for differences in the data formats used between the ePRFs and the paper-based forms. It was found that the date format used in the ePRFs was YYYY-MM-DD, while that used in the paper-based forms was DD-MM-YYYY; time format was the same for all records (hh:mm:ss). Normally, dates and times were reported in the same variable; when dates and times were in different columns, they were concatenated in one variable. A unification of the date/time formats was needed to calculate the prehospital times, all dates were converted to the DD-MM-YYYY format.

Outliers were identified through the calculation of minimum and maximum values for quantitative variables. Most of these values were observed when calculating the prehospital time components, so it was necessary to review the dates and times reported. For some cases, it was possible to cross-validate by comparing the entry in EMS with that in NZ TR (e.g. date/time arrived at hospital). For other cases, through the revision of the injury circumstances, false positive linkages were picked-up (e.g. extremely long times).

Once data linkage, extracting and cleaning was completed, the dataset was imported into the statistical software for analysis. The analysis was performed with the available data approach.

Figure 3.1 Data sources for analytical dataset



3.4.5 Data derivation

Prehospital time components were calculated considering the time variables reported by EMS providers (Figure 3.2):

- *Response time* was calculated as the difference between the time the phone was picked-up from the 111 call and the time the earliest time an ambulance arrived at scene.
- *On-scene time* was calculated as the difference between the time the transporting ambulance left the scene and the earliest time an ambulance arrived at scene.
- *Transport time* was calculated as the difference between the time the transporting ambulance arrived at the hospital and the time the transporting ambulance left the scene.

Total prehospital time was calculated as the sum of all EMS time intervals (response, on-scene, and transport).

Table 3.1 indicates the categorisation that was undertaken in this study.

Figure 3.2 EMS prehospital time intervals

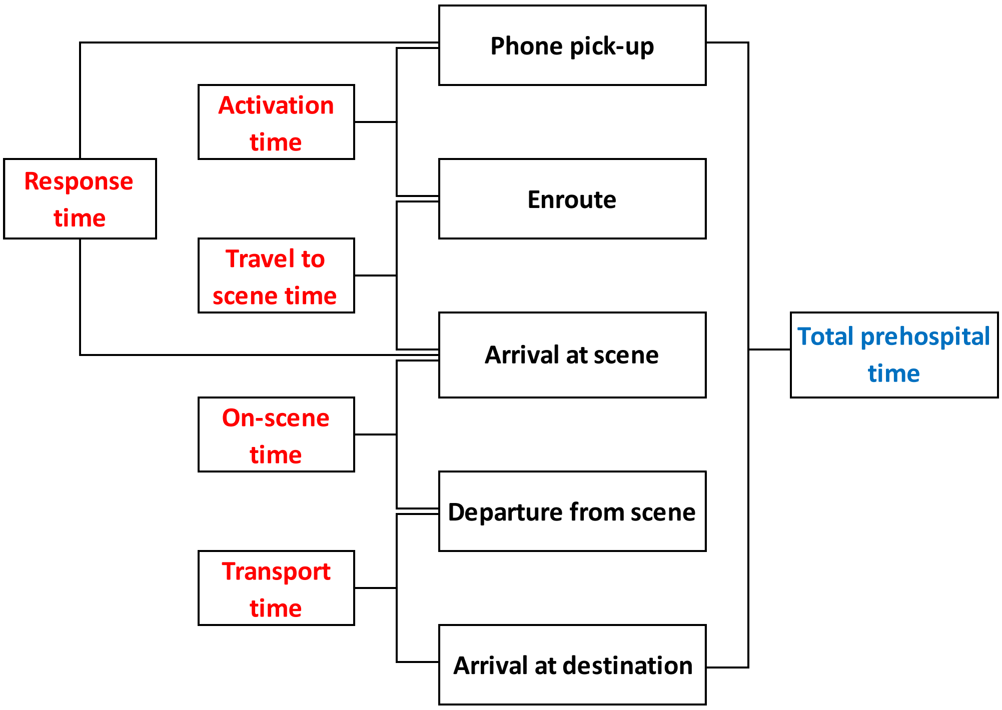


Table 3.1 New categories for analysis purposes

Variable name	Previous categories	New categories	Categories for modelling
Triage	Purple Red Orange Green Grey	Purple Red Orange Green Grey	Purple/Red Other
GCH of incident	U1 U2 R1 R2 R3	Rural Urban	Rural Urban
Age	Continuous	0-14 15-24 25-34 35-44 45-54 55-64 65-74 75-84 85+	0-14 15-44 45-64 65-79 80+
ISS	Continuous	Minor (1-8) Moderate (9-15) Severe (16-24) Very severe (>=25)	<=24 25-50 >50
Dominant injury type	Blunt Burn Penetrating	Blunt Burn Penetrating	Blunt Non-blunt
Injury intent	By other Self-inflicted Unintentional	By other Self-inflicted Unintentional	Intentional Unintentional
Mechanism	Multiple categories	Transport: MVT Fall Cut/Pierce Firearm Natural/Environmental Struck by or against Transport: Other Other Unspecified/No recorded	Transport: MVT Fall Other

Table 3.2 New categories for analysis purposes (continuation)

Variable name	Previous categories	Prioritised ethnicity from MoH categories	Categories for modelling
Ethnicity	NZ European Other European NZ Māori Pacific Island not further defined Samoan Cook Island Māori Tongan Niuean Tokelauan Fijian Other Pacific Island Asian not further defined Southeast Asian Chinese Indian Other Asian Middle Eastern Latin American/Hispanic African Other ethnicity Don't know Response unidentifiable Not stated	Māori Pacific Asian European/Other Response unidentifiable	Māori Non-Māori
Location	Multiple categories	Healthcare Facility Farm Footpath Home Public (Other) Road Workplace Unspecified place of occurrence/No recorded Other	Home Road Other
Charlson	0-13	0 1-2 >=3	0 1-2 >=3
NZDep	1-10	1-3 4-7 8-10	1-3 4-7 8-10

Table 3.3 New categories for analysis purposes (continuation)

Variable name	Previous categories	New categories	Categories for modelling
Response time	Continuous	<5 minutes 5-10 minutes 10-15 minutes ≥15 minutes	<5 minutes 5-10 minutes 10-15 minutes ≥15 minutes
On-scene time	Continuous	<20 minutes 20-30 minutes 30-45 minutes ≥45 minutes	<20 minutes 20-30 minutes 30-45 minutes ≥45 minutes
Transport time	Continuous	<10 minutes 10-20 minutes 20-30 minutes ≥30 minutes	<10 minutes 10-20 minutes 20-30 minutes ≥30 minutes

3.5 Statistical analysis

Stata 17.0 software was used to analyse all data relevant to the thesis objectives[239].

3.5.1 Profile of major trauma cases attended by EMS

A descriptive analysis was conducted. Frequency tables were created to show the distribution of the characteristics of major trauma cases attended by an EMS provider in NZ. Continuous variables are presented as measures of central tendency and dispersion, according to the distribution of the data, which was evaluated through the Shapiro-Wilk test. Categorical variables are shown as absolute and relative frequencies.

Bivariate analyses by survival to hospital and 24-hour mortality following injury were also performed to identify statistical differences between both groups. For categorical variables, the Fisher’s exact test or the chi squared test was used. For continuous variables, the t-test or the Mann-Whitney test was used according to the distribution of the data. A p value less than 0.05 was considered statistically significant.

3.5.2 Distribution of total prehospital time

The distributions of the total time and the component times were described using statistical measures such as mean and standard deviation and/or median and interquartile range. The average proportion of the total time spent in each component was calculated as follow:

$$Proportion = \frac{Total\ time\ spent\ for\ each\ component}{Total\ prehospital\ time\ spent}$$

The proportions for each component were presented with 95% Confidence Intervals (CIs).

Total prehospital time and its component's contribution was also calculated by survival to hospital and survival 24 hours after injury.

3.5.3 Factors associated to prehospital mortality

Univariate and multivariate modified Poisson regression models[240] were built to identify which factors increase the risk of prehospital death in major trauma patients that were attended by an EMS provider in NZ. Crude relative risks (RRs) and adjusted RRs were obtained. Results were presented with 95% CIs.

The stepwise method with backward selection was used to select the significant variables that were related with survival to hospital. The Wald test was applied to determine the significance of the explanatory variables. Some variables identified through previous research, which may have an impact on survival, were 'forced' to remain in the model regardless of statistical significance. The magnitude of the adjusted RRs and precision of the 95% CIs was assessed.

3.5.4 Relationship between prehospital time components and 24-hour mortality after injury

Inferential analysis was utilised to explore the relationship between prehospital time components (response, on-scene, transport) and survival to 24 hours after injury. The hypothesis tested was whether lower prehospital time (and lower time spent in each prehospital time component) is predictive of a decreased risk of mortality among patients with major trauma.

Crude RRs and adjusted RRs for known factors affecting survival 24 hours after injury (e.g. age, ethnicity, injury severity) were estimated through modified Poisson regression models[240] and presented with 95% CIs.

Separate models were built to explore the inclusion of total prehospital time spent and its components as categorical variables and as continuous. The inclusion of the total prehospital time as a binary variable (<60 minutes or not) in the regression model helped to evaluate the impact of the 'golden hour' in survival to 24 hours after injury.

As previously mentioned, the stepwise method with backward selection was used to select the significant time variables that were related with death 24 hours after injury. The Wald test was applied to determine the significance of the explanatory variables. Some variables identified through previous research, which may have an impact on survival, were 'forced' to remain in the model regardless of statistical significance. The magnitude of the adjusted RRs and precision of the 95% CIs was assessed.

3.5.5 Reasons for on-scene delays

As can be seen in Figure 3.2, on-scene time was calculated as the difference between time from arrival at scene to departure at scene. A time higher than the average on-scene time reported in the cohort was considered as a delay, and a dummy variable was created to quantify the percentage of major trauma patients who experienced on-scene delays. Reasons for delays on-scene were reported only in St John' ePRFs.

A descriptive analysis to identify the reasons for prolonged on-scene time in the prehospital care of major trauma patients was conducted. Information regarding reasons for on-scene delays were taken from the EMS database when they were reported. In other case, those reasons were extracted from the NZ-TR record using an analysis of the free text reported in the clinical notes, the history of incident or in additional information registered. Although reporting this information is not mandatory, if information could not be found in neither both databases, it was considered as missing. If the reason was found in the free text, it was considered and classified in categories to analysis used by EMS. The results are presented in a frequency table as absolute and relative frequencies.

3.6 Ethical considerations

Ethics approval for the project was obtained from the Health and Disability Ethics Committee (Ref 18NTB142) by the principal investigator. Permission to access to three of the MoH's National Collections: the NMDS (hospital events) and the NHI database was given by amendments obtained in February 2020.

Research approvals were obtained from the NZ-TR, St John, WFA, and the Australasian National Coronial Information System (Ref NZ007) to access their data for the period of interest.

Information that identifies individuals was removed once the linkage and data checking process was completed, creating a de-identified dataset for analysis, and guaranteeing the confidentiality of the cases. Only aggregated data was reported.

Chapter 4 Results

4.1 Introduction

This results chapter focuses on the relationship between prehospital time spent and survival to first hospital in patients with major trauma in NZ obtained from the analysis of from the "Evaluating the impact of prehospital care on mortality following major trauma"[222] study described in Chapter 3.

The chapter begins with a description of the cohort, highlighting the characteristics of major trauma patients attended by EMS and the distribution of prehospital time between response time (activation and travel to scene), on-scene time and transport time. In part two, a bivariate analysis by prehospital mortality (or survival) is presented and factors associated with this outcome are explored. In part three, an analysis without considering prehospital deaths is conducted and the relationship between prehospital time components and survival to 24 hours after injury is presented. The final part of the chapter reports the reasons for on-scene delays in the prehospital care of patients with major trauma in NZ. Interpretation of results will be discussed in Chapter 6.

4.2 Major trauma attended by EMS in NZ

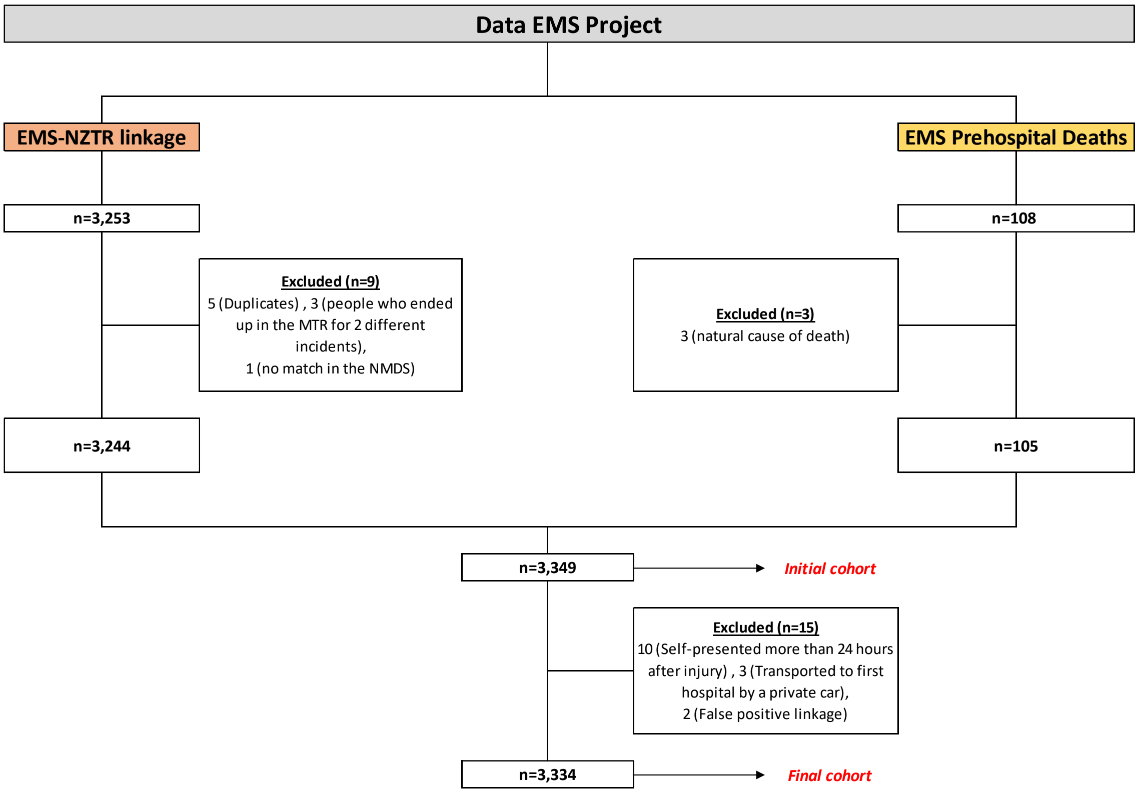
4.2.1 Creation of the analytical dataset

There were 346,179 St John ePRFs and 20,842 PRFs from WFA (9,108 of which were paper-based forms) pertaining to trauma/injury during the period of interest (01/12/2016 to 30/11/2018). Initial linkage identified some injury events had been miscoded by EMS as medical events, resulting in an additional 2,610 ePRFs provided for the linkage with the NZ-TR database (369,631 records). When multiple vehicles responded to an event, only the transporting vehicle ePRFs were retained. After the EMS dataset was probabilistically linked to the NZ-TR dataset, 3,253 records were identified as EMS-attended major trauma cases (Figure 4.1). However, nine were excluded as one record did not match the NMDS database so patients' information could not be confirmed, five records were duplicated (many to 1 linkage with insufficient EMS patient identifiers or different NHI but same patient) and three ended up into the NZ-TR for two different incidents (for these patients, the second incident was retained).

Using the recorded EMS clinical status at scene, 108 patients who were attended by an EMS provider but died prehospital were identified. When reviewing the coronial files to determine eligibility, three cases were excluded because a natural cause of death was found. Note for 32.4% (n=34/105) of prehospital deaths a PM was not located as it was not available on NCIS; in this case, an ISS=75 was assigned.

Out of the 3,349 cases (3,244 that reached hospital and 105 prehospital deaths) that met the inclusion criteria during the study period, 15 were excluded from this analysis. Of these, 10 patients were attended by EMS but then self-presented to hospital more than 24 hours following injury; three were attended by EMS but subsequently transported to hospital by a private car so there was insufficient information regarding EMS care received; and two were false positive linkages were identified through the analysis of 'extreme times' and therefore excluded from the cohort.

Figure 4.1 Patient selection



St John attended 91% of cases included in the cohort and WFA attended the remaining 9%. All PRFs from St John were electronic, while 62.4% of WFA's PRFs were paper-based. Missing information regarding ethnicity, alcohol consumption and times variables was observed in most

WFA paper-based forms as well as for the prehospital deaths, so it was necessary to obtain information from the original record held by EMS or get the information through another dataset where possible (e.g. time arrived at hospital from NZ-TR could be used when EMS missing).

As mentioned in Chapter 3 (Section 3.3.4) there were differences in the data formats used between the ePRFs and the paper-based PRFs to report times that were changed to a standard format DD-MM-YYYY. When calculating prehospital times and its components, some negative and extreme values were identified, which made it necessary to carefully check the original time variables. This identified that in some cases the date was out by one day (more so for cases that occurred or were attended to around midnight), the month and date had been interchanged, or there were data-entry errors. Because this dataset contains numerous dates such as date of injury, date of arrival to hospital, date of discharged in the EMS and the same dates in the NZ-TR and the NMDS, obtaining a logical and consistent date was possible.

4.2.2 Characteristics of major trauma cases

4.2.2.1 *Demographic characteristics*

A total of 3,334 patients met the eligibility criteria, of which 105 (3.1%) died prehospital. The characteristics of major trauma patients attended by EMS are shown in Table 4.1. The majority of patients were male (69.5%), and 21.6% were Māori. Median age was 48 years (IQR: 27-65) with 69.3% of patients aged between 15 and 64 years. There was a significant difference in the median age by gender ($p<0.05$).

4.2.2.2 *Injury characteristics*

Approximately 80% (n=2,494/3,148) of patients were transported to first hospital by a road vehicle. As measured by the GCH, most of trauma incidents occurred in an urban area (66.5%; n= 2,209/3,323). The distribution of socioeconomic status as measured by NZDep2018 showed no significant differences by gender. Previous hospital admissions were reported in 21.7% (n=696/3,211) of the patients and no comorbidities (Charlson index) were observed in 77.3% (n=2,481/3,211) of patients. For those patients in which the alcohol variable was recorded at scene (62.5%; n=2,085/3,334), 17.5% had consumed alcohol before the trauma incident (n=363).

Table 4.1 Demographic characteristics of major trauma patients by gender

Characteristics	Male=2,318 n (%)	Female=1,016 n (%)	Total=3,334 n (%)
Median age in years (IQR)	46 (26 - 61) Min: 0 - Max: 97	55 (29 - 75) Min: 0 - Max: 102	48 (27 - 65) Min: 0 - Max: 102
Age groups (in years)			
0-14	115 (5.0)	61 (6.0)	176 (5.3)
15-24	390 (16.8)	133 (13.1)	523 (15.7)
25-34	348 (15.0)	110 (10.8)	458 (13.7)
35-44	259 (11.2)	86 (8.5)	345 (10.3)
45-54	374 (16.1)	113 (11.1)	487 (14.6)
55-64	356 (15.3)	143 (14.1)	499 (15.0)
65-74	208 (9.0)	110 (10.8)	318 (9.5)
75-84	176 (7.6)	149 (14.7)	325 (9.8)
85+	92 (4.0)	111 (10.9)	203 (6.1)
Ethnicity (prioritised)			
Māori	516 (22.3)	201 (19.8)	717 (21.6)
Pacific	133 (5.8)	30 (3.0)	163 (4.9)
Asian	115 (5.0)	68 (6.7)	183 (5.5)
European/Other specified	1,535 (66.4)	709 (69.9)	2,244 (67.5)
Unspecified	11 (0.5)	6 (0.6)	27 (0.5)

All percentages are column percentages.

The most common mechanism of injury was motor vehicle crashes (MVCs) (45.9%), followed by falls (25.7%) and other transport-related injuries (15.0%). Blunt trauma had occurred in 94.7% of patients, while penetrating trauma was uncommon (3.1%). Median ISS was 17 (IQR: 14-25); 45.7% of the patients had ‘severe’ scores (16-24) (Table 4.2). An ISS of 25 or more was observed for 32.3% of Māori compared to 26.0% of non-Māori.

4.2.2.3 *First outcome: prehospital mortality*

Out of the 3,334 major trauma patients included, 105 (3.1%) died prehospital and the remaining 3,229 (96.9%) survived to first hospital. Most of the patients who died prehospital were male (73.3%) and younger than those who survived (median age: 44 cf.48 years). Patients who died prehospital had a significantly higher ISS compared to those who survived to first hospital ($p<0.05$), with 86.6% of patients experiencing a very severe trauma (ISS≥25) (Table 4.33).

Table 4.2 Injury characteristics of major trauma patients by gender

Characteristics	Male=2,318 n (%)	Female=1,016 n (%)	Total=3,334 n (%)
Mechanism of injury			
Transport: MVC	1,032 (44.5)	498 (49.0)	1,530 (45.9)
Fall	542 (23.4)	317 (31.2)	859 (25.7)
Cut/Pierce	68 (2.9)	14 (1.4)	82 (2.5)
Firearm	21 (0.9)	5 (0.5)	26 (0.8)
Natural/Environment	20 (0.9)	14 (1.4)	34 (1.0)
Struck by or against	152 (6.6)	25 (2.4)	177 (5.3)
Transport: Other	385 (16.6)	115 (11.3)	500 (15.0)
Other	66 (2.9)	23 (2.3)	89 (2.7)
Unspecified/Not recorded	32 (1.4)	5 (0.5)	37 (1.1)
Dominant injury type			
Blunt	2,180 (94.1)	976 (96.0)	3,156 (94.7)
Burn	23 (1.0)	8 (0.8)	31 (0.9)
Penetrating	84 (3.6)	21 (2.1)	105 (3.1)
No recorded	31 (1.3)	11 (1.1)	42 (1.3)
Injury intent			
By other	182 (7.8)	35 (3.4)	217 (6.5)
Self-inflicted	49 (2.1)	24 (2.4)	73 (2.2)
Unintentional	2,079 (89.7)	950 (93.5)	3,029 (90.8)
No recorded	8 (0.4)	7 (0.7)	15 (0.5)
Median Injury Severity Score ISS (IQR)*	18 (14 - 25) Min: 4 - Max: 75	17 (14 - 25) Min: 1 - Max: 75	17 (14 - 25) Min: 1 - Max: 75
ISS groups*			
Minor (1-8)	20 (0.9)	10 (1.0)	30 (0.9)
Moderate (9-15)	591 (25.5)	265 (26.1)	856 (25.7)
Severe (16-24)	1,048 (45.2)	474 (46.8)	1,522 (45.7)
Very severe (≥25)	657 (28.4)	264 (26.1)	921 (27.7)

All percentages are column percentages - * n=3,329 patients

Table 4.3 Demographic and injury characteristics of major trauma patients by prehospital mortality

Characteristics	Survivors to hospital=3,229 n (%)	Died prehospital=105 n (%)
Gender		
Female	988 (30.6)	28 (26.7)
Male	2,241 (69.4)	77 (73.3)
Median age in years (IQR)	48 (27 - 65) Min: 0 - Max: 102	44 (25 - 60) Min: 13 - Max: 95
Ethnicity (prioritised)		
Māori	687 (21.3)	30 (28.5)
Pacific	159 (4.9)	4 (3.8)
Asian	180 (5.6)	3 (2.9)
European/Other	2,187 (67.7)	57 (54.3)
Response unidentifiable/Not recorded	16 (0.5)	11 (10.5)
Mechanism of injury		
Transport: MVC	1,460 (45.2)	70 (66.7)
Fall	851 (26.3)	8 (7.6)
Cut/Pierce	80 (2.5)	2 (1.9)
Firearm	23 (0.7)	3 (2.9)
Natural/Environment	34 (1.1)	0 (0.0)
Struck by or against	171 (5.3)	6 (5.7)
Transport: Other	499 (15.4)	1 (0.9)
Other	80 (2.5)	9 (8.6)
Unspecified/Not recorded	31 (1.0)	6 (5.7)
Dominant injury type		
Blunt	3,096 (95.9)	60 (57.1)
Burn	31 (1.0)	0 (0.0)
Penetrating	102 (3.1)	3 (2.9)
Not recorded	0 (0.0)	42 (40.0)
Injury intent		
By other	209 (6.5)	8 (7.6)
Self-inflicted	72 (2.2)	1 (1.0)
Unintentional	2,933 (90.8)	96 (91.4)
Not recorded	15 (0.5)	0 (0.0)
Median Injury Severity Score ISS (IQR)*	17 (14 - 25) Min: 1 - Max: 75	57 (34 - 75) Min: 5 - Max: 75
ISS groups*		
Minor (1-8)	28 (0.9)	2 (1.9)
Moderate (9-15)	853 (26.5)	3 (2.9)
Severe (16-24)	1,513 (46.9)	9 (8.6)
Very severe (≥25)	830 (25.7)	91 (86.6)

All percentages are column percentages - * n=3,329 patients

4.2.2.4 *Second outcome: 24-hour mortality following injury for hospitalised patients*

In determining the cohort for the second outcome of interest ‘survival to 24 hours after injury’, 105 prehospital deaths were excluded and 3,229 cases analysed, of which 111 (3.4%) died 24 hours after injury. Median age was different between both groups, being significantly higher for hospitalised patients who died within 24 hours compared to those who survived (65 cf. 48 years). Patients who died had a significant higher ISS (26 cf. 17), with 76.7% of patients experiencing a very severe trauma (ISS≥25). A description of the demographic and injury characteristics of the patients included is shown in Table 4.4.

Table 4.4 Demographic and injury characteristics of hospitalised major trauma patients by 24-hour mortality after injury

Characteristics	Survivors to 24 hours after injury=3,118 n (%)	Died within 24 hours after injury=111 n (%)
Gender		
Female	949 (30.4)	39 (35.1)
Male	2,169 (69.6)	72 (64.9)
Median age in years (IQR)	48 (27 - 64) Min: 0 - Max: 102	65 (40 - 80) Min: 8 - Max: 90
Ethnicity (prioritised)		
Māori	668 (21.4)	19 (17.1)
Pacific	155 (5.0)	4 (3.6)
Asian	169 (5.4)	11 (9.9)
European/Other	2,114 (67.8)	73 (65.8)
Response unidentifiable/Not recorded	12 (0.4)	4 (3.6)
Charlson index		
0	2,419 (77.6)	62 (55.9)
1-2	465 (14.9)	28 (25.2)
≥3	220 (7.0)	17 (15.3)
Missing	14 (0.5)	4 (3.6)

All percentages are column percentages.

Table 4.5 Demographic and injury characteristics of hospitalised major trauma patients by 24-hour mortality after injury (continuation)

Characteristics	Survivors to 24 hours after injury=3,118 n (%)	Died within 24 hours after injury=111 n (%)
Previous hospital admissions (last 12 months)		
0	2,448 (78.5)	67 (60.4)
1-2	519 (16.6)	31 (27.9)
≥3	137 (4.4)	9 (8.1)
Missing	14 (0.5)	4 (3.6)
Mechanism of injury		
Transport: MVC	1,413 (45.3)	47 (42.4)
Fall	817 (26.2)	34 (30.6)
Cut/Pierce	75 (2.4)	5 (4.5)
Firearm	17 (0.5)	6 (5.4)
Natural/Environment	34 (1.1)	0 (0.0)
Struck by or against	168 (5.4)	3 (2.7)
Transport: Other	489 (15.7)	10 (9.0)
Other	77 (2.5)	3 (2.7)
Unspecified/Not recorded	28 (0.9)	3 (2.7)
Dominant injury type		
Blunt	2,999 (96.2)	97 (87.4)
Burn	28 (0.9)	3 (2.7)
Penetrating	91 (2.9)	11 (9.9)
Injury intent		
By other	198 (6.4)	11 (9.9)
Self-inflicted	64 (2.1)	8 (7.2)
Unintentional	2,842 (91.1)	91 (82.0)
No recorded	14 (0.4)	1 (0.9)
Median Injury Severity Score ISS (IQR)*	17 (14 - 24) Min: 1 - Max: 75	26 (25 - 41) Min: 4 - Max: 75
ISS groups*		
Minor (1-8)	22 (0.7)	6 (5.6)
Moderate (9-15)	849 (27.2)	4 (3.7)
Severe (16-24)	1,498 (48.1)	15 (14.0)
Very severe (≥25)	748 (24.0)	82 (76.7)

All percentages are column percentages - * n=3,324 patients

4.2.3 Distribution of total prehospital time

4.2.3.1 ***First outcome: prehospital mortality***

Only response time (activation time and travel to scene time) was relevant for this outcome, as on scene time and transport time will be systematically different for those that were attended by EMS but died prehospital. It was found that median response time was lower in those patients who died prehospital compared to those who survived (11.5 vs 14.4 minutes) (Table 4.5). 33.3% of patients who died prehospital experienced a response time between 5-10 minutes, while in 47.6% of patients who survived to hospital the response time was 15 or more minutes.

Table 4.6 Distribution of response time by prehospital mortality for EMS-attended major trauma patients

Characteristics	Survivors to hospital (n=3,210)	Died prehospital (n=105)	Total (n=3,315)*	Contribution (%)**
Response time	14.4 (9.4 - 23.5) Min: 0.0 - Max: 99.5	11.5 (8.0 - 17.1) Min: 1.8 - Max: 87.0	14.3 (9.4 - 23.4) Min: 0.0 - Max: 99.5	
Activation time	3.7 (2.6 - 5.7) Min: 0.0 - Max: 89.5	2.9 (1.7 - 4.4) Min: 0.5 - Max: 12.2	3.7 (2.5 - 5.6) Min: 0.0 - Max: 89.5	28.3 (27.4 - 29.2)
Travel to scene time	9.8 (5.7 – 16.9) Min: 0.0 - Max: 94.0	7.7 (5.4 - 13.8) Min: 0.0 - Max: 83.8	9.8 (5.6 – 16.7) Min: 0.0 - Max: 94.0	71.7 (70.8 - 72.6)

* Extreme response times (>100 minutes) were removed from analysis (n=19)

** Percentage (95% confidence interval)

Median total activation time was 3.7 minutes (IQR: 2.5–5.6), being statistically significant higher in patients who survived to hospital (p<0.001). 71.7% of total response time was spent on travelling to scene with a median of 9.8 minutes (IQR: 5.7–17.0). Median travel to scene time was lower in patients who died prehospital (7.7 vs 9.8 minutes) (Table 4.5).

4.2.3.2 ***Second outcome: 24-hour mortality following injury for hospitalised patients***

Median total prehospital time was 74.6 minutes (IQR: 50.6–104.8), with patients who survived to 24 hours after injury experiencing the longest times. Approximately one-third of patients (34.3%) arrived at hospital during the first 60 minutes after injury (golden hour).

Median response time (11.9 cf. 14.6 minutes) and transport time (16.6 cf. 20.1 minutes) was significantly lower for hospitalised patients who died 24 hours after injury compared to those who survived ($p<0.05$ for both). On-scene time represented 45.7% of total prehospital time, median was 30.6 minutes (IQR: 19.7–49.3). There were no significant differences between on-scene time for patients who died or survived to hospital 24 hours after injury (Table 4.6).

A third of patients who died within 24 hours after injury (33.3%) and a quarter of patients who survived 24 hours after injury (25.0%) experienced a response time between 5-10 minutes. Only 3.6% of patients had a shorter response time (less than five minutes).

Table 4.7 Distribution of TPT and prehospital time components by 24-hour mortality after injury for hospitalised major trauma patients attended by EMS

Characteristics	Survivors to 24 hours after injury	Died within 24 hours after injury	Total	Contribution (%)*
Total prehospital time (n=3,178)	75.0 (51.0 – 104.8) Min: 0.0 - Max: 272.8	58.4 (40.6 – 99.1) Min: 1.3 - Max: 284.4	74.6 (50.6 – 104.8) Min: 1.3 - Max: 284.4	
Response time (n=3,210)	14.6 (9.5 - 23.8) Min: 0.0 - Max: 99.5	11.9 (7.6 - 16.6) Min: 0.3 - Max: 87.5	14.4 (9.4 - 23.5) Min: 0.0 - Max: 99.5	24.2 (23.7 - 24.7)
On-scene time (n=3,212)	30.6 (19.9 - 49.3) Min: 0.1 - Max: 179.5	28.0 (15.4 - 47.5) Min: 1.0 - Max: 104.7	30.6 (19.7 - 49.3) Min: 0.1 - Max: 179.5	45.7 (45.1 – 46.4)
Transport time (n=3,209)	20.1 (11.4 - 33.3) Min: 0.0 - Max: 119.2	16.6 (7.7 - 29.9) Min: 0.0 - Max: 111.3	20.0 (11.2 - 33.1) Min: 0.0 - Max: 119.2	30.1 (29.5 – 30.6)

* Percentage (95% confidence interval)

4.3 Factors associated to prehospital mortality

4.3.1 Univariate analysis

A univariate analysis was conducted to individually identify those variables that were potential predictors of the outcome. Patients aged 85 years or more were excluded (6.1%, n=203/3,334) as the presence of multiple comorbidities may affect the outcome. For analysis purposes, variables were regrouped as described in Chapter 3 (Section 3.3.5). Table 4.7 provides a brief description of the variables.

Table 4.8 Risk of prehospital mortality: univariate analysis

Factors	Survivors to hospital=3,033 n (%)	Died prehospital=98 n (%)	RR (95%CI)	p value
Gender				
Female	881 (29.0)	24 (24.5)	1.00	0.3
Male	2,152 (71.0)	75 (75.5)	1.25 (0.80 - 1.97)	
Age groups				
0-14	174 (5.7)	2 (2.0)	1.00	0.1
15-44	1,274 (42.0)	52 (53.1)	3.45 (0.85 - 14.05)	
45-64	956 (31.5)	30 (30.6)	2.68 (0.65 - 11.11)	
65-79	473 (15.6)	12 (12.3)	2.18 (0.49 - 9.63)	
80-84	156 (5.2)	2 (2.0)	1.11 (0.16 - 7.82)	
Ethnicity - n=3,106				
Non-Māori	2,334 (77.3)	58 (65.9)	1.00	0.01
Māori	684 (22.7)	30 (34.1)	1.73 (1.12 - 2.67)	
NZDep2018 - n=3,100				
1-3	767 (25.6)	22 (22.5)	1.00	0.7
4-7	1,312 (43.7)	46 (46.9)	1.21 (0.74 - 2.00)	
8-10	923 (30.7)	30 (30.6)	1.13 (0.66 - 1.94)	
Geographic Classification for Health				
Urban	1,974 (65.1)	60 (61.2)	1.00	0.4
Rural	1,059 (34.9)	38 (38.8)	1.17 (0.79 - 1.75)	
Triage priority (on scene)				
Other	1,630 (53.7)	48 (49.0)	1.00	0.4
Purple/Red	1,403 (46.3)	50 (51.0)	1.20 (0.81 - 1.78)	
Mechanism of injury - n= 3,096				
Fall	711 (23.7)	5 (5.3)	1.00	<0.001
Transport: MVC	1,414 (47.1)	68 (72.3)	6.57 (2.66 - 16.22)	
Other	877 (29.2)	21 (22.3)	3.35 (1.27 - 8.84)	
Dominant injury type - n=3,094				
Blunt	2,901 (95.7)	58 (95.1)	1.00	0.7
Non-Blunt	132 (4.3)	3 (4.9)	1.13 (0.36 - 3.57)	
ISS groups - n=3,126				
<25	2,243 (74.1)	14 (14.3)	1.00	<0.001
≥25	785 (25.9)	84 (85.7)	15.58 (8.90 - 27.29)	

Table 4.9 Risk of prehospital mortality: univariate analysis (continuation)

Factors	Survivors to hospital=3,033 n (%)	Died prehospital=98 n (%)	RR (95%CI)	p value
Response time - n=3,120				
<5 minutes	106 (3.5)	5 (5.1)	1.00	0.06
5-10 minutes	742 (24.6)	32 (32.7)	0.92 (0.37 - 2.31)	
10-15 minutes	723 (23.9)	27 (27.6)	0.80 (0.31 - 2.03)	
≥15 minutes	1,451 (48.0)	34 (34.7)	0.51 (0.20 - 1.27)	

Results indicate that, for those attended by EMS, Māori had a higher risk of dying prehospital (RR=1.73; 95% CI: 1.12–2.67). Mechanism of injury was also a predictor of prehospital mortality with transport-related injuries (RR=6.57; 95%CI: 2.66–16.22) and other mechanisms (RR=3.35; 95%CI: 1.27–8.84)) having higher relative risks compared to fall injury. Prehospital mortality risk was higher when ISS was greater than 24 (RR=17.0; 95% CI: 9.7–29.7). Although the results showed that increasing response times, decreased the risk of prehospital mortality, no significant association was found between these variables (p=0.06) (Table 4.7). This result is likely to be related to triage status or other possible confounding variables that will be explored in the multivariate analyses.

As mentioned in Section 4.2.2.2 a little over 60% of patients had information regarding alcohol consumption. When exploring this relationship, the association between alcohol consumption (for those with data) and prehospital mortality, no relationship was found (RR=1.02; 95% CI: 0.5–2.1).

4.3.2 Multivariate analysis

A modified Poisson regression model[240] was developed to identify factors that predict the risk of prehospital mortality in major trauma patients that were attended by an EMS provider.

Key variables in the univariate analysis ($p<0.20$) or those that were identified through previous research, which may have an impact on survival to hospital, were included in the initial model. The final model, adjusted by potential confounding variables (age, gender and ethnicity), included all variables that were identified as significant predictors ($p<0.05$) with the outcome (Table 4.8).

A clear relationship was observed between mechanism of injury and ISS with prehospital mortality after controlling for age, gender and ethnicity. Risk of dying prehospital increased when the incident was due to MVCs (aRR=5.12; 95%CI: 2.08–12.59) or other mechanisms (aRR=3.57; 95%CI: 1.36–9.34) compared with falls. Patients with an ISS of 25 or more relative to those with ISS≤24 had a substantially higher risk of prehospital mortality (aRR=13.89; 95%CI: 7.74–24.93).

Table 4.10 Risk of prehospital mortality: multivariable adjusted model

Factors	Initial model RR (95%CI)	Final model[a] aRR (95%CI)	p value[b]
Gender (Female)			
Male	1.16 (0.72 - 1.85)	1.14 (0.71 - 1.82)	0.6
Age groups (0-14)			
15-44	2.61 (0.65 - 10.48)	2.56 (0.65 - 10.03)	0.6
45-64	3.07 (0.77 - 12.28)	3.04 (0.77 - 12.00)	
65-79	2.76 (0.62 - 12.28)	2.78 (0.63 - 12.20)	
80-84	2.07 (0.31 - 14.03)	2.03 (0.30 - 13.69)	
Ethnicity (Non-Māori)			
Māori	1.47 (0.95 - 2.25)	1.41 (0.92 - 2.16)	0.1
NZDep2018 (1-3)			
4-7	1.29 (0.76 - 2.19)		
8-10	1.01 (0.55 - 1.85)		
Triage priority (Other)			
Purple/Red	0.91 (0.60 - 1.38)		
Mechanism of injury (Fall)			
Transport: MVC	4.87 (1.89 - 12.55)	5.12 (2.08 - 12.59)	0.001
Other	3.65 (1.33 - 9.99)	3.57 (1.36 - 9.34)	
ISS groups (<25)			
≥25	13.94 (7.73 - 25.14)	13.89 (7.74 - 24.93)	<0.001
Response time (<5 minutes)			
5-10 minutes	1.20 (0.45 - 3.18)		
10-15 minutes	1.01 (0.37 - 2.73)		
≥15 minutes	0.83 (0.31 - 2.23)		

4.4 Relationship between prehospital time components and 24-hour mortality after injury

4.4.1 Univariate analysis

Out of the 3,229 hospitalised major trauma patients in the cohort, 196 patients aged 85 or more were excluded (6.1%) for analysis. Univariate analysis indicated that being aged between 80 and 84 years (RR=7.44; 95% CI: 2.25–24.55), being triaged by EMS as purple or red (RR=2.55; 95% CI: 1.68–3.87) and having an ISS greater than 24 (RR=10.71; 95% CI: 6.59–17.43) increased the risk of dying 24 hours after injury for those hospitalised. Additionally, other factors predictive of the outcome were having one or more comorbidities, one or more previous hospital admissions, experiencing non-blunt trauma or intentional injury (p<0.001) (Table 4.9).

On the other hand, results revealed that higher response and transport times were predictive of risk of death 24 hours after injury (p<0.001). Although the risk ratios (RRs) for on-scene time suggest longer times was a protective factor for death, no significant relationship was found (p=0.2). However, results showed that patients who spent between 30-45 minutes on scene had 45% less risk of dying 24 hours after injury compared to those who spent less than 20 minutes on-scene. Arriving at hospital more than 60 minutes after injury was predictive of lower mortality, although this is likely to be related to triage status with higher response times likely for less severe patients (Table 4.10).

Table 4.11 Risk of 24-hour mortality after injury for hospitalised major trauma patients: univariate analysis

Factors	Survivors to 24 hours after injury=2,934 n (%)	Died within 24 hours after injury=99 n (%)	RR (95%CI)	p value
Gender				
Female	846 (28.8)	35 (35.3)	1.00	0.2
Male	2,088 (71.2)	64 (64.7)	0.75 (0.50 - 1.12)	
Age groups (in years)				
0-14	171 (5.8)	3 (3.0)	1.00	
15-44	1,242 (42.3)	32 (32.3)	1.46 (0.45 - 4.71)	
45-64	936 (31.9)	20 (20.2)	1.21 (0.36 - 4.04)	<0.001
65-79	449 (15.3)	24 (24.3)	2.94 (0.90 - 9.65)	
80-84	136 (4.6)	20 (20.2)	7.44 (2.25 - 24.55)	

Table 4.12 Risk of 24-hour mortality after injury for hospitalised major trauma patients: univariate analysis (continuation)

Factors	Survivors to 24 hours after injury=2,934 n (%)	Died within 24 hours after injury=99 n (%)	RR (95%CI)	p value
Ethnicity				
Non-Māori	2,258 (77.3)	76 (80.0)	1.00	0.5
Māori	665 (22.7)	19 (20.0)	0.85 (0.52 - 1.40)	
NZDep2018				
1-3	740 (25.5)	27 (27.3)	1.00	0.7
4-7	1,273 (43.8)	39 (39.4)	0.84 (0.52 - 1.37)	
8-10	890 (30.7)	33 (33.3)	1.02 (0.62 - 1.67)	
Zone				
Urban	1,896 (64.6)	78 (78.8)	1.00	0.004
Rural	1,038 (35.4)	21 (21.2)	0.50 (0.31 - 0.81)	
Triage priority				
Other	1,599 (54.5)	31 (31.3)	1.00	<0.001
Purple/Red	1,335 (45.5)	68 (68.7)	2.55 (1.68 - 3.87)	
Charlson index				
0	2,351 (80.5)	57 (60.0)	1.00	<0.001
1-2	397 (13.6)	25 (26.3)	2.50 (1.58 - 3.96)	
≥3	172 (5.9)	13 (13.7)	2.97 (1.66 - 5.32)	
Previous hospital admissions (last 12 months)				
0	2,360 (80.8)	59 (62.1)	1.00	<0.001
1-2	451 (15.5)	28 (29.5)	2.40 (1.55 - 3.72)	
≥3	109 (3.7)	8 (8.4)	2.80 (1.37 - 5.73)	
Mechanism of injury				
Fall	683 (23.5)	28 (29.2)	1.00	0.4
Transport: MVC	1,370 (47.1)	44 (45.8)	0.79 (0.50 - 1.26)	
Other	853 (29.4)	24 (25.0)	0.69 (0.41 - 1.19)	
Dominant injury type				
Blunt	2,816 (96.0)	85 (85.9)	1.00	<0.001
Non-Blunt	118 (4.0)	14 (14.1)	3.62 (2.11 - 6.20)	
Injury intent				
Unintentional	2,659 (91.1)	79 (80.6)	1.00	<0.001
Intentional	261 (8.9)	19 (19.4)	2.35 (1.45 - 3.82)	
ISS groups				
<25	2,223 (75.8)	20 (21.0)	1.00	<0.001
≥25	710 (24.2)	75 (79.0)	10.71 (6.59 - 17.43)	

Table 4.13 Risk of mortality 24-hour mortality after injury for hospitalised major trauma: univariate analysis for time components

Factors	Survivors to 24 hours after injury=2,934 n (%)	Died within 24 hours after injury=99 n (%)	RR (95%CI)	p value
Response time - n=3,022				
<5 minutes	98 (3.4)	8 (8.1)	1.00	<0.001
5-10 minutes	713 (24.4)	29 (29.3)	0.52 (0.24 - 1.10)	
10-15 minutes	694 (23.7)	29 (29.3)	0.53 (0.25 - 1.13)	
≥15 minutes	1,418 (48.5)	33 (33.3)	0.30 (0.14 - 0.64)	
On-scene time - n=3,017				
<20 minutes	737 (25.3)	34 (34.3)	1.00	0.2
20-30 minutes	666 (22.8)	21 (21.2)	0.69 (0.41 - 1.18)	
30-45 minutes	639 (21.9)	16 (16.2)	0.55 (0.31 - 0.99)	
≥45 minutes	876 (30.0)	29 (28.3)	0.70 (0.43 - 1.15)	
Transport time - n=3,013				
<10 minutes	575 (19.7)	34 (34.3)	1.00	<0.001
10-20 minutes	853 (29.3)	27 (27.3)	0.55 (0.34 - 0.90)	
20-30 minutes	566 (19.4)	15 (15.2)	0.46 (0.25 - 0.84)	
≥30 minutes	920 (31.6)	23 (23.2)	0.44 (0.26 - 0.73)	
Total prehospital time - n=2,991				
≤60 minutes	979 (33.8)	50 (50.5)	1.00	<0.001
>60 minutes	1,913 (66.2)	49 (49.5)	0.51 (0.35 - 0.76)	

4.4.2 Multivariate analysis

4.4.2.1 *Prehospital time components*

Modified Poisson regression models[240] were developed to examine the relationship between prehospital time components and survival to 24 hours after injury for those hospitalised for major trauma. Model 1 included adjustment for age, gender and ethnicity; socio-economic characteristics were added to the model if they were significant in the univariate analysis ($p<0.20$). Model 2 adjusted for clinical variables and Model 3 adjusted for the characteristics of injury. For each model, variables that were significant in the univariate analysis ($p<0.20$) were included (potentially confounding).

There was a relationship between the risk of death 24 hours after injury and response time for those hospitalised for major trauma, in all models. In Model 3 the aRRs for response time between 5 to 10 minutes and 15 or more minutes compared with less than 5 minutes were 0.39 (95%CI: 0.18 – 0.84) and 0.37 (95%CI: 0.18 – 0.80) respectively, suggesting that higher longer times predict lower mortality within 24 hours following injury. No significant relationship was observed between on-scene time and transport time with survival to 24 hours after injury (p>0.05) (Table 4.11).

Table 4.14 Risk of 24-hour mortality after injury for hospitalised major trauma patients: multivariate adjusted model for prehospital time components

Factors	Model 1[a] aRR (95%CI)	Model 2[b] aRR (95%CI)	Model 3[c] aRR (95%CI)	p value[d]
Gender (Female)				
Male	0.84 (0.56 - 1.26)	0.90 (0.60 - 1.36)	0.91 (0.60 - 1.40)	0.7
Age groups (0-14)				
15-44	1.44 (0.43 - 4.76)	2.18 (0.51 - 9.26)	2.56 (0.60 - 11.00)	p<0.001
45-64	1.32 (0.39 - 4.47)	1.82 (0.42 - 7.84)	2.35 (0.54 - 10.24)	
65-79	2.90 (0.88 - 9.58)	3.81 (0.88 - 16.53)	6.31 (0.47 - 27.18)	
80-84	7.34 (2.23 - 24.16)	8.17 (1.89 - 35.45)	13.17 (2.96 - 58.55)	
Ethnicity (Non-Māori)				
Māori	1.00 (0.61 - 1.65)	0.97 (0.58 - 1.61)	0.83 (0.19 - 1.39)	0.5
Zone (Urban)				
Rural	0.61 (0.37 - 1.01)	0.50 (0.30 - 0.86)	0.66 (0.38 - 1.14)	0.1
Triage priority (Other)				
Purple/Red	-	2.71 (0.72 - 4.25)	2.19 (1.38 - 3.47)	0.001
Charlson index (0)				
1-2	-	1.57 (0.94 - 2.62)	1.15 (0.68 - 1.94)	0.9
≥3	-	1.61 (0.83 - 3.11)	1.16 (0.62 - 2.17)	
Previous hospital admissions (last 12 months) (0)				
1-2	-	1.76 (1.10 - 2.81)	1.83 (1.13 - 2.97)	0.03
≥3	-	1.40 (0.69 - 2.83)	0.82 (0.35 - 1.91)	
Dominant injury type (Blunt)				
Non-Blunt	-	-	2.64 (1.16 - 6.02)	0.02
Injury intent (Unintentional)				
Intentional	-	-	1.29 (0.65 - 2.55)	0.5
ISS groups (<25)				
≥25	-	-	10.19 (6.03 - 17.20)	p<0.001

Table 4.15 Risk of 24-hour mortality after injury for hospitalised major trauma patients: multivariate adjusted model for prehospital time components (continuation)

Factors	Model 1[a] aRR (95%CI)	Model 2[b] aRR (95%CI)	Model 3[c] aRR (95%CI)	p value[d]
Response time (<5 minutes)				
5-10 minutes	0.49 (0.24 - 1.02)	0.46 (0.22 - 0.98)	0.39 (0.18 - 0.84)	0.06
10-15 minutes	0.57 (0.28 - 1.19)	0.58 (0.27 - 1.22)	0.47 (0.22 - 1.01)	
≥15 minutes	0.40 (0.19 - 0.82)	0.47 (0.21 - 1.05)	0.37 (0.18 - 0.80)	
On-scene time - (<20 minutes)				
20-30 minutes	0.66 (0.39 - 1.13)	0.67 (0.39 - 1.14)	0.58 (0.33 - 1.02)	0.2
30-45 minutes	0.60 (0.33 - 1.09)	0.67 (0.36 - 1.23)	0.68 (0.36 - 1.26)	
≥45 minutes	1.06 (0.62 - 1.79)	1.07 (0.62 - 1.86)	0.90 (0.49 - 1.67)	
Transport time (<10 minutes)				
10-20 minutes	0.58 (0.29 - 1.03)	0.65 (0.38 - 1.08)	0.77 (0.45 - 1.34)	0. 8
20-30 minutes	0.55 (0.29 - 1.03)	0.61 (0.32 - 1.16)	0.77 (0.41 - 1.45)	
≥30 minutes	0.61 (0.35 - 1.05)	0.72 (0.42 - 1.23)	0.85 (0.48 - 1.52)	

[a] Model 1: Adjusted for age, gender, ethnicity and Geographic Classification for Health
[b] Model 2: Adjusted those variables in Model 1, plus triage, Charlson index, previous hospital admissions
[c] Model 3: Adjusted those variables in Model 1 and Model 2, plus dominant type of injury, injury intent and ISS
[d] Model 3 p value

4.4.2.2 *Total prehospital time*

The same models described in Section 4.4.2.1 were used to evaluate the impact of total prehospital time as categorical variable ('golden hour') in survival to 24 hours after injury. Results showed that when adjusted for socio-demographic and rurality of incident (Model 1), hospitalised major trauma patients with a longer prehospital time (more than 60 minutes) had 41% lower risk of mortality 24 hours after injury. However, this relationship was attenuated when variables related to the injury and prior health status were included (Table 4.12).

Table 4.16 Risk of 24-hour mortality after injury: multivate adjusted by 'golden hour'

Factors	Model 1[a] RR (95%CI)	Model 2[b] RR (95%CI)	Model 3[c] RR (95%CI)	p value[d]
Gender (Female)				
Male	0.88 (0.59 - 1.31)	0.94 (0.63 - 1.41)	0.91 (0.60 - 1.40)	0.7
Age groups (0-14) in years				
15-44	1.54 (0.47 - 5.08)	2.33 (0.55 - 9.86)	2.41 (0.57 - 10.23)	p<0.001
45-64	1.36 (0.40 - 4.60)	1.86 (0.43 - 8.06)	2.14 (0.49 - 9.35)	
65-79	2.96 (0.89 - 9.86)	3.88 (0.88 - 17.03)	5.55 (1.29 - 23.81)	
80-84	7.42 (2.25 - 24.46)	8.66 (2.00 - 37.46)	12.60 (2.96 - 53.63)	

Table 4.17 Risk of 24-hour mortality after injury: multivate adjusted by 'golden hour' (continuation)

Factors	Model 1[a] RR (95%CI)	Model 2[b] RR (95%CI)	Model 3[c] RR (95%CI)	p value[d]
Ethnicity (Non-Māori)				
Māori	1.05 (0.64 - 1.73)	0.99 (0.59 - 1.66)	0.85 (0.51 - 1.43)	0.5
Zone (Urban)				
Rural	0.71 (0.43 - 1.20)	0.61 (0.35 - 1.06)	0.74 (0.42 - 1.30)	0.3
Triage priority (Other)				
Purple/Red	-	2.81 (1.82 - 4.35)	2.18 (1.39 - 3.40)	0.001
Charlson index (0)				
1-2	-	1.55 (0.92 - 2.62)	1.17 (0.70 - 1.97)	0.8
≥3	-	1.63 (0.85 - 3.14)	1.11 (0.60 - 2.05)	
Previous hospital admissions (last 12 months) (0)				
1-2	-	1.70 (1.06 - 2.73)	1.64 (1.02 - 2.65)	0.1
≥3	-	1.45 (0.71 - 2.93)	0.96 (0.43 - 2.13)	
Dominant injury type (Blunt)				
Non-Blunt	-	-	2.66 (1.21 - 5.86)	0.02
Injury intent (Unintentional)				
Intentional	-	-	1.36 (0.69 - 2.69)	0.4
ISS groups (<25)				
≥25	-	-	10.09 (6.01 - 16.94)	p<0.001
Total prehospital time (≤60 minutes)				
>60 minutes	0.59 (0.39 - 0.90)	0.68 (0.45 - 1.04)	0.70 (0.46 - 1.07)	0.1

[a] Model 1: Adjusted for age, gender, ethnicity, and Geographic Classification for Health
[b] Model 2: Adjusted those variables in Model 1, plus triage, Charlson index, previous hospital admissions
[c] Model 3: Adjusted those variables in Model 1 and Model 2, plus dominant type of injury, injury intent and ISS
[d] Model 3 p value

4.5 EMS on-scene delays for major trauma patients

45.7% of total prehospital time for major trauma patients in New Zealand attended by an EMS provider was spent on-scene. Mean and median on-scene times were 38.7minutes and 30.6 minutes (IQR: 19.7-49.3), respectively. A time longer than the mean on-scene time reported in the cohort was considered as a delay.

In one third of cases (n=1,171; 35.1%) experienced on-scene delays were recorded. However, reasons for this were documented only for 368 cases (31.4%). Reasons for on-scene delays were located for 39 more cases through free text searching, giving an overall of 407. Difficult extrication (31.0%), patient's condition (24.3%), trapped patients (19.9%) and multiple patients involved in the event (12.0%) were the most common reasons for on-scene delays (Table 4.13).

Table 4.18 Reasons for on-scene delays for major trauma patients

Reasons	n (%)
Difficult extrication (upstairs etc.)	126 (31.0)
Patient condition (required intervention)	99 (24.3)
Trapped/encased	81 (19.9)
Multiple patients	49 (12.0)
Awaiting assistance	34 (8.3)
Complex decision (patient/crew indecision)	7 (1.7)
Patient not ready	5 (1.2)
Awaiting family or caregiver	4 (1.0)
Alternative pathway organised	1 (0.3)
Reportable event occurred	1 (0.3)

4.6 Summary

These findings suggest that the mechanism of injury (MVCs and other mechanism) and an ISS greater than 25 are strong predictors of prehospital mortality for major trauma patients attended by EMS at the scene. This relationship remained when adjusted for age, gender, and ethnicity. In this study, response time was not predictive of prehospital mortality, but it was with mortality 24 hours after injury. In fact, after adjusting for socio-demographic characteristics, rurality of incident, clinical variables and injury characteristics, longer prehospital times were predictive of improved survival 24 hours after injury. The interpretation of these findings and implications for policy, practice and future research are discussed in Chapter 6.

Chapter 5 Comparison of Injury Severity Scores derived from ICD-10-AM codes with the New Zealand Trauma Registry derived scores

5.1 Introduction

Trauma registries play a key role in trauma systems as they provide useful information regarding patterns of trauma and outcomes, monitor the quality of trauma care, and inform injury prevention and control[108]. Injury severity is an important measure in trauma research, with the ISS one of the most commonly used indices[148]. The ISS has been used extensively to define major trauma using an ISS≥16[147,149]. As discussed in Chapter 2 (Section 2.2), ISS is calculated using the AIS[144,145].

Manual coding has been considered the 'gold standard' to determine the severity of an individual injury[241]. However, it is time consuming and leads to extra costs for medical institutions[242,243], as a minimum 16 hours of special training is required to become a coder[244]. Additionally, when using large databases in research, manual coding is labour-intensive as a review of the complete medical report is needed to calculate AIS[241,245], which can take many hours depending on the number of injuries the patient has. The International Classification of Diseases (ICD)[13,242], is a standard diagnostic tool, developed by the WHO for coding and classifying injuries, diseases, and medical procedures[13,241]. Although these administrative databases represent a useful source of population data, the ICD system does not consider the severity of injuries[241,246].

Various attempts have been made to reduce the administrative burden of manually assigning AIS codes including the development of a mapping tool to derive AIS 2005 scores (updated 2008) from ICD-10th Version-Clinical Modification (ICD-10-CM)[243,246–248]. However, the accuracy of these programmes remains unclear, especially for the NZ context.

5.2 Aim

The aim of this study was to compare ISS manually derived for the NZ Trauma Registry (NZ TR) with scores derived using a modified ICD/AIS mapping tool.

5.3 Methods

5.3.1 Data sources

A retrospective analysis was conducted using the cohort previously described in Chapter 3 (Section 3.3), which includes data from the EMS providers, the NZ TR and the MOH's NMDS.

An email from Paul McBride (personal communication, July 19, 2021) confirmed that the AIS codes used by the NZ TR to derive the ISS are collected within the first 24 hours of hospitalisation and are based on all confirmed diagnoses at that time. The coding process is performed manually by AIS coding specialists, who collate information from the patient hospital records and radiology reports.

The MoH's NMDS contains hospital discharge information including ICD-10th Version-Australian Modification (ICD-10-AM) diagnosis codes[223] (see Chapter 3, Section 3.2.2). Hospital coding includes up to 99 diagnoses associated with a hospitalisation[232]; it is done by administrative coders after a patient has been discharged.

The detailed linkage process to establish the dataset is described in Section 3.3.2. Once the linkage was completed, a de-identified dataset was created for analysis.

5.3.2 Sample

The sample of patients included in this study are those described in Section 3.3.1 and is formed individuals who were attended by an EMS provider in NZ after suffering major trauma between 1 December 2016 and 30 November 2018 and met the NZ TR's eligibility criteria. Patients in which a link with the NMDS was not possible or the link obtained did not include at least one injury-related ICD Diagnosis code (S or T) were excluded. Cases with no ISS recorded or with an ISS recorded as zero (ISS=0) in the NZ TR were considered missing and therefore excluded from this study.

5.3.3 Algorithm

As previously mentioned, the NZ TR has the ISS score contained in it. To derive ISS codes from the hospital discharge data coded using ICD-10-AM, a modified version of the ICD/AIS mapping tool to convert ICD-10 codes into AIS 2005 (update 2008) by Dr Dinh was used[249]. This modified version considered those codes that are in the AM version but not in the CM version and included the AIS severity scores for all injury-related ICD-10-AM codes, as well as its corresponding ISS body region[249].

Permission was obtained from Dr Dinh to use the mapping tool (personal communication, September 15, 2021). The mapping tool was provided via email and contained two files: an Excel spreadsheet with three columns (clinical codes, AIS severity and ISS body region) and a text file with a description on how to use the tool.

To calculate the ISS scores, an algorithm based on Dr Dinh's tool was created as each patient could have had multiple injuries per body region. Based on the ICD-10-AM codes reported by the NZ TR, the maximum AIS score (MAIS) for each body region was obtained and then, the three most severely injured body regions were identified. The sum of squares of the AIS scores from these three body regions was automatically calculated, giving as a result the ISS score (Appendix B).

5.3.4 Statistical analysis

Data management and statistical analyses were conducted using Stata SE version 17[239]. A descriptive analysis was conducted to show the distribution of the characteristics of the major trauma cases included. Categorical variables are shown as absolute and relative frequencies. The severity of injuries was defined as minor injury (MAIS 1-2) and serious injury (MAIS 3+)[250].

The Intraclass Correlation Coefficient (ICC) was calculated for raw scores to determine the correlation between ISS scores calculated by the NZ TR and the ICD/AIS mapping tool. A Bland-Altman chart was assessed to compare the scores obtained.

Analysis was conducted by subgroups of sex (male, female), ethnicity (Māori, non-Māori) and mechanism of injury (transport, fall, other). As severity and injury outcomes differ between paediatric (<15 years of age) and adult populations (≥15 years of age), an analysis by age groups to explore variation in performance of the ICD/AIS mapping tool was undertaken. Age was categorised into three groups for the paediatric population (0-4, 5-9, 10-14 years)[251] and four groups for the adult population (15-44, 45-64, 65-79 and greater or equal than 80 years)[206].

NZ-TR ISS derived scores were considered as the gold standard. To determine the proportion of cases that were correctly classified as major trauma by the ICD/AIS mapping tool, ISS scores were categorised according to two commonly used international definitions of major trauma (ISS>12 and ISS>15)[148]. ISS scores were also categorised according to the NZ-TR & National Trauma Network: mild (ISS≤12), moderate (ISS=13-24), severe (ISS=25-44) and very severe (ISS≥45)[206]. For these cases, Cohen's Kappa was calculated to assess the agreement between NZ TR scores and those obtained by the ICD/AIS mapping tool. Interpretation of the findings was done according to Landis and Koch[252].

5.3.5 Ethics

Ethics approval to access the data sources were obtained from the Health and Disability Ethics Committee (see Chapter 3, Section 3.5). Permission to use the ICD/AIS mapping tool was given via email by the author (personal communication, September 15, 2021), Dr Michael Dinh, Clinical Director of the New South Wales Institute of Trauma and Injury Management in Australia.

5.4 Results

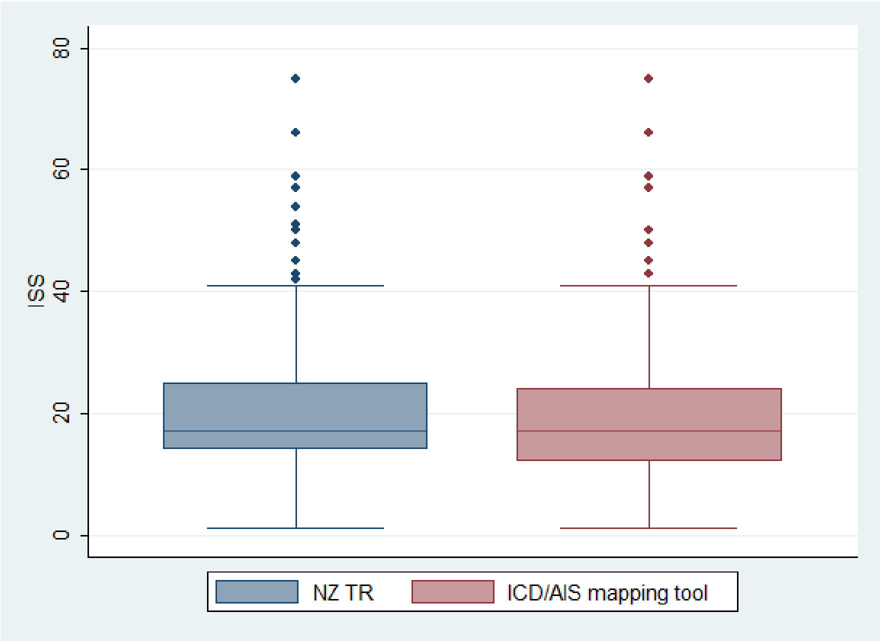
5.4.1 Study population

3,156 of the 3,229 patients in the linked dataset from the main study (see Chapter 3, Section 3.3.2) met the inclusion criteria. Among the 73 cases that were excluded, linkage to the NMDS was not possible in 60 cases, there was no injury-related ICD-10-AM code in eight cases, and in five cases the ISS was 0.

The majority of patients included were adult (94.7%; n=2,987/3,156), non-Māori (78.5%; n=2,464/3,141), male (69.7%; n=2,200/3,156) and were discharged alive (91.4%; n=2,885/3,156). MVCs and falls were the most common mechanism of injury (45.8% [n=1,431/3,127] and 26.3% [n=822/3,127], respectively). Less than 2% (1.2%; n=39/3,156) of patients had one injury diagnosis, while 96% had three or more injury diagnosis (n=3,029/3,156).

The distribution of ISS scores for the NZ-TR and ICD/AIS mapping tool is presented in Figure 5.1. In both cases, the median ISS was 17 (Range: 1 – 75).

Figure 5.1 Distribution of ISS scores, NZ-TR ISS data compared with ISS derived from MoH's data using the mapping tool (n=3,156)



5.4.2 Severity of injuries

According to the NZ-TR, 99.0% of patients had at least one serious injury (MAIS3+). The body region most affected was thorax and the least affected was external. The ICD/AIS mapping tool, on the other hand, classified 82.3% of patients with at least one serious injury. Table 5.1 shows the proportion of injuries MAIS3+ by body region for both methods. It can be seen that for body regions such as head, thorax, abdominal and extremities there is an underestimation of severity by the ICD/AIS mapping tool.

Table 5.1 Proportion of serious injuries (MAIS3+) by body region (n=5,980)*

ISS body region	Total MAIS3+ injuries	NZ TR	ICD/AIS mapping tool
Head and neck	1,557	1,186 (76.17)	1,116 (71.68)
Face	309	34 (11.00)	194 (62.78)
Thorax	1,278	1,120 (87.64)	866 (67.76)
Abdominal or pelvic content	743	341 (45.9)	312 (41.99)
Extremities	787	344 (43.71)	4 (0.51)
External	1,306	40 (3.06)	326 (24.96)
Total	5,980	3,065 (51.25)	2,818 (47.12)

** Note and individual case can have injuries in multiple body regions*

The agreement between NZ-TR ISS and ICD/AIS mapping tool scores is shown in Table 5.2. In most of the cases (except for face), over 50% of injuries were correctly classified. The highest concordance was observed in the head and neck region (0.6145; 95%CI: 0.5519-0.6771) and the lowest in extremities, in which the number of serious injuries classified by the mapping tool was very low.

Table 5.2 Agreement of serious injuries (MAIS3+) by body region

ISS body region	Agreement (%)	Kappa	95% CI	Interpretation
Head and neck	85.10	0.6145	0.5519 - 0.6771	Substantial
Face	41.75	0.0286	-0.0624 - 0.1197	Slight
Thorax	74.18	0.2951	0.2230 - 0.3672	Fair
Abdominal or pelvic content	58.41	0.1572	0.0843 - 0.2300	Slight
Extremities	56.04	-0.0043	-0.084 - 0.0748	Poor
External	76.11	0.0983	0.0080 - 0.1887	Slight

5.4.3 Agreement in ISS scores (continuous)

The ICC for agreement between NZ-TR ISS and ICD/AIS mapping tool scores was 0.396 (95% CI: 0.367 – 0.425), indicating poor agreement[253]. The Bland-Altman plot showed a bias toward lower ISS by the mapping tool than the NZ-TR ISS (average difference was 1.825±10.092). Limits of agreement were wide (-17.954 to 21.605) but only 3.8% of the observations were outside these limits, which indicates some agreement between the methods. However, a particular trend was observed when the average severity increased (Figure 5.2); for those cases, the difference between scores was higher and outside the limits of agreement.

There was no difference in the agreement by gender; for both male and female, the ICC was 0.394 (Male: 95% CI: 0.359 – 0.429; Female: 95% CI: 0.342 – 0.445). The ICC was similar for Māori (0.379; 95% CI: 0.316 – 0.442) and non-Māori (0.388; 95% CI: 0.355 – 0.421). Differences by mechanism of injury were observed. For transport-related trauma cases the ICC was 0.435 (95% CI: 0.393 – 0.476), higher than for falls (0.314; 95% CI: 0.257 – 0.371) and other mechanisms (0.381; 95% CI: 0.326 – 0.435). In all cases, the ICC suggested poor agreement between the two methods to calculate ISS.

For both the paediatric and adult populations, the ICC also suggested poor agreement (0.437; 95% CI: 0.332 – 0.542 and 0.394; 95% CI: 0.364 – 0.423, respectively). However, it was found that the agreement was better for the 10-14 years old paediatric age group (Table 5.3).

Figure 5.2 Bland-Altman plot (difference between NZ TR ISS scores and ICD/AIS mapping tool scores against their means)

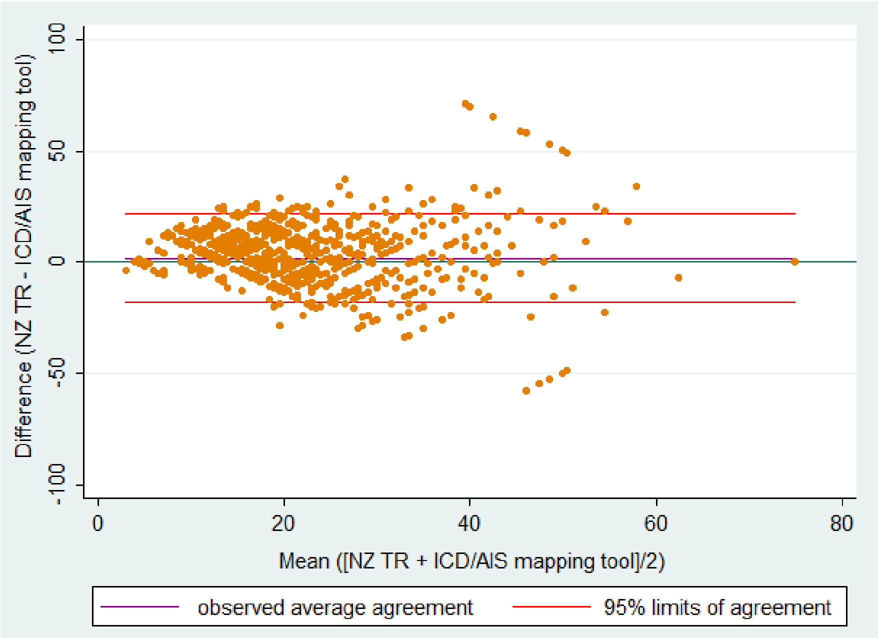


Table 5.3 Agreement of serious injuries (MAIS3+) by body region

Population	ICC	95% CI	Agreement
Paediatric (age in years)			
0-4	0.380	0.196 - 0.565	Poor
5-9	0.260	0.058 - 0.462	Poor
10-14	0.532	0.381 - 0.683	Moderate
Adult (age in years)			
15-44	0.442	0.398 - 0.486	Poor
45-64	0.371	0.316 – 0.425	Poor
65-79	0.305	0.225 - 0.385	Poor
≥80	0.227	0.134 - 0.321	Poor

5.4.4 Agreement in ISS scores (categorical)

The kappa coefficient for overall agreement in grouped scores according to the international major trauma ISS definition[148] is shown in Table 5.4. Observed agreement was higher when an ISS cut-off value of 12 was used (72.81% cf. 60.84%). However, kappa was better for an ISS cut-off value of 15 (0.1308 cf. 0.0613). In both cases, the kappa indicated a slight agreement between the two methods (NZ-TR and ICD/AIS mapping tool).

Table 5.4 Cross-tabulation of the ISS scores grouped in two categories. (a) Cut-off value of 12 (b) Cut-off value of 15

(a)

		ICD/AIS mapping tool		
		ISS≤12	ISS>12	Total
NZ TR	ISS≤12	46	18	64
	ISS>12	840	2,252	3,092
	Total	886	2,270	3,156

K=0.0613 (p<0.05) ; 95%CI (0.0067 - 0.1160)

Agreement = 2,298 (72.81%)

(b)

		ICD/AIS mapping tool		
		ISS≤15	ISS>15	Total
NZ TR	ISS≤15	434	443	877
	ISS>15	793	1,486	2,279
	Total	1,227	1,929	3,156

K=0.1308 (p<0.05) ; 95%CI (0.0923 - 0.1694)

Agreement = 1,920 (60.84%)

It was found that the two scores were the same in 1,539 of cases (48.8%) when ISS was grouped into four categories. In this case, a kappa of 0.1388 (95%CI: 0.1099 - 01676) was obtained, which suggested slight agreement (Table 5.5).

Table 5.5 Cross-tabulation of the ISS scores grouped in four categories

		ICD/AIS mapping tool				
		Minor (1-12)	**Moderate (13-24)**	**Severe (25-44)**	**Very severe (45+)**	**Total**
NZ TR	**Minor (1-12)**	46	13	5	0	64
	Moderate (13-24)	672	1,209	398	12	2,291
	Severe (25-44)	164	269	274	17	724
	Very severe (45+)	4	15	48	10	77
	Total	886	1,506	725	39	3,156

K=0.1388 (p<0.05) ; 95%CI (0.1099 - 0.1676)

Agreement = 1,539 (48.76%)

An analysis by subgroups of sex, ethnicity, mechanism of injury and age was conducted considering an ISS cut-off value of 15 and the ISS grouped into four categories, which were the groups in which a better agreement was observed. The results obtained were similar to those when analysing the continuous variable. In most of the cases the agreement was slight, with an exception in children aged 5-9 years where the kappa was negative, indicating poor agreement (Table 5.6).

Table 5.6 Kappa coefficients by subgroups

Group	Cut-off value of 15			ISS grouped in 4 categories		
	Kappa	95% CI	Agreement	Kappa	95% CI	Agreement
Gender						
Male	0.1220	0.0747 - 0.1692	Slight	0.1480	0.1132 - 0.1828	Slight
Female	0.1472	0.0806 - 0.2137	Slight	0.1163	0.0649 - 0.1676	Slight
Ethnicity						
Māori	0.0981	0.0103 - 0.1859	Slight	0.1408	0.0803 - 0.2012	Slight
Non-Māori	0.1373	0.0943 - 0.1803	Slight	0.1369	0.1039 - 0.1699	Slight
Mechanism of injury						
Transport-related	0.1737	0.1111 - 0.2362	Slight	0.1581	0.1116 - 0.2045	Slight
Falls	0.0952	0.0288 - 0.1615	Slight	0.1100	0.0600 - 0.1599	Slight
Other	0.1036	0.0315 - 0.1757	Slight	0.1399	0.0857 - 0.1940	Slight
Age						
Paediatric	0.0231	-0.1180 - 0.1642	Slight	0.0556	-0.0441 - 0.1554	Slight
Adult	0.1421	0.1023 - 0.1819	Slight	0.1447	0.1148 - 0.1746	Slight
Paediatric						
0-4	0.1152	-0.1330 - 0.3634	Slight	0.0906	-0.0801 - 02613	Slight
5-9	-0.1614	-0.4260 - 0.1033	Poor	-0.0582	-0.2558 - 0.1394	Poor
10-14	0.0866	-0.1384 - 0.3117	Slight	0.1101	-0.0443 - 0.2644	Slight
Adult						
15-44	0.1795	0.1127 - 0.2464	Slight	0.1752	0.1291 - 0.2214	Slight
45-64	0.0896	0.0186 - 0.1607	Slight	0.1250	0.0683 - 0.1816	Slight
65-79	0.0967	0.0004 - 0.1929	Slight	0.0739	-0.0021 - 0.1500	Slight
80+	0.1353	0.0317 - 0.2389	Slight	0.1339	0.0525 - 0.2153	Slight

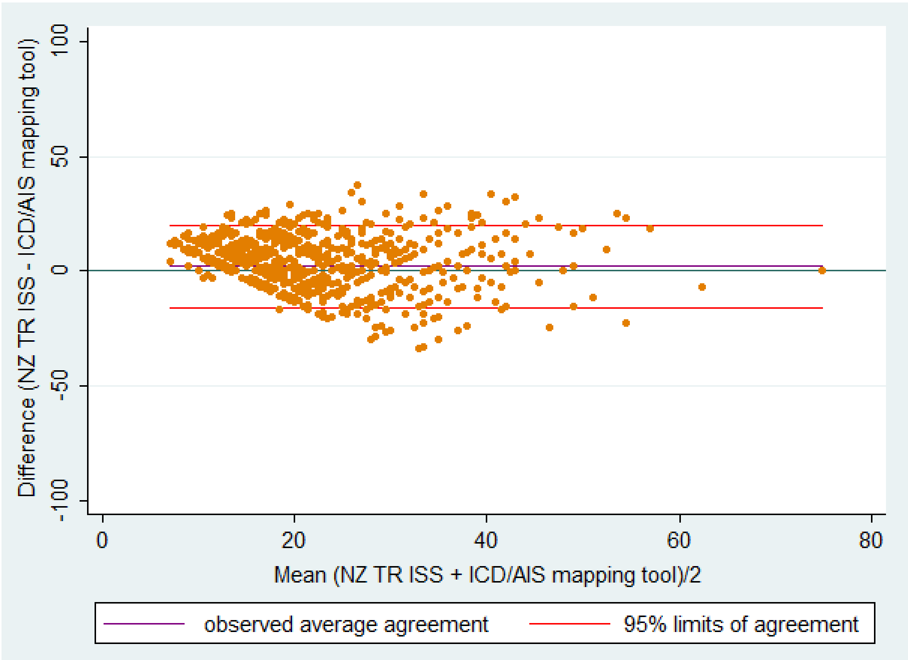
5.4.5 Sensitivity analysis

To be eligible for entry in the NZ-TR, an ISS of greater than 12 or death in hospital as a result of injury is required[108,109,141,223]. In this dataset, 58 cases were identified in which the NZ-TR reported an ISS≤12 and the patient died. In addition, there were 20 cases in which one of the methods for ISS calculation assigned the maximum score (ISS=75), but the other method did not. Because these patients ended up in the NZ-TR under a different criterion (death instead of ISS) and it was a misclassification of 'fatal injury' by either method, these cases were excluded, and a sensitivity analysis was conducted.

The sensitivity analysis included 3,078 cases. Although the overall ICC for agreement improved (0.434; 95%CI: 0.407–0.462), it continued to be considered as poor agreement. The Bland-Altman plot confirmed the tendency of ICD/AIS mapping tool to underestimate severity

(Figure 3). However, the average difference was lower in this case (1.875±9.012) and the limits of agreement also improved (-15.788 to 19.537).

Figure 5.3 Bland-Altman plot (difference between NZ TR ISS scores and ICD/AIS mapping tool scores against their means). Sensitivity analysis.



When conducting the sensitivity analysis by age, sex, ethnicity, and mechanism of injury, it was found that although the kappa coefficients improved, the interpretation of the findings did not change. In all cases, a poor agreement is suggested, except for the 10-14 years old age group in which a moderate agreement was observed (Table 5.7).

For the analysis of the categorical variable, it was necessary to redefine the ISS subgroups (ISS≤24, ISS=25-44 and ISS≥45), as the cases with an ISS≤12 in the NZ TR were removed from the database. The results showed that the agreement was better in this case (70.6% cf. 38.9%). The kappa coefficient increased from 0.1388 (95% CI: 0.1099 - 01676) to 0.2262 (95% CI: 0.1811 – 0.2714), suggesting fair concordance (Table 5.8).

Table 5.7 ICC by age groups (sensitivity analysis)

Group	ICC	95% CI	Agreement
Gender			
Male	0.445	0.412 - 0.479	Poor
Female	0.404	0.353 - 0.455	Poor
Ethnicity			
Māori	0.434	0.374 - 0.494	Poor
Non-Māori	0.421	0.389 - 0.453	Poor
Mechanism of injury			
Transport-related	0.467	0.427 - 0.507	Poor
Falls	0.298	0.243 - 0.354	Poor
Other	0.459	0.409 - 0.509	Poor
Age			
Paediatric	0.493	0.394 - 0.591	Poor
Adult	0.431	0.402 - 0.460	Poor
Paediatric			
0-4	0.380	0.196 - 0.565	Poor
5-9	0.260	0.058 - 0.462	Poor
10-14	0.655	0.530 - 0.779	Moderate
Adult			
15-44	0.489	0.447 - 0.530	Poor
45-64	0.443	0.392 - 0.494	Poor
65-79	0.290	0.210 - 0.371	Poor
80+	0.160	0.063 - 0.257	Poor

Table 5.8 Cross-tabulation of the ISS scores grouped in three categories (sensitivity analysis)

		ICD/AIS mapping tool			
		Moderate (≤24)	**Severe (25-44)**	**Very severe (45+)**	**Total**
NZ TR	**Moderate (≤24)**	1,889	399	7	2,295
	Severe (25-44)	433	274	12	719
	Very severe (45+)	13	41	10	64
	Total	2,335	714	29	3,078

K=0.2262 (p<0.05); 95%CI (0.1811 - 0.2714)

Agreement = 2,173 (70.60%)

5.5 Discussion

In this study, we compared the ISS of major trauma patients attended by an EMS provider in NZ manually derived for the NZ-TR to those scores generated through the ICD/AIS mapping tool. Results demonstrated that the agreement between both methods was poor, which indicates the ICD/AIS mapping tool cannot be used to calculate ISS on an individual level.

These results are similar to the findings reported bt Dihn et al.[249] who reported a low to moderate correlation between estimated ISS and ISS values in adult trauma cases in the New South Wales Trauma Registry in Australia between 2012 and 2016. Results indicate that the AIS-ICD mapping tool applied cannot be used on an individual basis to accurately score ISS.

In contrast, the study of Airaksinen et al.[250] evaluated the reliability of the ICD-AIS map using data from the Trauma Unit of the University Hospital of Helsinki, founding that the proportion of correct classification of MAIS 3+ patients by ICD/AIS map was 86% in pedestrian accidents and 76% in motorcycle accidents. A study by Durbin et al.[254] determined the performance of the ICD/AIS map as a method for classifying the severity of injuries in children younger than 16 years of age in trauma centres in Pennsylvania between 1994-1996. The results demonstrated excellent overall agreement between the AIS and ISS scores determined by the ICD/AIS map.

Although ICD codes can be easily accessed, it is important to remember that as ICD codes are reported by medical personnel, the information quality could be affected. One limitation of this study is that there are not recent studies about the topic, and the ones available used different ICD versions, which make it difficult to compare our results with others around the world.

As mentioned before, manually calculating ISS is expensive and time consuming, so more research focusing on the validation of ICD mapping tools is needed to improve the efficiency in collecting ISS for trauma patients.

5.6 Conclusion

Independent if analysing ISS as continuous or categorical variables, the agreement between the ICD/AIS mapping tool and the NZ TR ISS was poor. On average, the mapping tool tended to underestimate ISS, with a few exceptions in which it slightly or grossly overestimated it. Manually ISS calculation should not be replaced.

Chapter 6 Discussion

6.1 Introduction

The main aim of this thesis was to explore the relationship between time spent by EMS providers in the prehospital phase (response, on-scene and transport) and survival to 24 hours after injury in patients with major trauma in NZ. This final chapter begins with a summary of the main findings of this research, followed by a comparison of the obtained results with previous studies. Strengths and limitations of the study are presented. The chapter closes with a discussion of the implications for policy, practice, and future research.

6.2 Main findings

6.2.1 Literature review (Chapter Two)

Trauma is one of the major causes of disability and death worldwide. In NZ, injuries account for an estimated 8% of total health loss, representing an immense impact on population health. Although descriptive studies investigating the patterns and mechanisms of trauma have been conducted, little is known about the incidence of major trauma in both child and adult populations in NZ.

Therefore, a review of the literature published between 1987 and 2021 was conducted to describe the incidence of major trauma and to understand how major trauma is distributed in terms of time, geographic location, and population groups in NZ (Chapter 2). Thirty-nine studies fulfilled the inclusion criteria. The findings confirmed that major trauma is a significant contributor to morbidity and mortality in NZ, which is consistent with the results reported in the published literature (Section 2.5, Chapter 2). The incidence rate of fatal major trauma is highest among older Māori males who experienced head injuries due to MVCs and falls. The non-fatal major trauma incidence rate is highest among young Māori males.

The main strengths of this review are that it included an exhaustive search of the current data in multiple electronic databases to identify relevant studies and the provision of an historical context for those working in the trauma field through a summary of studies of major trauma in NZ. Limitations included differences in the major trauma definition due to the AIS versions used and the heterogeneity of the included studies, which made it difficult to describe trends over the time period and to compare the obtained findings with those from other countries.

In summary, the review findings highlight the need for further analytical studies that can explore factors that may impact survival from major trauma and continued efforts to prevent injuries in NZ. Changes in major trauma admissions during the COVID-19 pandemic as part of public health interventions, reinforce the notion that trauma is a social disease.

6.2.2 Distribution of total prehospital time (Chapters Three and Four)

Time is an important determinant of trauma outcome. The literature suggests that optimising prehospital trauma care and, where appropriate, minimising prehospital time could have a positive impact on survival in major trauma patients. Although the recommendation is not to spend more than 60 minutes in the prehospital setting, it is not always possible as the individual patient's circumstances and non-controllable factors might influence times. In light of this, a cohort study analysing routinely collected data in NZ was conducted to describe the characteristics of major trauma patients and to determine the distribution of total prehospital time and its components (response, on-scene and transport) to first hospital for major trauma in NZ. Chapter Three describes the methodology used and the results are presented in Chapter Four.

In total 3,334 cases of major trauma met the eligibility criteria during the study period. The majority of patients were male (69.5%) and Māori accounted for 21.6%. Most injuries (66.5%) occurred in an urban area and the majority of patients (80%) were transported to first hospital by a road vehicle. Comorbidities were documented in approximately one-quarter of patients and one-fifth had previous hospital admissions. Although alcohol is an important variable as it is related to trauma severity, it was only recorded by EMS for 62.5% of patients, of which 17.5% reported having consumed alcohol preceding the trauma incident. MVCs accounted for approximately half of the major trauma cases followed by falls (25.7%), while penetrating trauma was uncommon (3.1%). Median ISS was 17 (IQR: 14 – 25).

The majority of EMS attended patients survived to first hospital (96.9%). Of those who died prehospital (3.1%), the majority were male with a higher ISS compared to those who survived. Median response time was lower in patients who died prehospital compared to those who survived (11.5 vs 14.4 minutes); 28.3% of total response time was spent on activation.

Patients who survived 24 hours after injury (96.8%) typically experienced longer total prehospital time compared to those who died (median 75.0 vs 58.4 minutes). Median response time, on-scene time and transport time were higher for the survivors' group. Transport time contributed to 30.1% of total prehospital time, while on-scene time represented 45.7% of total prehospital time. Reasons for reported on-scene delays included difficult extrication, patient's condition, trapped patients and multiple patients involved in the event.

6.2.3 Factors predictive of prehospital mortality and 24-hour mortality after injury (Chapters Three and Four)

To address the knowledge gap regarding possible factors that may impact survival from major trauma described in Chapter Two, univariate and multivariate analyses were undertaken to explore factors predictive of survival to hospital in major trauma patients attended by an EMS in NZ.

Being Māori (RR=1.73; 95% CI: 1.12–2.67), suffering transport-related injuries (RR=6.57; 95%CI: 2.66–16.22) or injuries from non-fall related mechanisms (RR=3.35; 95%CI: 1.27–8.84), and having an ISS greater than 24 (RR=17.0; 95% CI: 9.7–29.7) were found to be individual risk factors for prehospital death. This relationship remained following adjusting for age, gender and ethnicity. No evidence of a relationship between response time and survival to first hospital was apparent at the univariate or multivariate level.

When analysing survival to 24 hours after injury as an outcome, the univariate cohort analyses suggested that being aged between 80 and 84 years, being triaged by EMS as purple or red, having an ISS greater than 24, having one or more comorbidities, having one or more previous hospital admissions, and experiencing non-blunt trauma or intentional injury increased the risk of mortality. Following adjusting for the characteristics of injury, the relationships between mortality 24 hours after injury with age (80-84 years), triage (purple/red), having one or two previous hospital admissions, experiencing non-blunt trauma, and having an ISS greater than 24 remained.

6.2.4 Relationship between prehospital time components and 24-hour mortality after injury (Chapters Three and Four)

Knowing the importance of arriving at hospital within the 'golden hour' (first 60 minutes after injury) for a trauma patient as described in Chapter One, this research focused on exploring the relationship between prehospital time components and survival to 24 hours after injury in patients who suffered major trauma and were attended by an EMS provider in NZ.

Univariate analysis showed that response times equal or greater than 15 minutes, on-scene times between 30 and 45 minutes and transport times of 10 minutes or more predict survival. Additionally, arriving at hospital after the ‘golden hour’ was predictive of lower mortality.

Multivariate models were developed adjusting for socio-economic, clinical and injury characteristics. Longer response time was found as a predictor of survival in all models, while there was no evidence of a significant relationship between on-scene time and transport time with survival to 24 hours after injury. When adjusting for socio-economic characteristics, it was found that total prehospital times greater than 60 minutes reduced the risk of mortality 24 hours after injury by 41%, representing a protective factor for death.

6.2.5 NZ-TR versus ICD-10-AM Injury Severity Scores (Chapter Five)

Although not the primary focus of this research, a comparison between the Injury Severity Scores obtained (following manual calculation) from the NZ-TR with those derived from the ICD-10-AM codes using a modified ICD/AIS mapping tool was conducted. This study found that independent of analysing ISS as a continuous or categorical variable, the agreement between the ICD/AIS mapping tool and the NZ-TR ISS was poor. On average, the mapping tool tended to underestimate ISS, with a few exceptions in which it slightly or grossly overestimated it.

Although the majority of studies in the literature have found a moderate to excellent agreement between the ICD/AIS mapping tool and ISS, the results obtained in this study are consistent with those reported in a study conducted in Italy and a study conducted in Australia, which found a poor and a low to moderate agreement between both methods, respectively.

The findings suggest that the ICD/AIS mapping tool cannot be used to calculate ISS on an individual level, making manual coding still the ‘gold standard’ in the trauma setting. In order to improve the efficiency in collecting the ISS for major trauma patients, more research regarding the validation of ICD mapping programs (considering the different ICD versions) to generate ISS is needed.

6.3 Findings in relation to previous research

In order to address the research gap identified in the literature review (Chapter Two), a cohort study was conducted to explore the predict factors of 24-hour mortality after injury in patients with major trauma attended by an EMS in NZ, with a particular emphasis on the total prehospital time and its components. It is worth pointing out that although response time was calculated for both outcomes (prehospital mortality and 24-hour mortality after injury), there were no significant differences in the time obtained, so the results discussed in sections 6.3.1 – 6.3.6 will focus on the second outcome of interest total prehospital time.

6.3.1 Distribution of time spent pre-hospital

The cohort analysis showed that median total prehospital time in NZ for major trauma patients is likely to be higher than the recommended 'golden hour' (74.6 minutes; IQR: 50.6-104.8). These results are consistent with the findings of studies investigating the relationship between prehospital time and mortality. While most studies have reported total prehospital times less than 60 minutes for trauma patients[76,131,255–258], others have found greater times[121] mainly due to the prolonged on-scene and transport times spent by EMS providers.

The international published literature recommends EMS providers spend no more than 10 minutes on-scene ("10-platinum minutes")[54,132,259] with trauma patients, favouring the "rapid transport and treat en route"[53–55] approach. However, this is sometimes not possible in practice because non-controllable factors can influence on-scene times. For HEMS, for example, factors such as patient's characteristics, number of interventions, remote location, night-time, climate conditions and helicopter hoist operations have been reported to influence on-scene times.[260,261] A study exploring the factors influencing on-scene times among patients who experienced MVCs injuries in Japan, conducted by Ito et al.,[262] found that an age of 65 years or more, night-time (00:00-07:00) occurrence of the incident and consciousness level were associated with increasing on-scene times.

Median on-scene time in our cohort was 30.6 minutes (IQR: 19.7-49.3), which represents 45.7% of total prehospital time. Similar results were obtained by Wyen et al.[258] who analysed data of injured patients from a German t trauma registry between 1993 and 2010. They reported an average on-scene time of 32.7±18.6 minutes, contributing 47.1% of total prehospital time. Although the mean on-scene time reported by Esmaeiliranjbar et al.[131] in their Iranian study evaluating the association between prehospital time intervals and 24-hour mortality was lower than ours (12.9±5.1 minutes), the contribution of this interval in total prehospital was similar at 41.4%.

On-scene time was the biggest contributor of total prehospital time (45.7%) in the present study, which was expected as the incident characteristics, the number of people involved and the requirement of minimal interventions in field to the patient, are likely to increase the time spent in this interval. In our study we described the reasons for on-scene delays for those cases in which they were recorded. The findings suggested that difficult extrication (31.0%), patient's condition (24.3%), and trapped patients (19.9%) were the most common reasons for delays. Similar reasons are found in the study by Levitan et al.[132] who explored the paramedic perspectives on factors that may influence on-scene times, identifying that the scene characteristics, the collaboration of allied services (police and fire) and the crew's skills are some of the main reasons that impact the duration of time on-scene.

The retrospective study by Goodacre et al.[263] of major trauma patients in the UK, reported that 13.3% of patients were entrapped and that the mean on-scene time was higher for this group of patients (46.8 minutes; range: 30-78) compared to non-entrapped patients (26 minutes; range: 7-80). The study by McNicholl[118] of major trauma patients who reached hospital alive in Northern Ireland reported that 15.1% of patients had extrication delays and that for this group of patients mean response time (10.56±8.12 cf. 7.9 minutes [range: 0-44]), mean on-scene time (26.89±13.42 cf. 11.3 minutes [range: 0-74]), mean transport time (11.81±9.85 cf. 9.8 minutes [range: 0-42]) and mean total prehospital (47.31±24.82 cf. 30.5 minutes [range: 0-119]) time were higher.

In our cohort, transport time was the second biggest contributor to total prehospital time (30.1%) with a median transport time of 20 minutes (IQR: 11.2-33.1). Similar results were reported by Esmaeiliranjbar et al.[131] in Iran, where the transport time contribution to total prehospital time was 31.4%. However, mean transport time was lower than in our study (9.8±4.1 minutes). Wyen et al.[258] reported an average transport time of 18.5±12.7 minutes, contributing 26.7% of total prehospital time. Although reasons for transport delays were not explored in this study, it is known that factors such as EMS coverage, geographical location of the incident, weather, congestion in urban areas and distance to the hospital influence transport times[256,264]. Mode of transport also contributes greatly to transport time.[69,265] HEMS may be considered the preferable option for transport of severely injured patients, however, factors such as time required to request, notify, and respond can lead to longer transport time compared to ground EMS.[69,72]

Median response time in the present study was 14.4 minutes (IQR: 9.4-23.5) and accounted for 24.2% of total prehospital time. This time is a bit longer according to the reported in the study by Esmaeiliranjbar et al.[131] who found a mean response time of 8.5±3.6 of minutes for trauma patients in Iran, representing a contribution of 27.2% to prehospital time. However, the study by Wyen et al.[258] reported a mean response time of 18.2±14.7 minutes with a contribution of 26.2% to total prehospital, which was higher than in our study. Factors influencing EMS response time includes the place of incident, weather, traffic condition, peak hours and the day of the week that the incident occurred.[266,267] In addition to these factors, a multicentre study by Chen et al.[257] analysing data of trauma patients who were transported by EMS in four Asian countries (Japan, Korea, Malaysia and Taiwan) reported that an age of 65 or more was associated with shorter response time. In NZ, according to the MoH, the response target for rural incidents is that EMS should respond to 95% of life-threating events within 30 minutes[268]. Although our results showed that EMS providers in NZ are meeting the target, reducing the period of time spent on response, in which no EMS care is provided to the patient could have a positive impact on patient outcomes.

Studies analysing the difference in prehospital times between dead patients and survivors have found statistical significance for some time intervals but not for others. Our study found that total prehospital time and EMS time intervals are higher in those patients who survived to hospital compared to those who reached hospital alive but died within 24 hours after injury. These results are similar to the findings reported in the study of Ali et al.[269], who analysed data from the Major Trauma Registry of Navarre (Spain) to explore the relationship between prehospital times and mortality. Although there were not statistically significant differences, they found that median response time (18 minutes [IQR: 10-34] cf. 17 minutes [IQR: 13-31]) and median transport times (65 minutes [IQR: 44-99] cf. 63 minutes [IQR: 50-79]) were longer in the survivors' group, while median on-scene times was the same among both groups.

The multicentre study by Chen et al.[257] in four Asian countries, reported that mean response time (20.0±27.0 cf. 19.0±9.8) and mean total prehospital time (47.0±28.0 cf. 41.0±25.3) were significantly higher in patients who survived compared to those who died 30 day after injury.

There were no differences on-scene time between both groups (21.0±13.0 cf. 20.0±12.8). A study conducted in Iran by Saberian et al.[270] compared EMS time intervals between survivors and dead patients and explored the relationship between these intervals and in-hospital mortality for major trauma patients. No differences were found in total prehospital time between alive and dead patients (46.9±18.1 cf. 44.8±18.4; p=0.35). However, statistically significant differences were reported for on-scene (18.4±11.6 cf. 16.3±14.8; p=0.008) and transport (16.5±11.2 cf. 14.7±10.8; p=0.019) with higher times in the survivor group. Greater response times were found for those patients who died (13.8±8.2 cf. 12.0±7.2; p=0.002).

In contrast, the retrospective review by Feero et al.[129] of major trauma cases attended by EMS in Portland found that average total prehospital time (29.3±12.4 cf. 20.8±5.2; p=0.02) and average response time (5.9±4.3 cf. 3.5±1.2 minutes; p=0.04) were higher for unexpected deaths than for unexpected survivors. Although a statistically significant difference was not found for on-scene and transport time, higher times were reported for unexpected deaths. On the other hand, the study by Funder et al.[271] analysed a cohort of penetrating torso trauma patients to evaluate the influence of on-scene time on 30-day mortality. While a statistically significant difference was found in median response between those patients who died and survived (p=0.04), no difference was observed for on-scene time, transport time and total prehospital time between both groups. Similar results were reported by Blackwell et al.[272] and Berkeveld et al.[273] who did not observe differences between median response time and mean total prehospital time among survivors and non-survivors, respectively.

6.3.2 Relationship between overall prehospital time and 24-hour mortality

The cohort analyses suggest that total prehospital times greater than 60 minutes reduce the risk of 24-hour mortality in major trauma patients. This relationship remained when estimates were adjusted for sociodemographic characteristics.

These results are consistent with the findings published by Clements et al.[121], who evaluated the relationship between total prehospital time and mortality in blunt injured patients in Canada. The authors found that mortality decreased when total prehospital time increased and that for unstable patients arriving at hospital between 121 to 150 minutes (compared to 0-30 minutes interval) after injury, reduces mortality in 78% (p<0.0002). Similar results were found by Ryb et al.[120] who reported that for those patients attended by EMS with total prehospital time longer than 60 minutes, the odds of survival were higher (OR: 1.68; 95%CI: 1.52-1.87).

Previous studies investigating the association between prehospital time and mortality in trauma patients have not been conclusive. While some studies suggest that longer prehospital time increases the risk of mortality, others did not find a relationship between these variables.

A population-based study by Tansley et al.[58] in Nova Scotia investigated the association between total prehospital time and mortality in patients who were transported via ground to a trauma centre. They found that the risk of death increased when total prehospital time was greater than 30 minutes (compared to less than 10 minutes) in patients with penetrating trauma (OR: 3.43; 95%CI: 1.37-8.59) and for victims of MVCs (OR: 1.66; 95%CI: 1.09-2.52). A study by Gauss et al.[274] using data from two trauma registries in France between 2009 and 2016 found that for each 10-minute increase in total prehospital time, the odds of in-hospital death increased by 9% (OR: 1.09; 95%CI: 1.07-1.11); this relationship remained when controlling for potential confounders (OR: 1.04; 95%CI: 1.01-1.07). In addition, the study by Esmaeiliranjbar et al.[131] in Iran found a positive relationship between 24-hour mortality and total prehospital time in the univariate analysis. However, when adjusting for other variables, this relationship was not maintained.

In contrast, a prospective cohort study conducted in North America by Newgard et al.[118] evaluating the association between EMS time intervals and mortality, was not able to demonstrate the influence of total prehospital time on mortality (OR: 1.00; 95%CI: 0.99-1.01). The study by Dharap et al.[52] assessed the influence of prehospital time on survival of major trauma patients who did not receive prehospital care and no association between total prehospital time and mortality was found (OR: 1.0, 95%CI: 0.45-1.61). Additionally, the study of Brown et al.[269] evaluating the association between prehospital time intervals and mortality showed no association between mortality and prolonged total prehospital time after adjusting for confounders (OR: 0.98; 95%CI: 0.76-1.24).

Although our hypothesis was that prehospital time longer than one hour would increase the risk of mortality, the opposite association was found in this study. We found that ‘triage status’ acted as a confounding variable as most of patients who arrived alive at hospital had less severe injuries (ISS<15) and were triaged as ‘green’, which resulted in prolonged response times by EMS providers. In NZ, the triage of major trauma patients is typically assigned by trained EMS personnel based on different factors such as the presence of significant injuries, the mechanism of injury and the patient’s medical condition; it is initially assigned when the called is received and revised, if need be, at the scene of the incident and during transport to the hospital[275]. Previous studies have shown that triage can have a significant impact on prehospital times in trauma patients as it helps to identify critical patients who require urgent attention, potentially leading to faster response times or vice versa[123,124]. However, it has been reported an over or under triage classification, which impacts not only on prehospital times, but also on patient's mortality[276,277] and that is why, an accurate triage is very important in the prehospital phase for major trauma patients.

Additionally, longer prehospital times may be associated with less risk of mortality as on-scene times can be longer due to difficulties in patients' rescue or because of the provision of prehospital interventions. As mentioned in Section 6.3.1 this study identified on-scene delays in one-third of cases, which will have played a key role in increasing total prehospital time. Furthermore, uncontrollable factors such as traffic jams and the weather may affect transport times, making total prehospital times longer.

The results obtained in this study reinforce the idea that mortality depends not only on prehospital times but also on the severity of the injury and other factors. That is why analysing prehospital time alone as a predictor of mortality is inadequate for major trauma patients.

6.3.3 Relationship between response time and 24-hour mortality

In our study longer response time (≥15 minutes) was found as a protective factor for mortality, reducing the risk of death in 70% (RR: 0.3; 95%CI: 0.14-0.64) for major trauma patients and not many studies that support our statement were found. The study by Esmaeiliranjbar et al.[131] in Iran, reported that an increase by 1 minute in response time, was associated with a 5% decrease in the risk of 24-hour mortality (OR: 0.95; 95%CI: 0.90-0.99). In addition, the study by Saberian et al.[270] found that for each 10-minute increase in response time, the odds of in-hospital death increased by 22% (OR: 1.22; 95%CI: 1.03-1.44). However, this relationship did not remain following adjustment for confounders. Although the multicentre study by Chen et al.[257] suggested that longer response decreased the risk of 30-day mortality by 1%, the association was not significant (OR: 0.99; 95%CI: 0.92-1.06).

In contrast, the study by Gonzalez et al.[130] evaluating the association between prehospital time and mortality in patients victims of MVCs found that higher response times were associated with higher mortality in the rural setting ($p<0.0001$). However, two studies conducted in the

United States evaluating the effect of response time on survival found that shorter response times increased the chances of survival. The study by Blackwell et al.[272] reported that response times less of than 5 minutes (p=0.002) resulted in a significant survival benefit for major trauma patients. The study by Pons et al.[132] found that response times within 4 minutes decreased the odds of death (OR: 0.7; 95%CI: 0.52-0.95).

These results are not aligned with the findings reported in the study by Ali et al.[269], who found no relationship between response time and mortality when analysing the variable as continuous (OR: 1.0; 95%CI: 0.99-1.01) or as a categorical (OR: 1.0; 95%CI: 0.91-1.02). Similarly, the study by Newgard et al.[118] did not find a relationship between response time and mortality (OR: 1.00; 95%CI: 0.97-1.01). Brown et al.[269] likewise showed no association between mortality and prolonged response time after adjusting for confounders (OR: 1.16; 95%CI: 0.83-1.63).

As mentioned in Section 6.3.2, response time was found to be influenced by triage status in this study because patients triaged as ‘green’ presented with less severe injuries and consequently, the risk of death for these patients was low.

6.3.4 Relationship between on-scene time and 24-hour mortality

In our study, no significant association was found between longer on-scene times and survival. However, when categorising the variable, on-scene times between 30-45 minutes were found to be protective for death, decreasing the risk by 45% (RR=0.55; 95%CI: [0.31-0.99]).

Evidence is still unclear regarding the association between time spent on-scene and mortality, as there are multiple factors such as the injury severity and the need to provide interventions at scene (e.g. intravenous access),[278] that could be influencing this relationship. Although the international recommendation is to have shorter on-scene times and rapid transport to a trauma centre (“rapid transport and treat en route” approach)[53–55], some studies have found greater on-scene times to be beneficial for patients, especially when prehospital interventions have been conducted to stabilise the injured patient and to improve outcomes.

A study by Lovely et al.[125] analysing data of patients who suffer MVCs and were attended by an EMS in Pennsylvania between 1992 and 2006 found that when controlling for ISS, on-scene time was not a predictor of mortality (p=0.3). The results are similar with the ones reported in the study of Ali et al.[269], who found no relationship between on-scene time and mortality when analysing the on-scene time as continuous (OR: 1; 95%CI: 0.98-1.02) or categorical (OR: 1;

95%CI: 0.93-1.03). Additionally, the multicentre study by Chen et al.[257] did not find any association between on-scene time and 30-day mortality (OR: 1.08; 95%CI: 1.00-1.17).

In contrast, a Korean study including trauma patients (ISS>9) attended by an EMS by Kim et al.[51] found that mortality was lower when on-scene times were greater than 6 minutes. Similar results were found in a recent study published by Van et al.[279] who reported that intermediate (9 to 16 minutes) and longer (17 minutes or more) on-scene times were independently associated with greater survival (OR: 1.41; 95%CI: 1.06-1.87 and OR: 2.18; 95%CI: 1.32-3.60, respectively); this relationship remained when adjusting for demographic and clinical characteristics (OR: 1.17; 95%CI: 1.03-1.33 and OR: 1.69; 95%CI: 1.52-1.88, respectively). Furthermore, the study by Esmaeiliranjbar et al.[131] found that an increase by 1 minute in on-scene time, decreased by 4% the risk of 24-hour mortality (OR: 0.96; 95%CI: 0.92-0.99).

The study by Newgard et al.[118] demonstrated that longer on-scene times ('more than 10 minutes') increased mortality, especially in patients with penetrating injuries. Similarly, Funder et al.[271] found that patients with penetrating torso trauma had a higher risk of mortality when on-scene time was greater than 20 minutes (p=0.0001). However, this relationship was not evident in multivariate analyses (OR: 3.71; 95%CI: 0.66-20.70). Brown et al.[269] found that there was an association (OR: 1.21; 95%CI: 1.02–1.44) between prolonged on-scene time and mortality, regardless of mode of transport. The study by Saberian et al.[270] reported that an increase of 10-minutes in on-scene time, was associated with a 20% increase in mortality risk (OR: 1.20; 95%CI: 1.03-1.40). In addition, Harmsen et al.[1] in their systematic review found that increasing on-scene-time is beneficial for haemodynamically stable undifferentiated trauma patients.

In general, the relationship between on-scene time and mortality in major trauma patients is complex as it depends on several and sometimes uncontrollable factors. As mentioned in Section 6.3.1, the circumstances surrounding the incident, the severity of trauma and the patient's condition can extend on-scene times.

6.3.5 Relationship between transport time and 24-hour mortality

Our study showed that longer transport times (greater than 10 minutes) decreased the risk of death. There were no studies located in the published literature that support this as most studies reported that longer transport times are harmful for injured patients. In fact, the international literature recommends to provide rapid transport to a trauma centre and high quality prehospital care for an injured patient in order to improve the chances of survival[54]. However, rapid transport may be unnecessary for some patients as life-saving prehospital interventions may need to be initiated at scene[55]. Evidence regarding rapid transport and its relationship with mortality is still unclear.

The study by Esmaeiliranjbar et al.[131] in Iran found a positive relationship between 24-hour mortality and transport time in the univariate analysis. When adjusting for other variables, an increase by 1 minute in transport time, increased the risk of 24-hour mortality by 20% (OR: 1.2; 95%CI: 1.16-1.24). In the univariate analyses, the study by Saberian et al.[270] did not find an association between transport time and in-hospital mortality. However, in the multivariate analysis an increase by 21% in the risk of mortality was found for each 10-minute increase in transport time (OR: 1.21; 95%CI: 1.05-1.41).

In contrast, the retrospective study by Möller et al.[256] explored the association between prehospital time and in-hospital mortality in major trauma patients who presented to a reference hospital in Cape Town, South Africa. They reported that in-hospital mortality was not affected by greater transport times ($p>0.09$). Similar results were found by Ali et al.[269] as they did not find a relationship between transport time and mortality when analysing the variable as continuous (OR: 1.00; 95CI%: 0.99-1.01) or categorical (OR: 1.00; 95%CI: 0.85-1.07). Brown et al.[269] likewise reported no association between mortality and prolonged transport time after adjusting for confounders (OR: 0.82; 95%CI: 0.65-1.04). In addition, the study by Lovely et al.[125] found that when controlling for ISS, transport time was not a predictor of mortality ($p=0.5$).

In general, we have observed that mortality mainly depends on the severity of injury rather than transport times, so even though a patient arrives in an expedient manner to hospital, they may still die because of their clinical status. Additionally, as mentioned in Section 6.3.1, uncontrollable factors such as the weather, the route taken, and traffic conditions may affect transport times.

6.3.6 Other factors associated to 24-hour mortality

Although not the focus of this research, other factors found to be independent predictors of 24-hour mortality in major trauma patients attended by an EMS provider in NZ included age greater than 80 years, triage (purple/red), having one or more comorbidities, having one or more hospital admissions, injury type (non-blunt), intentional injury and ISS greater than 24. However, in the multivariate analysis for the 'golden hour', this relationship did not remain once the analyses were controlled for the presence of one or comorbidities and intentional injury.

These results are consistent with the study conducted by Lovely et al.[125] which found that ISS predicts mortality independent of prehospital time in patients who suffered MVCs and reached hospital alive ($p<0.001$). Similar results were found by Tansley et al.[58] who reported that increased age (OR: 1.02; $p<0.001$) and increased ISS were associated with mortality (OR: 1.1; $p<0.001$). In addition, the multicentre study by Chen et al.[257] found that both an ISS≥16 (OR: 7.14; 95%CI: 5.21-9.78) and older age (OR: 1.03; 95%CI: 1.03-1.04) increased the risk of 30-day mortality.

Furthermore, while the study by Dharap et al.[52] found that independent factors associated with mortality in-hospital included age greater than 60 years, blunt trauma and an ISS≥16, the study by González-Robledo et al. found that an age greater than 65 years increased the risk of mortality (OR: 3.15; $p<0.05$)[280]. The study by Lentsck et al.[281] analysing the risk factors for death in trauma patients who were admitted to the ICU found that age 60 years of older ($p<0.001$) and the presence of comorbidities measured through the Charlson Comorbidity Index ($p<0.001$) were associated with death.

Although trauma has been known to be a time-sensitive disease[52,269], our results suggest that mortality after trauma depends on the injury severity, patient's age and other injury-related factors, but that is not associated with the duration of EMS prehospital times.

6.4 Strengths and weaknesses if this research

6.4.1 Study design

This study is novel research as it is the first study using EMS data at a national level that investigates the relationship between prehospital times and 24-hour mortality following injury in NZ. Although the primary sources of information were NZ's EMS providers, NZ TR and NCIS, additional information from other national databases was used to supplement and/or validate the data obtained, which ensure the veracity of the data used in this study.

A cohort study design was selected as we wanted to determine the incidence of death (prehospital and 24-hours after injury) and to identify risk factors associated to this outcome focusing especially on EMS prehospital times as the exposure factor. Cohort studies allow the generation of hypothesis for future research and play a key role in producing evidence to guide clinical decision in all fields[282,283].

Although confounding bias is inevitable in this type of study, analyses through multivariate regression models adjusting for these variables were done to minimise the bias.

6.4.2 EMS times

All data regarding trauma incidents between 1 December 2016 to 30 November 2018 were considered, which represents a strength of this research. This 'census' provided us with an optimal sample size, which increases the statistical power to obtained precise estimators and the certainty of the results.

EMS in NZ record prehospital times by manually pressing a button in their online system every time they arrive or leave the scene. This process is subject to bias as times may be missing or inaccurate (times may not indicate the exact patient's contact time). The collection of the time-related data has not been externally validated. We observed cases in our database with incomplete and/or improbable time e.g. departure time preceded arrival time. However, these times were verified and when possible, corrected. When multiple vehicles arrived at scene, it was necessary to manually search the databases and track all of them to get the correct times because the vehicle providing the initial care was not always the vehicle which finally transported the patient to hospital (fragmentation).

We did not include transferred patients as it was felt this would over-estimate prehospital times. Self-presented patients were also not included in this research because they did not have prehospital EMS information available. Information regarding the route taken (distance from the injury to hospital) and reasons for transport delays were not reported by EMS and therefore not included in this study.

One limitation of our study is that these are historical data corresponding to EMS care delivered in NZ between 2016 and 2018, therefore they may not reflect current EMS practice or destination policies or be directly generalisable to other countries. There were a limited number of studies that explored the relationship between EMS and 24-hour mortality at a national level, which limited our ability to compare our results within the NZ population.

Conclusions about on-scene time results in this study should be interpreted carefully. Although not measured in this research, on-scene times reported by EMS implicitly include rescue time and time for prehospital interventions, making the time spent on-scene longer.

6.4.3 Biases and confounding issues

Strengths of this study include a clear and standard definition of major trauma used. However, including only major trauma patients who were attended by an EMS in NZ, limits the generalisability of the findings to other patient populations. Injury severity was assessed from hospital and/or MoH data, increasing the reliability of the data. Furthermore, ISS for prehospital deaths was calculated based on the post-mortem reports by the PhD candidate who was formally trained in ISS scoring. Additionally, different to other studies, continuous time variables were categorised based on the opinion of specialist paramedics according to their daily clinical practice, which helped to reduce the residual confounding bias[284]. This study included information regarding ethnicity, which is not commonly included in the published international literature. However, the study findings do need to be considered in light of several limitations.

Survivorship bias was presented in this study. It was found that patients who died prehospital had more severe injuries than those who reached hospital alive. Although a brief description of prehospital deaths was provided, we excluded this group of patients from our analysis as the full set of EMS prehospital times was not available. In this case, data imputation was not considered because times were the main exposures evaluated in this research. Excluding patients with any missing data was done to minimise potential for bias.

One limitation of this study is that we did not include information regarding a few variables that may have an impact on prehospital times and 24-hour mortality. The need of prehospital interventions at scene or during transportation to hospital, rescue times, reasons for delays, vital signs and the hospital level are examples of this. Although alcohol consumption has been identified in previous studies as a protective factor for mortality[285–287], in this study we were unable to analyse this variable and it was only reported by EMS providers for less than 50% of patients. There is no clarity on whether the inclusion of these variables in this research would changes the results found or not. However, it is possible that they would have helped to explain more clearly the main finding of this thesis (reduction in mortality with higher prehospital time).

This research was a general study of major trauma in NZ. Injury types such as haemorrhage, TBI, thoracic injuries, lower limb fractures, etc, were not specifically analysed in this research due to the relatively small numbers in this cohort by subgroup. It is likely prehospital times and its relationship with 24-hour mortality may have been influenced due to the types of injuries, as it is known, for example, that in patients with severe bleeding or experiencing a traumatic cardiac arrest, prehospital time spent is more likely to impact mortality, while in patients with injuries such as limb fractures, prehospital time may not be quite so critical.[1]

Additionally, the relationship between EMS prehospital times with long-term outcomes, 30-day mortality and hospital were not evaluated. The outcome of this research was limited to 24-hour mortality, on the assumption that mortality after this period may be due to other factors that were not analysed in this study. This may not fully capture the long-term impact of prehospital time on patient outcomes.

6.5 Implications for policy, practice and future research

6.5.1 Contributions to policy and practice

Every injured patient is unique, not only because of their demographics and medical characteristics, but also because of the circumstances in which the trauma incident happens. It has been identified that time is essential in the initial care of trauma patients as it may have a significant impact on outcomes. This highlights the importance of trauma triage protocols to identify and prioritise patients who require urgent attention due to the severity of their injuries.

Our findings showed that more than 50% of patients were prehospital triaged as green. However, in subsequent analyses it was found that the triage for 40% of patients was underestimated. In NZ, prehospital triage policies exist and EMS providers are responsible for assigning triage to major trauma patients based on the injury severity, vital signs, and other clinical indicators[275]. These policies are a key element of EMS care as they help ensure that trauma patients receive the care they need in a timely manner. Therefore, it is important that where possible they are evidence-based, regularly reviewed, and that as paramedics, ambulance officers, and other emergency responders receive regular training regarding their application.

New Zealand is an island country with variations in terrain and distance which makes the provision of timely and optimal prehospital care challenging[42,93,288]. Highlighting the importance of the major trauma destination policy to help ensure that trauma patients are taken by EMS staff to the appropriate hospital or trauma centre in order to receive the most appropriate care[289]. In remote areas where prehospital times are longer, policy makers should efficiently and effectively allocate the resources to meet predicted demand.

In this study we showed that longer prehospital times are mainly due to triage classification, and longer on-scene and response times. Although we did not demonstrate a relationship between prehospital times and mortality, our results suggest that the standardisation of prehospital care through new guidelines or protocols for EMS providers and hospitals is needed to ensure that patients received timely and appropriate care following injury. Coordination between prehospital and hospital care also play a key role as it may guarantee timely interventions in the prehospital and hospital setting, which will have a positive impact on patient's outcomes.

In general, the identification of critical patients through an accurate triage classification, the efficient use of resources, the implementation of standardised protocols that positive impact prehospital times and improving communication and coordination between EMS providers and hospital care should ensure that major trauma patients received timely, quality, and appropriate care in NZ.

6.5.2 Future research

The findings from this study highlight the need to investigate the influence of geographical location of injury events, external factors, and the role of trauma patient's alcohol consumption, on EMS times and how they may impact on mortality. Conducting research like this could help to identify key variables and obtain information about trauma patterns, which would be very useful from the public health perspective as different initiatives can be coordinated to positively prevent injuries or to improve outcomes. Additionally, it may provide a better understanding of the relationship between prehospital time and mortality. Future research should consider prospective studies, which would eliminate some of the challenges the current study faced with incomplete data.

This study did not provide evidence of a relationship between longer on-scene time and mortality. However, it is known that longer on-scene times are most commonly associated with the need for prehospital interventions or difficulties in patient’s extrication. Future research should consider collecting information regarding the provision of prehospital interventions and their level (basic or advanced) to explore if there is benefit for the patient in terms of reducing mortality. Additionally, further studies focusing on mortality at different time points (3 days, 7 days, 30 days) and longer-term outcomes are necessary to evaluate the effect of prehospital interventions and EMS times on trauma patients. Studies that are particularly designed to look at mechanism of injury, hospital level and different injury types such as TBI and lower limb fractures, considering appropriate sample sizes should be included in future studies.

Studies of patients who experienced on-scene or transport delays could provide the reasons for such delays. These would also be useful to determine the outcomes for these patients to inform the coordination of the rescue plans of EMS providers and trauma teams, including the provision of medical interventions, for example during extrication.

Although we provided a description of prehospital deaths in this study, these patients were excluded from the time analysis as not all EMS time intervals were available for this group. Future research should consider investigating in more detail the prehospital deaths, analysing specifically in which prehospital time interval they occurred, which was the initial triage assigned and posteriorly, analysing if their injuries could have been potentially survivable.

As mentioned in Section 6.5.1, more than three-quarters of the population living in NZ’s North Island[42,93,288]. Although both the North and the South Islands are provided with EMS systems and hospitals, distances are longer in the South Island, which increases prehospital times. However, congestion is worse in the North Island due to the population density in the large North Island cities, impacting on EMS transport times. During the Covid pandemic, most New Zealanders had to stay home as a public measure of protection. Some studies in NZ[161,162,290] have reported that during that time, the number of trauma cases decreased, but no studies have yet looked at the impact of Covid on the relationship between EMS times and mortality in the country yet.

6.6 Conclusion

The findings of this thesis have shown that higher total prehospital times independently predict survival 24-hour after injury for major trauma patients. However, the results showed that prehospital time intervals themselves do not predict survival, as there are other factors influencing this relationship such as age, triage, injury severity and other related-injury factors; the severity of trauma is, without hesitation, the most important factor associated with mortality. Recommendations for improving prehospital times or providing prehospital interventions, may be given according to the patient and injury condition. These results may only be applicable in local or national circumstances, or in areas with similar trauma and EMS systems as those seen in NZ. Further research is necessary to examine in more detail other factors (such as vital signs, length of hospital stay, etc) that may impact the relationship between EMS times and mortality. Additionally, studies considering 30-day mortality as an outcome and exploring reasons for on-scene and transport delays are important in the trauma field.

References

1. Harmsen AMK, Giannakopoulos GF, Moerbeek PR, Jansma EP, Bonjer HJ, Bloemers FW. The influence of prehospital time on trauma patients outcome: A systematic review. *Injury*. 2015;46(4):602-609. doi:10.1016/j.injury.2015.01.008

2. Derrett S, Wilson S, Samaranayaka A, et al. Prevalence and predictors of disability 24-months after injury for hospitalised and non-hospitalised participants: results from a longitudinal cohort study in New Zealand. *PLoS One*. 2013;8(11):e80194. doi:https://dx.doi.org/10.1371/journal.pone.0080194

3. Harris IA, Young JM, Rae H, Jalaludin BB, Solomon MJ. Predictors of general health after major trauma. *J Trauma*. 2008;64(4):969-974. doi:10.1097/01.ta.0000245972.83948.1a

4. Alberdi F, García I, Atutxa L, Zabarte M. Epidemiology of severe trauma. *Med Intensiva (English Ed*. 2014;38(9):580-588. doi:10.1016/j.medine.2014.06.002

5. Søreide K. Epidemiology of major trauma. *Br J Surg*. 2009;96(7):697-698. doi:10.1002/bjs.6643

6. Søreide K, Krüger AJ, Vårdal AL, Ellingsen CL, Søreide E, Lossius HM. Epidemiology and contemporary patterns of trauma deaths: Changing place, similar pace, older face. *World J Surg*. 2007;31(11):2092-2103. doi:10.1007/s00268-007-9226-9

7. Vali Y, Rashidian A, Jalili M, Omidvari AH, Jeddian A. Effectiveness of regionalization of trauma care services: a systematic review. *Public Health*. 2017;146:92-107. doi:10.1016/j.puhe.2016.12.006

8. Lansink KWW, Leenen LPH. Do designated trauma systems improve outcome? *Curr Opin Crit Care*. 2007;13(6):686-690. doi:10.1097/MCC.0b013e3282f1e7a4

9. Mock C, Quansah R, Krishnan R, Arreola-Risa C, Rivara F. Strengthening the prevention and care of injuries worldwide. *Lancet*. 2004;363:2172-2179. doi:10.1016/S0140-6736(04)16510-0

10. Langley J, Brenner R. What is an injury? *Inj Prev*. 2004;10(2):69-71.

11. Krug EG, Sharma GK, Lozano R. The global burden of injuries. *Am J Public Health*. 2000;90(4):523-526. doi:10.2105/AJPH.90.4.523

12. Mock C, Quansah R, Krishnan R, Arreola-Risa C, Rivara F. Strengthening the prevention and care of injuries worldwide. *Lancet*. 2004;363(9427):2172-2179. doi:10.1016/S0140-6736(04)16510-0

13. Thompson L, Hill M, Shaw G. Defining major trauma: a literature review. *Br Paramed J*. 2019;4(1):22-30. doi:10.29045/14784726.2019.06.4.1.22

14. Thompson L, Hill M, Lecky F, Shaw G. Defining major trauma : a Delphi study. Published online 2021:1-20.

15. Victorian State Trauma System. Accessed July 15, 2019. https://trauma.reach.vic.gov.au/guidelines/victorian-trauma-system/definition-of-major-trauma

16. Hofman K, Primack A, Keusch G, Hrynkow S. Addressing the growing burden of trauma and injury in low- and middle-income countries. *Am J Public Health*. 2005;95(1):13-17. doi:10.2105/AJPH.2004.039354

17. James SL, Castle CD, Dingels Z V., et al. Global injury morbidity and mortality from 1990 to 2017: Results from the global burden of disease study 2017. *Inj Prev*. 2020;26(1):I96-I114. doi:10.1136/injuryprev-2019-043494

18. Roudsari BS, Nathens AB, Arreola-Risa C, et al. Emergency Medical Service (EMS) systems in developed and developing countries. *Injury*. 2007;38(9):1001-1013. doi:10.1016/j.injury.2007.04.008

19. Paniker J, Graham SM, Harrison JW. Global trauma: the great divide. *Sicot-J*. 2015;1:19. doi:10.1051/sicotj/2015019

20. Mitchell R, Chong S. Comparison of injury-related hospitalised morbidity and mortality in urban and rural areas in Australia. *J Rural Remote Heal Res*. Published online 2010. doi:10.3316/informit.326729169638989

21. Moshiro C, Heuch I, Åstrøm AN, Setel P, Hemed Y, Kvåle G. Injury morbidity in an urban and a rural area in Tanzania: An epidemiological survey. *BMC Public Health*.

2005;5. doi:10.1186/1471-2458-5-11

22. Kim K, Ozegovic D, Voaklander DC. Differences in incidence of injury between rural and urban children in Canada and the USA: A systematic review. *Inj Prev*. 2012;18(4):264-271. doi:10.1136/injuryprev-2011-040306

23. Coben JH, Tiesman HM, Bossarte RM, Furbee PM. Rural-Urban Differences in Injury Hospitalizations in the U.S., 2004. *Am J Prev Med*. 2009;36(1):49-55. doi:10.1016/j.amepre.2008.10.001

24. Lilley R, Kool B, Davie G, et al. Preventable injury deaths: Identifying opportunities to improve timeliness and reach of emergency healthcare services in New Zealand. *Inj Prev*. 2018;24(5):384-389. doi:10.1136/injuryprev-2016-042304

25. Tan CP, Ng A, Civil I. Co-morbidities in trauma patients: common and significant. *N Z Med J*. 2004;117(1201).

26. Burstow M, Civil I, Hsee L. Trauma in the Elderly: Demographic Trends (1995–2014) in a Major New Zealand Trauma Centre. *World J Surg*. 2019;43:466-475. doi:10.1007/s00268-018-4794-4

27. Ministry of Health and Accident Compensation Corporation. *Injury-Related Heath Loss: A Report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study 2006-2016*.; 2013.

28. Beck B, Cameron P, Lowthian J, Fitzgerald M, Judson R, Gabbe BJ. Major trauma in older persons. *BJS Open*. 2018;2(5):310-318. doi:10.1002/bjs5.80

29. Curtis K, Caldwell E, Delprado A, Munroe B. Traumatic injury in Australia and New Zealand. *Australas Emerg Nurs J*. 2012;15:45-54. doi:10.1016/j.aenj.2011.12.001

30. Boland M, Staines A, Fitzpatrick P, Scallan E. Urban-rural variation in mortality and hospital admission rates for unintentional injury in Ireland. *Inj Prev*. 2005;11(1):38-42. doi:10.1136/ip.2004.005371

31. Liu Q, Zhang L, Li J, et al. The gap in injury mortality rates between urban and rural residents of Hubei province, China. *BMC Public Health*. 2012;12(1). doi:10.1186/1471-2458-12-180

32. Derrett S, Samaranayaka A, Wilson S, et al. Prevalence and predictors of sub-acute phase disability after injury among hospitalised and non-hospitalised groups: a longitudinal cohort study. *PLoS One*. 2012;7(9):e44909. doi:https://dx.doi.org/10.1371/journal.pone.0044909

33. Martino C, Russo E, Santonastaso D Pietro, et al. Long-term outcomes in major trauma patients and correlations with the acute phase. *World J Emerg Surg*. 2020;15(1):3-9. doi:10.1186/s13017-020-0289-3

34. World Health Organization. Global Health Estimates 2016: Deaths by Cause, Age, Sex, by Country and by Region, 2000-2016. Published 2018. Accessed August 20, 2019. https://www.who.int/healthinfo/global_burden_disease/estimates/en/index1.html

35. James SL, Lucchesi LR, Bisignano C, et al. Morbidity and mortality from road injuries: Results from the Global Burden of Disease Study 2017. *Inj Prev*. Published online 2019. doi:10.1136/injuryprev-2019-043302

36. Miller GF, Daugherty J, Waltzman D, Sarmiento K. Predictors of traumatic brain injury morbidity and mortality: Examination of data from the national trauma data bank: Predictors of TBI morbidity & mortality. *Injury*. 2021;52(5):1138-1144. doi:10.1016/j.injury.2021.01.042

37. Bouzat P, Ageron FX, Brun J, et al. A regional trauma system to optimize the pre-hospital triage of trauma patients. *Crit Care*. 2015;19(1):1-9. doi:10.1186/s13054-015-0835-7

38. Peden M, McGee K SG. The injury chart book: a graphical overview of the global burden of injuries. World Health Organization. Published 2002. Accessed April 14, 2020. https://apps.who.int/iris/bitstream/handle/10665/42566/924156220X.pdf;jsessionid=464C005122CCE712E401082358EE1894?sequence=1

39. Magruder KM, McLaughlin KA, Elmore Borbon DL. Trauma is a public health issue. *Eur J Psychotraumatol*. 2017;8(1):1-9. doi:10.1080/20008198.2017.1375338

40. Murad MK, Issa DB, Mustafa FM, Hassan HO, Husum H. Prehospital trauma system reduces mortality in severe trauma: A controlled study of road traffic casualties in Iraq.

Prehosp Disaster Med. 2012;27(1):36-41. doi:10.1017/S1049023X11006819

41. Wisborg T, Montshiwa TR, Mock C. Trauma research in low- and middle-income countries is urgently needed to strengthen the chain of survival. *Scand J Trauma Resusc Emerg Med*. 2011;19. doi:10.1186/1757-7241-19-62

42. Christey GR. Trauma care in New Zealand: It’s time to move ahead. *World J Surg*. 2008;32(8):1618-1621. doi:10.1007/s00268-008-9590-0

43. Injury Prevention Research Unit, Department of Preventive and Social Medicine, University of Otago NZ. NZ Injury Query System (NIQS). Accessed July 5, 2019. https://psm-dm.otago.ac.nz/niqs/

44. Ministry of Health. *Health Loss in New Zealand: A Report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study, 2006–2016.*; 2013. http://www.health.govt.nz/publication/health-loss-new-zealand-report-new-zealand-burden-diseases-injuries-and-risk-factors-study-2006-2016

45. O’ea D, Wren J. New Zealand estimates of the total social and economic costs of injuries. *Inj Prev*. 2012;18:A10-A11. doi:10.1136/injuryprev-2012-040580a.31

46. Molcho M, Walsh S, Donnelly P, De Matos MG, Pickett W. Trend in injury-related mortality and morbidity among adolescents across 30 countries from 2002 to 2010. *Eur J Public Health*. 2015;25:33-36. doi:10.1093/eurpub/ckv026

47. Civil I, Isles S. Is high-quality trauma care “business as usual” in New Zealand? *N Z Med J*. 2017;130(1455):120-122.

48. Hooper R, Coggan C, Adams B. Injury prevention attitudes and awareness in New Zealand. *Inj Prev*. 2003;9(1):42-47. doi:10.1136/ip.9.1.42

49. Vecino-Ortiz AI, Jafri A, Hyder AA. Effective interventions for unintentional injuries: a systematic review and mortality impact assessment among the poorest billion. *Lancet Glob Heal*. 2018;6(5):e523-e534. doi:10.1016/S2214-109X(18)30107-4

50. Mock C, Jurkovich G, Nii-Amon-Kotei D, Arreola-Risa C. Trauma Mortality Patterns in Three Nations at Different Economic Levels: Implications for Global Trauma System Development. *J Trauma*. 1998;44:804-814.

51. Kim J, Song KJ, Shin S Do, Ro YS, Hong KJ, Holmes JF. Does Prehospital Time Influence Clinical Outcomes in Severe Trauma Patients?: A Cross Sectional Study. *Prehospital Emerg Care*. 2017;21(4):466-475. doi:10.1080/10903127.2017.1294223

52. Dharap SB, Kamath S, Kumar V. Does prehospital time affect survival of major trauma patients where there is no prehospital care? *J Postgrad Med*. 2017;63:169-175. doi:10.4103/0022-3859.201417

53. Lerner EB, Moscati RM. The Golden Hour: Scientific Fact or Medical "Urban Legend"? *Acad Emerg Med*. 2001;8(7):758-760. doi:10.1111/j.1553-2712.2001.tb00201.x

54. Beuran M, Paun S, Gaspar B, et al. Prehospital Trauma Care: a Clinical Review. *Chirurgia (Bucur)*. 2012;107(5):564-570. https://sci-hub.tw/https://www.ncbi.nlm.nih.gov/pubmed/23116846

55. Smith RM, Conn AK. Prehospital care - Scoop and run or stay and play? *Injury*. 2009;40(SUPPL. 4):S23-S26. doi:10.1016/j.injury.2009.10.033

56. Klein K, Lefering R, Jungbluth P, Lendemans S, Hussmann B. Is prehospital time important for the treatment of severely injured patients? A matched-triplet analysis of 13,851 patients from the TraumaRegister DGU®. *Biomed Res Int*. Published online 2019:1-10. doi:10.1155/2019/5936345

57. The American Trauma Society. Trauma system agenda for the future. Washington DC: National Highway Traffic Safety Administration. Published 2004. Accessed April 13, 2020. https://one.nhtsa.gov/people/injury/ems/emstraumasystem03/traumasystem.htm

58. Tansley G, Schuurman N, Bowes M, et al. Effect of predicted travel time to trauma care on mortality in major trauma patients in Nova Scotia. *Can J Surg*. 2019;62(2):123-130. doi:10.1503/cjs.004218

59. Palmer CS, Davey TM, Mok MT, et al. Standardising trauma monitoring: The development of a minimum dataset for trauma registries in Australia and New Zealand. *Injury*. 2013;44(6):834-841. doi:10.1016/j.injury.2012.11.022

60. Chekijian S, Paul M, Kohl VP, et al. The Global Burden of Road Injury: Its Relevance to the Emergency Physician. *Emerg Med Int*. 2014;2014:1-9. doi:10.1155/2014/139219

61. Murad MK, Issa DB, Mustafa FM, Hassan HO, Husum H. Prehospital trauma system reduces mortality in severe trauma: A controlled study of road traffic casualties in Iraq. *Prehosp Disaster Med*. 2012;27(1):36-41. doi:10.1017/S1049023X11006819

62. Hofman M, Sellei R, Peralta R, et al. Trauma systems: Models of prehospital and inhospital care. *Eur J Trauma Emerg Surg*. 2012;38(3):253-260. doi:10.1007/s00068-012-0192-z

63. Christey GR. Trauma care in New Zealand: It's time to move ahead. *World J Surg*. 2008;32(8):1618-1621. doi:10.1007/s00268-008-9590-0

64. Choi J, Carlos G, Nassar AK, Knowlton LM, Spain DA. The impact of trauma systems on patient outcomes. *Curr Probl Surg*. 2021;58.

65. Harrington DT, Connolly M, Biffl WL, Majercik SD, Cioffi WG. Transfer Times to Definitive Care Facilities Are Too Long A Consequence of an Immature Trauma System. *Ann Surg*. 2005;241(6):961-968. doi:10.1097/01.sla.0000164178.62726.f1

66. Aljerian N, Alhaidar S, Alothman A, Aljohi W, Albaqami FA, Alghnam SA. Association between the mode of transport and in-hospital medical complications in trauma patients: findings from a level-I trauma center in Saudi Arabia. *Ann Saudi Med*. 2018;38(1):8-14. doi:10.5144/0256-4947.2018.8

67. de Anda H, Moy H. EMS Ground Transport Safety. StatPearls [Internet]. Accessed January 3, 2024. https://www.ncbi.nlm.nih.gov/books/NBK558971/

68. Van der Velden MWA, Ringburg AN, Bergs EA, Steyerberg EW, Patka P, Schipper IB. Prehospital interventions: Time wasted or time saved? An observational cohort study management in initial trauma care. *Emerg Med J*. 2008;25(7):444-449. doi:10.1136/emj.2007.052662

69. Berkeveld E, Sierkstra TCN, Schober P, et al. Characteristics of helicopter emergency medical services (HEMS) dispatch cancellations during a six-year period in a Dutch HEMS region. *BMC Emerg Med*. 2021;50. doi:https://doi.org/10.1186/s12873-021-00439-x

70. Lapidus O, Wahlin RR, Bäckström D. Trauma patient transport to hospital using

helicopter emergency medical services or road ambulance in Sweden : a comparison of survival and prehospital time intervals. *Scand J Trauma Resusc Emerg Med*. 2023;31(101). doi:10.1186/s13049-023-01168-9

71. Stewart KE, Cowan LD, Thompson DM, Sacra JC, Albrecht R. Association of Direct Helicopter Versus Ground Transport and In-hospital Mortality in Trauma Patients: A Propensity Score Analysis. *Acad Emerg Med*. 2011;18(11):1208-1216. doi:10.1111/j.1553-2712.2011.01207.x

72. Chen X, Gestring ML, Rosengart MR, et al. Logistics of air medical transport: When and where does helicopter transport reduce prehospital time for trauma? In: *Journal of Trauma and Acute Care Surgery*. Vol 85. Lippincott Williams and Wilkins; 2018:174-181. doi:10.1097/TA.0000000000001935

73. Sm GJ, Thomas S, Stephens C, et al. Helicopter emergency medical services for adults with major trauma (Review). *Cochrane Collab*. 2013;(3). doi:10.1002/14651858.CD009228.pub2.www.cochranelibrary.com

74. Galvagno Jr SM. Comparative effectiveness of helicopter emergency medical services compared to ground emergency medical services. *Crit Caretical*. 2013;17(169). http://ccforum.com/content/17/4/169

75. Civil I. Trauma: still a problem in New Zealand. *N Z Med J*. 2004;117(1201):1-3. doi:10.1016/s0140-6736(49)91933-9

76. McNicholl BP. The golden hour and prehospital trauma care. *Injury*. 1994;25(4):251-254. doi:10.1016/0020-1383(94)90073-6

77. Haghparast-Bidgoli H, Hasselberg M, Khankeh H, Khorasani-Zavareh D, Johansson E. Barriers and facilitators to provide effective pre-hospital trauma care for road traffic injury victims in Iran: A grounded theory approach. *BMC Emerg Med*. 2010;10(20). doi:10.1186/1471-227X-10-20

78. Moore L. Measuring quality and effectiveness of prehospital EMS. *Prehospital Emerg Care*. 1999;3(4):325-331. doi:10.1080/10903129908958963

79. American College of Surgeons. Trauma Systems Components/Models. Accessed April

25, 2020. https://www.facs.org/quality-programs/trauma/tqp/systems-programs/tscp/components

80. American College of Surgeons Committee on Trauma. Resources for optimal care of the injured patient. doi:10.1097/00043860-200007000-00002

81. El Sayed MJ. Measuring Quality in Emergency Medical Services: A Review of Clinical Performance Indicators. *Emerg Med Int*. Published online 2012:1-7. doi:10.1155/2012/161630

82. Razzak JA, Kellermann AL. Emergency medical care in developing countries: Is it worthwhile? *Bull World Health Organ*. 2002;80(11):900-905. doi:10.1590/S0042-96862002001100011

83. Al-Shaqsi S. Models of international emergency medical service (EMS) systems. *Oman Med J*. 2010;25(4):320-323. doi:10.5001/omj.2010.92

84. Isenberg DL, Bissell R. Does advanced life support provide benefits to patients?: A literature review. *Prehosp Disaster Med*. 2005;20(4):265-270. doi:10.1017/S1049023X0000265X

85. Roudsari BS, Nathens AB, Cameron P, et al. International comparison of prehospital trauma care systems. *Injury*. 2007;38(9):993-1000. doi:10.1016/j.injury.2007.03.028

86. Liberman M, Mulder D, Sampalis J. Advanced or basic life support for trauma: Meta-analysis and critical review of the literature. *J Trauma - Inj Infect Crit Care*. 2000;49(4):584-599. doi:10.1097/00005373-200010000-00003

87. Bochicchio G V., Ilahi O, Joshi M, Bochicchio K, Scalea TM. Endotracheal intubation in the field does not improve outcome in trauma patients who present without an acutely lethal traumatic brain injury. *J Trauma*. 2003;54(2):307-311. doi:10.1097/01.TA.0000046252.97590.BE

88. Makrides T, Ross L, Gosling C, Acker J, Meara PO. From stretcher bearer to practitioner: A brief narrative review of the history of the Anglo-American paramedic system. *Australas Emerg Care*. 2022;25(4):347-353. doi:10.1016/j.auec.2022.05.001

89. National Ambulance Sector Clinical Working Group. *Clinical Procedures and*

Guidelines - Comprehensive Edition.; :432. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.stjohn.org.nz/globalassets/documents/health-practitioners/cpg_comprehensive_web170525.pdf

90. St John. *Emergency Ambulance Service CPGs*.; 2023. https://cpg.stjohn.org.nz/tabs/guidelines

91. Hoyle S, Swain AH, Fake P, Larsen PD. Introduction of an extended care paramedic model in New Zealand. *Emerg Med Australas*. 2012;24(6):652-656. doi:https://doi.org/10.1111/j.1742-6723.2012.01608.x

92. Rogers FB, Rittenhouse KJ, Gross BW. The golden hour in trauma: Dogma or medical folklore? *Injury*. 2015;46(4):525-527. doi:10.1016/j.injury.2014.08.043

93. Lilley R, De Graaf B, Kool B, et al. Geographical and population disparities in timely access to prehospital and advanced level emergency care in New Zealand: A cross-sectional study. *BMJ Open*. 2019;9(7):1-8. doi:10.1136/bmjopen-2018-026026

94. Cornwell EE, Belzberg H, Hennigan K, et al. Emergency medical services (EMS) vs non-EMS transport of critically injured patients: A prospective evaluation. *Arch Surg*. 2000;135(3):315-319. doi:10.1001/archsurg.135.3.315

95. New Zealand Government. 2018 New Zealand Census population and dwelling counts. Published 2019. Accessed April 22, 2020. https://www.stats.govt.nz/information-releases/2018-census-population-and-dwelling-counts

96. Paice R. An overview of New Zealand's trauma system. *J Trauma Nurs*. 2007;14(4):211-213. doi:10.1097/01.JTN.0000318926.13498.a8

97. Civil ID, Judson JA. Injury in Auckland, New Zealand: an unexplored epidemic. *Injury*. 1988;19:205-208. doi:10.1016/0020-1383(88)90017-4

98. Al-Shaqsi S. Current challenges in the provision of ambulance services in New Zealand. *Int J Emerg Med*. 2010;3(4):213-217. doi:10.1007/s12245-010-0239-z

99. Ministry of Health. The New Zealand Ambulance Service Strategy. Accessed June 1, 2020. https://www.moh.govt.nz/notebook/nbbooks.nsf/0/CD3CDA2EBCA13DB3CC257501

00010BC7/$file/draftstrategy.pdf

100. New Zealand Parliament - Health Committee. *Inquiry into the Provision of Ambulance Services in New Zealand.*; 2008. https://www.parliament.nz/en/pb/sc/reports/document/48DBSCH_SCR4100_1/inquiry-into-the-provision-of-ambulance-services-i6e

101. St John. New policy for major trauma patients. Accessed June 2, 2020. https://www.stjohn.org.nz/news--info/news-articles/new-policy-for-major-trauma-patients/

102. St John. ST JOHN RELEASES EMERGENCY AMBULANCE DATA FOR 2019. Published 2019. Accessed June 2, 2020. https://www.stjohn.org.nz/news--info/news-articles/st-john-releases-emergency-ambulance-data-for-2019/

103. National Ambulance Sector Office. Emergency Ambulance Service National Performance Reports. Accessed May 1, 2020. http://www.health.govt.nz/new-zealand-health-system/key-health-sector-organisations-and-people/naso-national-ambulance-sector-office/emergency-ambulance-services-eas/performance-quality-and-safety/emergency-ambulance-service-national-performance-reports

104. St John. *Annual Report 2019.*; 2019. https://www.stjohn.org.nz/news--info/our-performance/annual-reports/

105. Beck B, Bray JE, Smith K, et al. Description of the ambulance services participating in the Aus-ROC Australian and New Zealand out-of-hospital cardiac arrest Epistry. *Emerg Med Australas*. 2016;28(6):673-683. doi:10.1111/1742-6723.12690

106. Ministry of Health. Air Ambulance Service. Accessed June 2, 2020. https://www.health.govt.nz/new-zealand-health-system/key-health-sector-organisations-and-people/national-ambulance-sector-office-naso/emergency-ambulance-services-eas/air-ambulance-service

107. Ministry of Health. Air ambulance services – 10 year modernisation programme. Accessed June 2, 2020. https://www.health.govt.nz/new-zealand-health-system/key-health-sector-organisations-and-people/national-ambulance-sector-office-naso/emergency-ambulance-services-eas/air-ambulance-service/air-ambulance-

services-10-year-modernisation-programme

108. Isles S, Christey G, Civil I, Hicks P. The New Zealand Major Trauma Registry: the foundation for a data-driven approach in a contemporary trauma system. *N Z Med J*. 2017;130(1463):19-27. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med13&NEWS=N&AN=28981491

109. The New Zealand Major Trauma National Clinical Network. Accessed July 5, 2019. https://www.majortrauma.nz/about

110. Brown JB, Rosengart MR, Forsythe RM, et al. Not all prehospital time is equal: Influence of scene time on mortality. *J Trauma Acute Care Surg*. 2016;81(1):93-100. doi:10.1097/TA.0000000000000999

111. Kivell P, Keith M. Trauma systems and major injury centres for the 21st century: an option. *Health Place*. 1999;5:99-110. doi:10.1016/S1353-8292(98)00042-2

112. Oliver GJ, Walter DP, Redmond AD. Are prehospital deaths from trauma and accidental injury preventable? A direct historical comparison to assess what has changed in two decades. *Injury*. 2017;48(5):978-984. doi:10.1016/j.injury.2017.01.039

113. Kool B, Lilley R, Davie G, et al. Potential survivability of prehospital injury deaths in New Zealand: A cross-sectional study. *Inj Prev*. Published online 2020:1-6. doi:10.1136/injuryprev-2019-043408

114. Pigneri DA, Beldowicz B, Jurkovich GJ. Trauma Systems: Origins, Evolution, and Current Challenges. *Surg Clin North Am*. 2017;97(5):947-959. doi:10.1016/j.suc.2017.06.011

115. Spaite DW, Valenzuela TD, Meislin HW, Criss EA, Hinsberg P. Prospective Validation of a New Model for Evaluating Emergency Medical Services Systems by In-Field Observation of Specific Time Intervals in Prehospital Care. *Ann Emerg Med*. 1993;22(4):638-645. doi:10.1016/S0196-0644(05)81840-2

116. Hu W, Freudenberg V, Gong H, Huang B. The ‘‘ Golden Hour ” and field triage pattern for road trauma patients. *J Safety Res*. 2020;75:57-66. doi:10.1016/j.jsr.2020.08.001

117. Carr BG, Caplan JM, Pryor JP, Branas CC. A meta-analysis of prehospital care times for trauma. *Prehospital Emerg Care*. 2006;10(2):198-206. doi:10.1080/10903120500541324

118. Newgard CD, Schmicker RH, Hedges JR, et al. Emergency Medical Services Intervals and Survival in Trauma: Assessment of the “Golden Hour” in a North American Prospective Cohort. *Ann Emerg Med*. 2010;55(3):235-246.e4. doi:10.1016/j.annemergmed.2009.07.024

119. Sampalis JS, Lavoie A, Williams JI, Mulder DS, Kalina M. Impact of on-site care, prehospital time, and level of in-hospital care on survival in severely injured patients. *J Trauma - Inj Infect Crit Care*. 1993;34(2):252-261. doi:10.1097/00005373-199302000-00014

120. Ryb GE, Dischinger P, Cooper C, Kufera JA. Does helicopter transport improve outcomes independently of emergency medical system time? *J Trauma Acute Care Surg*. 2013;74(1):149-156. doi:10.1097/TA.0b013e31827890cc

121. Clements TW, Vogt K, Hameed SM, et al. Does increased prehospital time lead to a “trial of life” effect for patients with blunt trauma? *J Surg Res*. 2017;216:103-108. doi:10.1016/j.jss.2017.04.027

122. Báez AA, Lane PL, Sorondo B, Giráldez EM. Predictive effect of out-of-hospital time in outcomes of severely injured young adult and elderly patients. *Prehosp Disaster Med*. 2006;21(6):427-430. doi:10.1017/S1049023X00004143

123. Bhaumik S, Hannun M, Dymond C, Desanto K, Barrett W, Wallis LA. Prehospital triage tools across the world : a scoping review of the published literature. *Scand J Trauma Resusc Emerg Med*. Published online 2022:1-11. doi:10.1186/s13049-022-01019-z

124. Marcussen CE, Bräuner KB, Alstrøm H, Møller AM. Accuracy of prehospital triage systems for mass casualty incidents in trauma register studies - A systematic review and meta-analysis of diagnostic test accuracy studies. *Injury*. 2022;53(8):2725-2733. doi:10.1016/j.injury.2022.05.006

125. Lovely R, Trecartin A, Ologun G, et al. Injury Severity Score alone predicts mortality when compared to EMS scene time and transport time for motor vehicle trauma patients

who arrive alive to hospital. *Traffic Inj Prev*. 2018;19(sup2):S167-S168. doi:10.1080/15389588.2018.1532217

126. Arleth T, Rudolph SS, Svane C, Rasmussen LS. Time from injury to arrival at the trauma centre in patients undergoing interhospital transfer. *Dan Med J*. 2020;67(9).

127. Haslam NR, Bouamra O, Lawrence T, Moran CG, Lockey DJ. Time to definitive care within major trauma networks in England. *BJS Open*. 2020;4(5):963-969. doi:10.1002/bjs5.50316

128. Kidher E, Krasopoulos G, Coats T, et al. The effect of prehospital time related variables on mortality following severe thoracic trauma. *Injury*. 2012;43(9):1386-1392. doi:10.1016/j.injury.2011.04.014

129. Feero S, Hedges JR, Simmons E, Irwin L. Does out-of-hospital EMS time affect trauma survival? *Am J Emerg Med*. 1995;13(2):133-135. doi:10.1016/0735-6757(95)90078-0

130. Gonzalez RP, Cummings GR, Phelan HA, Mulekar MS, Rodning CB. Does increased emergency medical services prehospital time affect patient mortality in rural motor vehicle crashes? A statewide analysis. *Am J Surg*. 2009;197(1):30-34. doi:10.1016/j.amjsurg.2007.11.018

131. Esmaeiliranjbar A, Mayel M, Movahedi M, Emaeiliranjbar F, Mirafzal A. Pre-hospital time intervals in trauma patient transportation by emergency medical service: association with the first 24- hour mortality. Published online 2016:0-4. doi:10.15171/jept.2015.15

132. Levitan M, Law MP, Ferron R, Lutz-Graul K. Paramedics' Perspectives on Factors Impacting On-Scene Times for Trauma Calls. *Prehosp Disaster Med*. 2018;33(3):250-255. doi:10.1017/S1049023X18000389

133. McCoy CE, Menchine M, Sampson S, Anderson C, Kahn C. Emergency medical services out-of-hospital scene and transport times and their association with mortality in trauma patients presenting to an urban level i trauma center. *Ann Emerg Med*. 2013;61(2):167-174. doi:10.1016/j.annemergmed.2012.08.026

134. Gregory JS, Walker C, Young K, Ralchenko A. Essential processes of successful trauma

systems: template for analysis of trauma systems. *J Emerg Crit Care Med*. 2018;2:22-22. doi:10.21037/jeccm.2018.02.05

135. Moore L, Champion H, Tardif PA, et al. Impact of Trauma System Structure on Injury Outcomes: A Systematic Review and Meta-Analysis. *World J Surg*. 2018;42(5):1327-1339. doi:10.1007/s00268-017-4292-0

136. Möller A, Hunter L, Kurland L, Lahri S, van Hoving DJ. The association between hospital arrival time, transport method, prehospital time intervals, and in-hospital mortality in trauma patients presenting to Khayelitsha Hospital, Cape Town. *African J Emerg Med*. 2018;8(3):89-94. doi:10.1016/j.afjem.2018.01.001

137. Major Trauma National Clinical Network. *New Zealand Out-of-Hospital Major Trauma Destination Policy*.; 2017. https://www.majortrauma.nz/publications-resources/trauma-resources-and-guidelines/out-of-hospital-training/

138. St John. *Clinical Procedures and Guidelines 2019-2022*.; 2019. https://www.stjohn.org.nz/globalassets/documents/health-practitioners/clinical-procedures-and-guidelines---comprehensive-edition.pdf

139. Kass NE. An ethics framework for public health. *Am J Public Health*. 2001;91(11):1776-1782. doi:10.2105/AJPH.91.11.1776

140. National Center for Injury Prevention and Control. Division of Violence Prevention. The public health approach to violence prevention. Accessed May 10, 2020. https://www.cdc.gov/violenceprevention/publichealthissue/publichealthapproach.html

141. New Zealand Major Trauma Registry & National Clinical Network. *Annual Report 2018-2019*.; 2019. https://www.majortrauma.nz/assets/Publication-Resources/Annual-reports/National-Trauma-Network-Annual-Report-2018-19.pdf

142. Petrucelli E, States JD, Hames LN. The abbreviated injury scale: Evolution, usage and future adaptability. *Accid Anal Prev*. 1981;13:29-35. doi:10.1016/0001-4575(81)90040-3

143. Association for the Advancement of Automotive Medicine. Abbreviated Injury Scale (AIS). Accessed September 18, 2019. https://www.aaam.org/abbreviated-injury-scale-

ais/

144. Ringdal KG, Skaga NO, Hestnes M, et al. Abbreviated Injury Scale: not a reliable basis for summation of injury severity in trauma facilities?. *Injury*. 2013;44(5):691-699. doi:10.1016/j.injury.2013.10.022

145. Copes WS, Champion HR, Sacco WJ, Lawnick MM, Keast SL, Bain LW. The Injury Severity Score Revisited. *J Trauma*. 1988;28(1):69-77.

146. Baker SP, O'neill B, Haddon W, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14(3):187-196.

147. McCullough AL, Haycock JC, Forward DP, Moran CG. Major trauma networks in England. *Br J Anaesth*. 2014;113(2):202-206. doi:10.1093/bja/aeu204

148. Palmer C. Major Trauma and the Injury Severity Score - Where Should We Set the Bar? *Annu Proc Assoc Adv Automot Med*. 2007;51:13-29.

149. Kehoe A, Smith JE, Edwards A, Yates D, Lecky F. The changing face of major trauma in the UK. *Emerg Med J*. 2015;32:911-915. doi:10.1136/emermed-2015-205265

150. New Zealand Major Trauma Registry & National Clinical Network. *Annual Report 2016-2017*.; 2017. https://www.midlandtrauma.nz/ebook/Annual Report 2016-17.pdf

151. Loftis KL, Price J, Gillich PJ. Evolution of the Abbreviated Injury Scale: 1990–2015. *Traffic Inj Prev*. 2018;19(sup2):S109-S113. doi:10.1080/15389588.2018.1512747

152. Jackson R, Ameratunga S, Broad J, et al. The Gate frame: critical appraisal with pictures. *Evid Based Med*. 2006;11(2):35-38. doi:10.1136/ebn.9.3.68

153. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *J Clin Epidemiol*. 2009;62:e1-e34. doi:10.1016/j.jclinepi.2009.06.006

154. Maclennan B, Wyeth E, Davie G, Wilson S, Derrett S. Twelve-month post-injury outcomes for Maori and non-Maori: findings from a New Zealand cohort study. *Aust N Z J Public Health*. 2014;38(3):227-233. doi:https://dx.doi.org/10.1111/1753-6405.12228

155. Creamer GL, Civil I, Koelmeyer T, Adams D, Čačala S, Thompson J. Population-based study of age, gender and causes of severe injury in Auckland, 2004. *ANZ J Surg*. 2008;78:995-998. doi:10.1111/j.1445-2197.2008.04719.x

156. Creamer G, Civil I, Ng A, et al. Ethnicity of severe trauma patients: results of a population-based study, Auckland, New Zealand 2004. *N Z Med J*. 2010;123(1316):26-32. http://www.nzma.org.nz/journal/123-1316/4168/content.pdf

157. Couch L, Yates K, Aickin R, Pena A. Investigating moderate to severe paediatric trauma in the Auckland region. *Emerg Med Australas*. 2010;22:171-179. doi:10.1111/j.1742-6723.2010.01283.x

158. Scott A, Dansey R, Hamill J. Dangerous toys. *ANZ J Surg*. 2011;81:172-175. doi:10.1111/j.1445-2197.2010.05484.x

159. Singh N, Joe N, Amey J, Smith A, Christey G. Cycling-related injuries and cycling promotion: A trauma service perspective. *N Z Med J*. 2019;132(1494):41-48.

160. Kandelaki T, Evans M, Beard A, Wakeman C. Exploring admissions for Māori presenting with major trauma at Christchurch Hospital. *N Z Med J*. 2021;134(1530):69-75.

161. Mcguinness MJ, Harmston C. Association between COVID-19 public health interventions and major trauma presentation in the northern region of New Zealand. 2021;91:633-638. doi:10.1111/ans.16711

162. Fan D, Scowcroft H, Mccombie A, Duncan R, Wakeman C. A comparison of major Christchurch Hospital during and after COVID-19 lockdown in New Zealand. 2021;134(1540):46-55.

163. Christey G, Amey J, Campbell A, Smith A. Variation in volumes and characteristics of trauma patients admitted to a level one trauma centre during national level 4 lockdown for COVID-19 in New Zealand. *N Z Med J*. 2020;133(1513):81-88.

164. Wood A, Duijff JW, Christey GR. Quad bike injuries in Waikato, New Zealand: an institutional review from 2007-2011. *ANZ J Surg*. 2013;83(4):206-210. doi:http://dx.doi.org/10.1111/ans.12106

165. O'Leary K, Kool B, Christey G. Characteristics of older adults hospitalised following trauma in the Midland region of New Zealand. *N Z Med J*. 2017;130(1463):45-53.

166. Kool B, Ameratunga S, Scott N, Lawrenson R, Christey G. The epidemiology of work-related injury admissions to hospitals in the Midland region of New Zealand. *Injury*. 2017;48:2478-2484. doi:10.1016/j.injury.2017.09.018

167. Tosswill M, Roskruge M, Smith A, Christey G. Livestock-related injuries in the Midland region of New Zealand. *N Z Med J*. 2018;131(1483):13-20. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=prem2&NEWS=N&AN=30286061

168. Johns E, Farrant G, Civil I. Animal-related injury in an urban New Zealand population. *Injury*. 2004;35:1234-1238. doi:10.1016/j.injury.2003.11.003

169. Tan C-P, Ng A, Civil I. Co-morbidities in trauma patients: common and significant. *N Z Med J*. 2004;117(1201):U1044. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med5&NEWS=N&AN=15476004

170. Hsee L, Civil I. A 12-year review of gunshot injuries: Auckland City Hospital experience. *N Z Med J*. 2008;121(1287):21-25.

171. Czuba KJ, Kersten P, Anstiss D, et al. Incidence and outcomes of major trauma in New Zealand: findings from a feasibility study of New Zealand's first national trauma registry. *N Z Med J*. 2019;132(1494):26-40.

172. Pearce R, Miles F. 7-year retrospective review of quad bike injuries admitted to Starship Children's Hospital. *N Z Med J*. 2015;128(1414):44-50. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med11&NEWS=N&AN=26117390

173. Mittal A, Blyth P, Civil I. Trauma and co-morbidity - a pilot study. *N Z Med J*. 2001;114(1132):232-233.

174. Gardiner JP, Judson JA, Smith GS, Jackson R, Norton RN. A decade of intensive care unit trauma admissions in Auckland. *N Z Med J*. 2000;113(1115):327-330.

http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med4&NEWS=N&AN=11008608

175. Safih MS, Norton R, Rogers I, Gardener JP, Judson JA. Elderly trauma patients admitted to the intensive care unit are different from the younger population. *N Z Med J*. 1999;112(1098):402-404. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med4&NEWS=N&AN=10606402

176. Roberts I, Streat S, Judson J, Norton R. Critical injuries in paediatric pedestrians. *N Z Med J*. 1991;104(914):247-248.

177. Civil ID, Ross SE, Schwab CW. Major Trauma in an Urban New Zealand Setting: Resource Requirements. *Aust N Z J Surg*. 1987;57:543-548. doi:10.1111/j.1445-2197.1987.tb01418.x

178. Streat SJ, Donaldson ML, Judson JA. Trauma in Auckland: an overview. *N Z Med J*. 1987;100(828):441-444.

179. Collins BA, Langley JD, Marshall SW. Injuries to pedal cyclists resulting in death and hospitalisation. *N Z Med J*. 1993;106(969):514-516. http://www.ncbi.nlm.nih.gov/pubmed/8183490

180. Langley JD, Begg DJ, Reeder AI. Motorcycle crashes resulting in death and hospitalisation II: Traffic crashes. *Accid Anal Prev*. 1994;26(2):165-171. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med3&NEWS=N&AN=8198685

181. Chalmers DJ, O'Hare DPA, McBride DI. The incidence, nature, and severity of injuries in New Zealand civil aviation. *Aviat Sp Environ Med*. 2000;71(4):388-395.

182. O'Hare D, Chalmers D, Arnold NA, Williams F. Mortality and morbidity in white water rafting in New Zealand. *Inj Control Saf Promot*. 2002;9(3):193-198. doi:10.1076/icsp.9.3.193.8710

183. Gulliver P, Dow N, Simpson J. The epidemiology of home injuries to children under five years in New Zealand. *Aust N Z J Public Health*. 2005;29:29-34.

http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med5&NEWS=N&AN=15782868

184. Kool B, Ameratunga S, Robinson E, Jackson R. Hospitalisations and deaths due to unintentional falls at home among working-aged New Zealanders. *Injury*. 2007;38(5):570-575. doi:10.1016/j.injury.2006.10.014

185. Anson K, Segedin E, Jones P. ATV (quad bike) injuries in New Zealand Children: their extent and severity. *N Z Med J*. 2009;122(1302):11-28.

186. Kool B, Chelimo C, Robinson E, Ameratunga S. Deaths and hospital admissions as a result of home injuries among young and middle-aged New Zealand adults. *N Z Med J*. 2011;124(1347):16-26.

187. Creamer G, Civil I, Ng A, et al. Ethnicity of severe trauma patients: results of a population-based study, Auckland, New Zealand 2004. *N Z Med J*. 2010;123(1316):26-32.

188. Pang JM, Civil I, Ng A, Adams D, Koelmeyer T. Is the trimodal pattern of death after trauma a dated concept in the 21st century? Trauma deaths in Auckland 2004. *Injury*. 2008;39:102-106. doi:10.1016/j.injury.2007.05.022

189. Wood A, Duijff JW, Christey GR. Quad bike injuries in Waikato, New Zealand: an institutional review from 2007-2011. *ANZ J Surg*. 2013;83:206-210. doi:10.1111/ans.12106

190. Kool B, Chelimo C, Ameratunga S. Head injury incidence and mortality in New Zealand over 10 Years. *Neuroepidemiology*. 2013;41(3-4):189-197. doi:https://dx.doi.org/10.1159/000354782

191. Wakeman C, Beasley S, Pearson S, Frizelle F, Sharr J, Dobbs B. Liver injury in children: causes, patterns and outcomes. *NZMJ*. 2003;116(1178):1-6.

192. Bajaj M, Stefanutti G, Crawford H, Upadhyay V. Paediatric pelvic fractures: Starship hospital experience. *N Z Med J*. 2018;131(1471):13-20.

193. Civil IDS, King M, Paice R. Penetrating Trauma in Auckland: 12 years on. *Aust N Z J Surg*. 1998;68:261-263. doi:10.1111/j.1445-2197.1998.tb02077.x

194. McGuinness MJ, Harmston C, Harmston C, et al. Association between COVID-19 public health interventions and major trauma presentation in the northern region of New Zealand. *ANZ J Surg*. 2021;91(4):633-638. doi:10.1111/ans.16711

195. Fan D, Scowcroft H, McCombie A, Duncan R, Wakeman C. A comparison of major trauma admissions to Christchurch Hospital during and after COVID-19 lockdown in New Zealand. *N Z Med J*. 2021;134(1540):46-55.

196. Civil ID, Schwab CW. Trauma Mortality and Trauma Center Designation: an International Comparison. *Aust N Z J Surg*. 1988;58(2):129-135. doi:10.1111/j.1445-2197.1988.tb01022.x

197. World Health Organization. WHO announces COVID-19 outbreak a pandemic. Accessed October 10, 2021. http://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/who-announces-covid-19-outbreak-a-pandemic%0A

198. McGuinness MJ, Hsee L. Impact of the COVID-19 national lockdown on emergency general surgery: Auckland City Hospital's experience. *ANZ J Surg*. 2020;90(11):2254-2258. doi:10.1111/ans.16336

199. Kojima M, Endo A, Shiraishi A, Otomo Y. Age-Related Characteristics and Outcomes for Patients With Severe Trauma: Analysis of Japan's Nationwide Trauma Registry. *Ann Emerg Med*. 2019;73(3):281-290. doi:10.1016/j.annemergmed.2018.09.034

200. Heim C, Bosisio F, Roth A, et al. Is trauma in Switzerland any different? Epidemiology and patterns of injury in major trauma - A 5-year review from a Swiss trauma centre. *Swiss Med Wkly*. 2014;144(April):1-9. doi:10.4414/smw.2014.13958

201. Chico-Fernández M, Llompart-Pou JA, Guerrero-López F, et al. Epidemiology of severe trauma in Spain. Registry of trauma in the ICU (RETRAUCI). Pilot phase. *Med Intensiva (English Ed*. 2016;40(6):327-347. doi:10.1016/j.medin.2015.07.011

202. New Zealand Major Trauma Registry & National Clinical Network. *Annual Report 2017-2018*.; 2019. https://www.majortrauma.nz/assets/Publication-Resources/Annual-reports/Annual-Report-2017-18.pdf

203. Department of Health & Human Services Victoria State Government. *Victorian State Trauma System and Registry Annual Report 1 July 2016 to 30 June 2017.*; 2017. https://www2.health.vic.gov.au/about/publications/annualreports/victorian-state-trauma-registry-annual-report-2016-17

204. Rastogi D, Meena S, Sharma V, Singh GK. Epidemiology of patients admitted to a major trauma centre in northern India. *Chinese J Traumatol*. 2014;17(2):103-107. doi:10.3760/cma.j.issn.1008-1275.2014.02.009

205. Dicker B, Swain A, Todd VF, et al. Changes in demand for emergency ambulances during a nationwide lockdown that resulted in elimination of COVID-19: An observational study from New Zealand. *BMJ Open*. 2020;10(12). doi:10.1136/bmjopen-2020-044726

206. New Zealand Major Trauma Registry & National Clinical Network. *Annual Report 2019-2020.*; 2020. https://www.majortrauma.nz/assets/Publication-Resources/Annual-reports/NZMT2019-20V2-FINAL.pdf

207. Harris D, Ellis DY, Gorman D, Foo N, Haustead D. Impact of COVID-19 social restrictions on trauma presentations in South Australia. *EMA - Emerg Med Australas*. 2021;33(1):152-154. doi:10.1111/1742-6723.13680

208. Hsu SY, Wu SC, Rau CS, et al. Impact of adapting the abbreviated injury scale (AIS)-2005 from AIS-1998 on injury severity scores and clinical outcome. *Int J Environ Res Public Health*. 2019;16(24). doi:10.3390/ijerph16245033

209. Barbosa Teixeira Lopes M, Yamaguchi Whitaker I. Measuring trauma severity using the 1998 and 2005 revisions of the Abbreviated Injury Scale. *Rev da Esc Enferm*. 2014;48(4):641-648. doi:10.1590/s0080-623420140000400010

210. Association for the Advancement of Automotive Medicine (AAAM). AIS 2015 Released. Accessed September 1, 2021. https://www.aaam.org/ais-2015-released/

211. Van Ditshuizen JC, Sewalt CA, Palmer CS, et al. The definition of major trauma using different revisions of the abbreviated injury scale. *Scand J Trauma Resusc Emerg Med*. 2021;29(1):1-10. doi:10.1186/s13049-021-00873-7

212. Palmer CS, Franklyn M. Assessment of the effects and limitations of the 1998 to 2008 Abbreviated Injury Scale map using a large population-based dataset. *Scand J Trauma Resusc Emerg Med*. 2011;19(1):1-10. doi:10.1186/1757-7241-19-1

213. Russell R, Halcomb E, Caldwell E, Sugrue M. Differences in mortality predictions between injury severity score triplets: A significant flaw. *J Trauma - Inj Infect Crit Care*. 2004;56(6):1321-1324. doi:10.1097/01.TA.0000062763.21379.D9

214. Restrepo-Álvarez CA, Valderrama-Molina CO, Giraldo-Ramírez N, et al. Trauma severity scores. *Colomb J Anesthesiol*. 2016;44(4):317-323. doi:10.1016/j.rcae.2016.06.004

215. Paffrath T, Lefering R, Flohé S. How to define severely injured patients? - An Injury Severity Score (ISS) based approach alone is not sufficient. *Injury*. 2014;45:S64-S69. doi:10.1016/j.injury.2014.08.020

216. Shi J, Shen J, Zhu M, et al. A new weighted injury severity scoring system: Better predictive power for adult trauma mortality. *Inj Epidemiol*. 2019;6(1):1-10. doi:10.1186/s40621-019-0217-8

217. Osler T, Glance LG, Bedrick EJ. *Injury Severity Scoring: Its Definition and Practical Application*. First Edit. Elsevier Inc.; 2008. doi:10.1016/B978-0-323-04418-9.50007-2

218. Davie G, Langley J, Samaranayaka A, Wetherspoon ME. Accuracy of injury coding under ICD-10-AM for New Zealand public hospital discharges. *Inj Prev*. 2008;14:319-323. doi:10.1136/ip.2007.017954

219. Robson B, Harris R (eds). *Hauora: Māori Standards of Health IV. A Study of the Years 2000–2005.* Wellington: Te Rōpū Rangahau Hauora a Eru Pōmare; 2007.

220. Gulliver PJ, Cryer C, Langley JD, Davie GS. Identifying Māori ethnicity for estimating trends in fatal and serious non-fatal injury. *Aust N Z J Public Health*. 2011;35(4):352-356. doi:10.1111/j.1753-6405.2011.00730.x

221. Scott N, Clark H, Kool B, Ameratunga S, Christey G, Cormack D. Audit of ethnicity data in the Waikato hospital patient management system and trauma registry: Pilot of the hospital ethnicity data audit toolkit. *N Z Med J*. 2018;131(1483):21-29.

222. Kool B, Lilley R, Davie G, et al. Evaluating the impact of prehospital care on mortality following major trauma in New Zealand: A retrospective cohort study. *Inj Prev*. 2021;27(6):582-586. doi:10.1136/injuryprev-2020-044057

223. New Zealand Trauma Registry. *New Zealand Major Trauma National Minimum Dataset*.; 2022:92. https://www.majortrauma.nz/assets/New-Zealand-Major-Trauma-Minimum-Dataset-January-2022.pdf

224. St John. Electronic Patient Records. https://www.stjohn.org.nz/news--info/Electronic-Patient-Records/

225. Wellington Free Ambulance. Wellington Free Ambulances moves to Electronic Patient Referral Forms (ePRF). Published 2018. https://www.wfa.org.nz/about-us/news/wellington-free-ambulances-moves-electronic-patient-referral-forms-eprf/

226. Health Informatics New Zealand. Electronic Patient Report Form system live across New Zealand ambulance services. Published 2018. https://www.hinz.org.nz/news/392962/Electronic-Patient-Report-Form-system-live-across-New-Zealand-ambulance-services.htm#:~:text=The ePRF system is provided,resourcing%2C such as helicopter deployments

227. St John. *The Electronic Patient Report Form (EPRF)*. https://www.stjohn.org.nz/globalassets/documents/publications/eprf-documents/eprf-brochure.pdf

228. New Zealand Trauma Registry. Guidelines for Provision of Data from The New Zealand Trauma Registry. Accessed January 7, 2022. https://www.majortrauma.nz/assets/Publication-Resources/NZ-MTR/NZTR-Data-Request-Form.pdf

229. Coronial Services of New Zealand. What happens during a post-mortem? Accessed December 12, 2021. https://coronialservices.justice.govt.nz/what-happens-during-a-post-mortem/

230. Nie L, Davie G, Lilley R. Factors related to absence of toxicological investigation following fatal injury: a retrospective quantitative review of Coronial records in New Zealand. *Forensic Sci Med Pathol*. 2021;17(4):643-648. doi:10.1007/s12024-021-

00422-9

231. Ministry of Health. *National Health Index Data Dictionary. Version 5.3.*; 2009.

232. National Health Board. *National Minimum Dataset (Hospital Events) Data Dictionary. Version 7.9.*; 2014.

233. Nixon G, Whitehead J, Davie G, et al. Developing the geographic classification for health, a rural-urban classification for New Zealand health research and policy: A research protocol. *Aust J Rural Health*. 2021;29(6):939-946. doi:10.1111/ajr.12778

234. Exeter DJ, Zhao J, Crengle S, Lee A, Browne M. The New Zealand Indices of Multiple Deprivation (IMD): A new suite of indicators for social and health research in Aotearoa, New Zealand. *PLoS One*. 2017;12(8):1-19. doi:10.1371/journal.pone.0181260

235. Environmental Health Intelligence New Zealand. Socioeconomic deprivation profile. Accessed October 20, 2021. https://www.ehinz.ac.nz/indicators/population-vulnerability/socioeconomic-deprivation-profile/#:~:text=to environmental risks-,New Zealand Index of Deprivation (NZDep),NZDep is displayed as deciles.

236. Atkinson J, Salmond C, Crampton P. *NZDep2018 Index of Deprivation, Final Research Report.*; 2020. https://www.otago.ac.nz/wellington/otago823833.pdf

237. Shuker C, Bohm G, Bramley D, et al. The Health Quality and Safety Commission: Making good health care better. *N Z Med J*. 2015;128(1408):97-109.

238. Health Quality & Safety Commission New Zealand. Our role. Published 2021. Accessed January 14, 2022. https://www.hqsc.govt.nz/about-us/our-role/

239. StataCorp. 2021. Stata Statistical Software: Release 17.

240. Zou G. A Modified Poisson Regression Approach to Prospective Studies with Binary Data. *Am J Epidemiol*. 2004;159(7):702-706. doi:10.1093/aje/kwh090

241. Abajas-Bustillo R, Amo-Setién FJ, Leal-Costa C, et al. Comparison of injury severity scores (ISS) obtained by manual coding versus “Two-step conversion” from ICD-9-CM. *PLoS One*. 2019;14(5):1-12. doi:10.1371/journal.pone.0216206

242. Fleischman et al. Validating the Use of ICD-9 Code Mapping to Generate Injury

Severity Scores. *J Trauma Nurs*. 2017;24(1):4-14. doi:10.1016/j.physbeh.2017.03.040

243. Loftis KL, Price JP, Gillich PJ, et al. Development of an expert based ICD-9-CM and ICD-10-CM map to AIS 2005 update 2008. *Traffic Inj Prev*. 2016;17:1-5. doi:10.1080/15389588.2016.1191069

244. Association for the Advancement of Automobile Medicine (AAAM). AIS course descriptions. https://www.aaam.org/abbreviated-injury-scale-ais/ais-course-descriptions/

245. Di Bartolomeo S, Tillati S, Valent F, Zanier L, Barbone F. ISS mapped from ICD-9-CM by a novel freeware versus traditional coding: A comparative study. *Scand J Trauma Resusc Emerg Med*. 2010;18(1):1-7. doi:10.1186/1757-7241-18-17

246. Haas B, Xiong W, Brennan-Barnes M, Gomez D, Nathens AB. Overcoming barriers to population-based injury research: Development and validation of an ICD-10-to-AIS algorithm. *Can J Surg*. 2012;55(1):21-26. doi:10.1503/cjs.017510

247. Glerum KM, Zonfrillo MR. Validation of an ICD-9-CM and ICD-10-CM map to AIS 2005 Update 2008. *Inj Prev*. 2019;25(2):90-92. doi:10.1136/injuryprev-2017-042519

248. Niemann M, Märdian S, Niemann P, et al. Transforming the German ICD-10 (ICD-10-GM) into Injury Severity Score (ISS)—Introducing a new method for automated re-coding. *PLoS One*. 2021;16(9 September):1-12. doi:10.1371/journal.pone.0257183

249. Dinh MM, Singh H, Sarrami P, Levesque JF. Correlating injury severity scores and major trauma volume using a state-wide in-patient administrative dataset linked to trauma registry data—A retrospective analysis from New South Wales Australia. *Injury*. 2020;51(1):109-113. doi:10.1016/j.injury.2019.09.022

250. Airaksinen NK, Heinänen MT, Handolin LE. The reliability of the ICD-AIS map in identifying serious road traffic injuries from the Helsinki Trauma Registry. *Injury*. 2019;50(9):1545-1551. doi:10.1016/j.injury.2019.07.030

251. Roberts L. *Children and Young People in Auckland: Results from the 2018 Census.*; 2020.

252. Civil I, Twaddle B. Trauma care systems in New Zealand. *Injury*. 2003;34(9):740-744.

doi:10.1016/j.injury.2003.08.013

253. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med*. 2016;15(2):155-163. doi:10.1016/j.jcm.2016.02.012

254. Durbin DR, Localio AR, Mackenzie EJ. Validation of the ICD / AIS MAP for pediatric use. *Inj Prev*. 2001;7:96-99.

255. Rouhani SA, Eliacin HC, Edmond MC, Checkett KA, Rimpel L, Marsh RH. Epidemiology of traumatic injuries presenting to an ED in Central Haiti: A retrospective cohort study. *Emerg Med J*. 2019;36(7):389-394. doi:10.1136/emermed-2018-207559

256. Möller A, Hunter L, Kurland L, Hoving DJ Van. The association between hospital arrival time , transport method , prehospital time intervals , and in-hospital mortality in trauma patients presenting to. *African J Emerg Med*. 2018;8(3):89-94. doi:10.1016/j.afjem.2018.01.001

257. Chen C, Shin S Do, Sun J, et al. Association between prehospital time and outcome of trauma patients in 4 Asian countries: A cross-national, multicenter cohort study. *PLoS Med*. 2020;498:16-29. doi:10.1371/journal.pmed.1003360

258. Wyen H, Lefering R, Maegele M, et al. The golden hour of shock - How time is running out: Prehospital time intervals in Germany - A multivariate analysis of 15, 103 patients from the TraumaRegister DGU®. *Emerg Med J*. 2013;30(12):1048-1055. doi:10.1136/emermed-2012-201962

259. Rogers FB, Rittenhouse KJ, Gross BW. The golden hour in trauma : Dogma or medical folklore ? 2015;46:525-527. doi:10.1016/j.injury.2014.08.043

260. Fuchs A, Huber M, Riva T, et al. Factors influencing on-scene time in a physician-staffed helicopter emergency medical service (HEMS): a retrospective observational study. *Scand J Trauma Resusc Emerg Med*. 2023;31(1). doi:10.1186/s13049-023-01085-x

261. Østerås Ø, Heltne JK, Vikenes BC, Assmus J, Brattebø G. Factors influencing on-scene time in a rural Norwegian helicopter emergency medical service: A retrospective

observational study. *Scand J Trauma Resusc Emerg Med*. 2017;25(1). doi:10.1186/s13049-017-0442-5

262. Ito S, Asai H, Kawai Y, Suto S, Ohta S, Fukushima H. Factors associated with EMS on-scene time and its regional difference in road traffic injuries: a population-based observational study. *BMC Emerg Med*. 2022;22(1). doi:10.1186/s12873-022-00718-1

263. Goodacre SW, Gray A, McGowan A. On-scene times for trauma patients in West Yorkshire. *Emerg Med J*. 1997;14(5):283-285. doi:10.1136/emj.14.5.283

264. Spoelder EJ, Slagt C, Scheffer GJ, van Geffen GJ. Transport of the patient with trauma: a narrative review. *Anaesthesia*. 2022;77(11):1281-1287. doi:10.1111/anae.15812

265. Butler DP, Anwar I, Willett K. Is it the H or the EMS in HEMS that has an impact on trauma patient mortality? A systematic review of the evidence. *Emerg Med J*. 2010;27(9):692-701. doi:10.1136/emj.2009.087486

266. Earnest A, Hock Ong ME, Shahidah N, Min Ng W, Foo C, Nott DJ. Spatial analysis of ambulance response times related to prehospital cardiac arrests in the city-state of Singapore. *Prehospital Emerg Care*. 2012;16(2):256-265. doi:10.3109/10903127.2011.615974

267. Lam SSW, Nguyen FNHL, Ng YY, et al. Factors affecting the ambulance response times of trauma incidents in Singapore. *Accid Anal Prev*. 2015;82:27-35. doi:10.1016/j.aap.2015.05.007

268. National Ambulance Sector Office. Emergency Ambulance Service National Performance Reports. Accessed May 1, 2020. http://www.health.govt.nz/new-zealand-health-system/key-health-sector-organisations-and-people/naso-national-ambulance-sector-office/emergency-ambulance-services-eas/performance-quality-and-safety/emergency-ambulance-service-national-performance-reports

269. Brown JB, Rosengart MR, Forsythe RM, et al. Not all prehospital time is equal: Influence of scene time on mortality. *J Trauma Acute Care Surg*. 2016;81(1):93-100. doi:10.1097/TA.0000000000000999

270. Saberian P, Kolivand PH, Sharamin PH, Modaber M, Farhoud A, Karimialavijeh E. The

Association between Time Intervals in Emergency Medical Services and In - hospital Mortality of Trauma Patients. Published online 2020:75-80. doi:10.4103/atr.atr

271. Funder KS, Petersen JA, Steinmetz J. On-scene time and outcome after penetrating trauma : an observational study. Published online 2011. doi:10.1136/emj.2010.097535

272. H. Blackwell T, S. Kaufman J. Response Time Effectiveness: Comparison of Response Time and Survival in an Urban Emergency Medical Services System. *Acad Emerg Med*. 2002;9(4):288-295.

273. Berkeveld E, Popal Z, Schober P, Zuidema WP, Bloemers FW, Giannakopoulos GF. Prehospital time and mortality in polytrauma patients: a retrospective analysis. *BMC Emerg Med*. 2021;21(1). doi:10.1186/s12873-021-00476-6

274. Gauss T, Ageron F-X, Devaud M-L, et al. Association of Prehospital Time to In-Hospital Trauma Mortality in a Physician-Staffed Emergency Medicine System. *JAMA Surg*. 2019;154(12):1117-1124. doi:10.1001/jamasurg.2019.3475

275. John S. *Clinical Procedures and Guidelines 2019-2022.*; 2019. https://www.stjohn.org.nz/globalassets/documents/health-practitioners/clinical-procedures-and-guidelines---comprehensive-edition.pdf

276. Cox S, Smith K, Currell A, Harriss L, Barger B, Cameron P. Differentiation of confirmed major trauma patients and potential major trauma patients using pre-hospital trauma triage criteria. 2023;42(2011):889-895. doi:10.1016/j.injury.2010.03.035

277. Lokerman RD, Waalwijk JF, Sluijs R Van Der, et al. Evaluating pre-hospital triage and decision-making in patients who died within 30 days post-trauma : A multi-site , multi-center , cohort study. *Injury*. 2022;53(5):1699-1706. doi:10.1016/j.injury.2022.02.047

278. Siripakarn Y, Triniti L, Srivilaithon W. Association of Scene Time with Mortality in Major Traumatic Injuries Arrived by Emergency Medical Service. *J Emerg Trauma Shock*. 2023;16(4):156-160. doi:10.4103/jets.jets_35_23

279. Van DB, Song KJ, Shin S Do, et al. Association between Scene Time Interval and Survival in EMS-Treated Major Trauma Admitted to the Intensive Care Unit : A Multinational , Multicenter Observational Study M AJOR T RAUMA A DMITTED TO

THE I NTENSIVE C ARE U NIT : A M ULTINATIONAL ,. *Prehospital Emerg Care*. 2022;26(4):600-607. doi:10.1080/10903127.2021.1992053

280. González-robledo J, Martín-gonzález F, Moreno-garcía M, Sánchez-barba M. Prognostic factors associated with mortality in patients with severe trauma : From prehospital care to the Intensive Care Unit ଌ. 2015;39(7):412-421.

281. Lentsck MH. Risk factors for death of trauma patients admitted to an Intensive Care Unit *. Published online 2020. doi:10.1590/1518-8345.3482.3236

282. Miroshnychenko A, Zeraatkar D, Phillips MR, et al. Cohort studies investigating the effects of exposures : key principles that impact the credibility of the results. 2022;(January):2021-2022. doi:10.1038/s41433-021-01897-0

283. Maninder Singh Setia. Methodology Series Module 1: Cohort Studies. *Indian J Dermatol*. 2016;61(1):21-25. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4763690/

284. Szklo M, Nieto F. *Epidemiology: Beyond the Basics*. Third. (Jones and Bartlett Learning, ed.).; 2014.

285. Riuttanen A. Alcohol use in severely injured trauma patients. *Sci Rep*. 2020;(0123456789):1-8. doi:10.1038/s41598-020-74753-y

286. Hsieh C, Su L, Sc M, Wang Y, Fu C. Does Alcohol Intoxication Protect Patients from Severe Injury and Reduce Hospital Mortality ? The Association of Alcohol Consumption with the Severity of Injury and Survival in Trauma Patients. Published online 2011:1289-1295.

287. Greenberg NAP. Patient mortality following alcohol use and trauma : a propensity - matched analysis. Published online 2019:151-158. doi:10.1007/s00068-017-0794-6

288. Paice R. An overview of New Zealand's trauma system. *J Trauma Nurs*. 2007;14(4):211-213.

289. Major Trauma National Clinical Network, St John, Wellintong Free Ambulance. *New Zealand Out-of-Hospital Major Trauma Destination Policy*.; 2017. https://www.northerntrauma.co.nz/wp-content/uploads/2021/03/New-Zealand-Out-of-

Hospital-Major-Trauma-Destination-Policy-—-AUCKLAND-AND-NORTHLAND.pdf

290. Christey G, Amey J, Campbell A, Smith A. Variation in volumes and characteristics of trauma patients admitted to a level one trauma centre during national level 4 lockdown for COVID-19 in New Zealand. 2020;133(1513).

Appendices

Appendix 1: Search strategy

Search Number	Search	Results
1	"major trauma".mp.	3,359
2	"severe trauma".mp.	3,030
3	"injury severity score".mp. or Injury Severity Score/	19,176
4	1 or 2 or 3	24,004
5	Epidemiology/ or epidemiology.mp.	1,653,572
6	incidence.mp. or Incidence/	802,020
7	Prevalence/ or prevalence.mp.	655,989
8	Vital Statistics/ or "vital statistics".mp.	9,452
9	5 or 6 or 7 or 8	2,405,875
10	. New Zealand/ or zealand.mp.	68,179
11	. 4 and 9 and 10	102

Appendix 2: Algorithm code

As mentioned before, Dr Dinh and his colleagues gave us the permission to use the mapping tool in this study. However, although the files provided by them included a description of how to use the tool, they did not contain any code written by the authors to calculate the ISS. The PhD candidate (LM) with the supervision of GD, BK and BD wrote the following algorithm in Stata SE version 17[239].

```
foreach var of varlist nmds_a1- nmds_b48 {

*replace `var'= lower(itrim(ltrim(rtrim(`var'))))

gen maxais1bodyreg1`var'= regexm(`var', "S0008") | regexm(`var', "S007") | regexm(`var', "S0088") | regexm(`var', "S0098") | regexm(`var', "S0129") | regexm(`var', "S0136") | regexm(`var', "S0137") | regexm(`var', "S0138") | regexm(`var', "S0139") | regexm(`var', "S0159") | regexm(`var', "S017") | regexm(`var', "S0188") | regexm(`var', "S035") | regexm(`var', "S060") | regexm(`var', "S069") | regexm(`var', "S089") | regexm(`var', "S090") | regexm(`var', "S098") | regexm(`var', "S099") | regexm(`var', "S1013") | regexm(`var', "S1018") | regexm(`var', "S107") | regexm(`var', "S1088") | regexm(`var', "S1098") | regexm(`var', "S117") | regexm(`var', "S1188") | regexm(`var', "S134") | regexm(`var', "S144") | regexm(`var', "S145") | regexm(`var', "S152") | regexm(`var', "S153") | regexm(`var', "S158") | regexm(`var', "S159") | regexm(`var', "S198") | regexm(`var', "S199") | regexm(`var', "T000") | regexm(`var', "T900") | regexm(`var', "T901") | regexm(`var', "T903") | regexm(`var', "T908") | regexm(`var', "T909") | regexm(`var', "T910")

*

gen maxais1bodyreg2`var'= regexm(`var', "S0023") | regexm(`var', "S0028") | regexm(`var', "S0038") | regexm(`var', "S0048") | regexm(`var', "S0058") | regexm(`var', "S0149") | regexm(`var', "S223") | regexm(`var', "S2231") | regexm(`var', "S2232") | regexm(`var', "S233") | regexm(`var', "S234")

*

gen maxais1bodyreg3`var'= regexm(`var', "S2013") | regexm(`var', "S2018") | regexm(`var', "S2033") | regexm(`var', "S2038") | regexm(`var', "S2043") | regexm(`var', "S2048") | regexm(`var', "S207") | regexm(`var', "S2080") | regexm(`var', "S2081") | regexm(`var', "S2082") | regexm(`var', "S2083") | regexm(`var', "S2084") | regexm(`var', "S2088") | regexm(`var', "S217") | regexm(`var', "S235") | regexm(`var', "S245") | regexm(`var', "S277") | regexm(`var', "S2784") | regexm(`var', "S312") | regexm(`var', "S313") | regexm(`var', "S314") | regexm(`var', "S335") | regexm(`var', "S348") | regexm(`var', "S374") | regexm(`var', "S376") | regexm(`var', "S3781") | regexm(`var', "S3782")

*
```

gen maxais1bodyreg4`var'= regexm(`var', "S307") | regexm(`var', "S3080") | regexm(`var', "S3083") | regexm(`var', "S3088") | regexm(`var', "S3090") | regexm(`var', "S336") | regexm(`var', "S429") | regexm(`var', "S433") | regexm(`var', "S434") | regexm(`var', "S435") | regexm(`var', "S436") | regexm(`var', "S440") | regexm(`var', "S441") | regexm(`var', "S442") | regexm(`var', "S443") | regexm(`var', "S444") | regexm(`var', "S445") | regexm(`var', "S448") | regexm(`var', "S449") | regexm(`var', "S453") | regexm(`var', "S458") | regexm(`var', "S459") | regexm(`var', "S460") | regexm(`var', "S461") | regexm(`var', "S462") | regexm(`var', "S463") | regexm(`var', "S468") | regexm(`var', "S469") | regexm(`var', "S498") | regexm(`var', "S499") | regexm(`var', "S530") | regexm(`var', "S531") | regexm(`var', "S5310") | regexm(`var', "S5311") | regexm(`var', "S5312") | regexm(`var', "S5313") | regexm(`var', "S5314") | regexm(`var', "S532") | regexm(`var', "S533") | regexm(`var', "S534") | regexm(`var', "S5340") | regexm(`var', "S5341") | regexm(`var', "S5342") | regexm(`var', "S5343") | regexm(`var', "S5344") | regexm(`var', "S540") | regexm(`var', "S541") | regexm(`var', "S542") | regexm(`var', "S543") | regexm(`var', "S548") | regexm(`var', "S549") | regexm(`var', "S550") | regexm(`var', "S551") | regexm(`var', "S552") | regexm(`var', "S558") | regexm(`var', "S560") | regexm(`var', "S561") | regexm(`var', "S562") | regexm(`var', "S563") | regexm(`var', "S564") | regexm(`var', "S565") | regexm(`var', "S568") | regexm(`var', "S598") | regexm(`var', "S599") | regexm(`var', "S625") | regexm(`var', "S6250") | regexm(`var', "S6251") | regexm(`var', "S6252") | regexm(`var', "S626") | regexm(`var', "S6260") | regexm(`var', "S6261") | regexm(`var', "S6262") | regexm(`var', "S6263") | regexm(`var', "S630") | regexm(`var', "S6300") | regexm(`var', "S6301") | regexm(`var', "S6303") | regexm(`var', "S6304") | regexm(`var', "S631") | regexm(`var', "S6310") | regexm(`var', "S6311") | regexm(`var', "S6312") | regexm(`var', "S632") | regexm(`var', "S633") | regexm(`var', "S634") | regexm(`var', "S635") | regexm(`var', "S6350") | regexm(`var', "S6351") | regexm(`var', "S6352") | regexm(`var', "S636") | regexm(`var', "S6360") | regexm(`var', "S6361") | regexm(`var', "S6362") | regexm(`var', "S6368") | regexm(`var', "S640") | regexm(`var', "S641") | regexm(`var', "S642") | regexm(`var', "S643") | regexm(`var', "S644") | regexm(`var', "S648") | regexm(`var', "S649") | regexm(`var', "S650") | regexm(`var', "S651") | regexm(`var', "S652") | regexm(`var', "S653") | regexm(`var', "S654") | regexm(`var', "S655") | regexm(`var', "S658") | regexm(`var', "S659") | regexm(`var', "S660") | regexm(`var', "S661") | regexm(`var', "S662") | regexm(`var', "S663") | regexm(`var', "S664") | regexm(`var', "S665") | regexm(`var', "S668") | regexm(`var', "S669") | regexm(`var', "S681") | regexm(`var', "S698") | regexm(`var', "S699") | regexm(`var', "S731") | regexm(`var', "S7310") | regexm(`var', "S7311") | regexm(`var', "S7312") | regexm(`var', "S742") | regexm(`var', "S748") | regexm(`var', "S749") | regexm(`var', "S752") | regexm(`var', "S758") | regexm(`var', "S760") | regexm(`var', "S761") | regexm(`var', "S762") | regexm(`var', "S763") | regexm(`var', "S798") | regexm(`var', "S799") | regexm(`var', "S830") | regexm(`var', "S833") | regexm(`var', "S836") | regexm(`var', "S842") | regexm(`var', "S848") | regexm(`var', "S849") | regexm(`var', "S851") | regexm(`var', "S852") | regexm(`var', "S853") | regexm(`var', "S854") | regexm(`var', "S858") | regexm(`var', "S859") | regexm(`var', "S860") | regexm(`var', "S898") | regexm(`var', "S899") | regexm(`var', "S924") | regexm(`var', "S925") | regexm(`var', "S931") | regexm(`var', "S9310") | regexm(`var', "S9311") | regexm(`var', "S9312") | regexm(`var', "S933") | regexm(`var', "S9330") | regexm(`var', "S9331") | regexm(`var', "S9332") | regexm(`var', "S9333") | regexm(`var', "S934") | regexm(`var', "S9340") | regexm(`var', "S9341") | regexm(`var', "S9342") | regexm(`var', "S9343") | regexm(`var', "S935") | regexm(`var', "S936") | regexm(`var', "S940") | regexm(`var', "S941") | regexm(`var', "S943") | regexm(`var', "S948") | regexm(`var', "S949") | regexm(`var', "S950") |

regexm(`var', "S951") | regexm(`var', "S952") | regexm(`var', "S958") | regexm(`var', "S969") | regexm(`var', "S998") | regexm(`var', "S999") | regexm(`var', "T0900") | regexm(`var', "T918") | regexm(`var', "T919")

*

gen maxais1bodyreg5`var'= regexm(`var', "S015") | regexm(`var', "S0150") | regexm(`var', "S0151") | regexm(`var', "S0152") | regexm(`var', "S0153") | regexm(`var', "S0154") | regexm(`var', "S0155") | regexm(`var', "S022") | regexm(`var', "S025") | regexm(`var', "S026") | regexm(`var', "S0260") | regexm(`var', "S0261") | regexm(`var', "S0262") | regexm(`var', "S0263") | regexm(`var', "S0264") | regexm(`var', "S0265") | regexm(`var', "S0266") | regexm(`var', "S0269") | regexm(`var', "S031") | regexm(`var', "S032") | regexm(`var', "S034") | regexm(`var', "S050") | regexm(`var', "S051") | regexm(`var', "S055") | regexm(`var', "S058") | regexm(`var', "S059") | regexm(`var', "S092") | regexm(`var', "S407") | regexm(`var', "S4083") | regexm(`var', "S4088") | regexm(`var', "S417") | regexm(`var', "S4180") | regexm(`var', "S47") | regexm(`var', "S497") | regexm(`var', "S507") | regexm(`var', "S5083") | regexm(`var', "S5088") | regexm(`var', "S517") | regexm(`var', "S5188") | regexm(`var', "S519") | regexm(`var', "S5348") | regexm(`var', "S567") | regexm(`var', "S579") | regexm(`var', "S597") | regexm(`var', "S607") | regexm(`var', "S6083") | regexm(`var', "S6088") | regexm(`var', "S617") | regexm(`var', "S618") | regexm(`var', "S6188") | regexm(`var', "S619") | regexm(`var', "S6353") | regexm(`var', "S6358") | regexm(`var', "S637") | regexm(`var', "S707") | regexm(`var', "S7081") | regexm(`var', "S7082") | regexm(`var', "S7083") | regexm(`var', "S7084") | regexm(`var', "S7088") | regexm(`var', "S717") | regexm(`var', "S7180") | regexm(`var', "S8083") | regexm(`var', "S8088") | regexm(`var', "S817") | regexm(`var', "S8188") | regexm(`var', "S819") | regexm(`var', "S8218") | regexm(`var', "S8343") | regexm(`var', "S8344") | regexm(`var', "S8353") | regexm(`var', "S8354") | regexm(`var', "S907") | regexm(`var', "S9083") | regexm(`var', "S9088") | regexm(`var', "S917") | regexm(`var', "T002") | regexm(`var', "T003") | regexm(`var', "T006") | regexm(`var', "T008") | regexm(`var', "T009") | regexm(`var', "T010") | regexm(`var', "T011") | regexm(`var', "T012") | regexm(`var', "T013") | regexm(`var', "T016") | regexm(`var', "T064") | regexm(`var', "T099") | regexm(`var', "T1100") | regexm(`var', "T1101") | regexm(`var', "T1102") | regexm(`var', "T1103") | regexm(`var', "T1104") | regexm(`var', "T1105") | regexm(`var', "T1108") | regexm(`var', "T111") | regexm(`var', "T113") | regexm(`var', "T114") | regexm(`var', "T115") | regexm(`var', "T118") | regexm(`var', "T119") | regexm(`var', "T1300") | regexm(`var', "T1301") | regexm(`var', "T1302") | regexm(`var', "T1303") | regexm(`var', "T1304") | regexm(`var', "T1305") | regexm(`var', "T1308") | regexm(`var', "T131") | regexm(`var', "T134") | regexm(`var', "T135") | regexm(`var', "T150") | regexm(`var', "T261") | regexm(`var', "T700") | regexm(`var', "T920") | regexm(`var', "T929") | regexm(`var', "T930") | regexm(`var', "T950") | regexm(`var', "T951") | regexm(`var', "T952") | regexm(`var', "T953") | regexm(`var', "T958")| regexm(`var', "T959")

*

gen maxais1bodyreg6`var'= regexm(`var', "S000") | regexm(`var', "S0000") | regexm(`var', "S0001") | regexm(`var', "S0003") | regexm(`var', "S001") | regexm(`var', "S002") | regexm(`var', "S0020") | regexm(`var', "S0021") | regexm(`var', "S003") | regexm(`var', "S0030") | regexm(`var', "S0031") | regexm(`var', "S0033") | regexm(`var', "S004") | regexm(`var', "S0040") | regexm(`var', "S0041") | regexm(`var', "S0043") | regexm(`var', "S005") | regexm(`var', "S0050") | regexm(`var', "S0051") | regexm(`var', "S0053") | regexm(`var', "S008") |

regexm(`var', "S0080") | regexm(`var', "S0081") | regexm(`var', "S0083") | regexm(`var', "S009") | regexm(`var', "S0090") | regexm(`var', "S0091") | regexm(`var', "S0093") | regexm(`var', "S010") | regexm(`var', "S011") | regexm(`var', "S012") | regexm(`var', "S0120") | regexm(`var', "S0121") | regexm(`var', "S0122") | regexm(`var', "S0123") | regexm(`var', "S013") | regexm(`var', "S0130") | regexm(`var', "S0131") | regexm(`var', "S0133") | regexm(`var', "S0134") | regexm(`var', "S0135") | regexm(`var', "S014") | regexm(`var', "S0141") | regexm(`var', "S0142") | regexm(`var', "S0143") | regexm(`var', "S0181") | regexm(`var', "S0182") | regexm(`var', "S0183") | regexm(`var', "S019") | regexm(`var', "S054") | regexm(`var', "S056") | regexm(`var', "S080") | regexm(`var', "S081") | regexm(`var', "S101") | regexm(`var', "S1010") | regexm(`var', "S1011") | regexm(`var', "S108") | regexm(`var', "S1080") | regexm(`var', "S1081") | regexm(`var', "S1083") | regexm(`var', "S109") | regexm(`var', "S1090") | regexm(`var', "S1091") | regexm(`var', "S1093") | regexm(`var', "S118") | regexm(`var', "S1181") | regexm(`var', "S1182") | regexm(`var', "S119") | regexm(`var', "S200") | regexm(`var', "S201") | regexm(`var', "S2010") | regexm(`var', "S2011") | regexm(`var', "S202") | regexm(`var', "S203") | regexm(`var', "S2030") | regexm(`var', "S2031") | regexm(`var', "S204") | regexm(`var', "S2040") | regexm(`var', "S2041") | regexm(`var', "S210") | regexm(`var', "S211") | regexm(`var', "S212") | regexm(`var', "S219") | regexm(`var', "S290") | regexm(`var', "S300") | regexm(`var', "S301") | regexm(`var', "S302") | regexm(`var', "S308") | regexm(`var', "S3081") | regexm(`var', "S309") | regexm(`var', "S3091") | regexm(`var', "S3092") | regexm(`var', "S3093") | regexm(`var', "S3094") | regexm(`var', "S3098") | regexm(`var', "S310") | regexm(`var', "S311") | regexm(`var', "S315") | regexm(`var', "S318") | regexm(`var', "S390") | regexm(`var', "S400") | regexm(`var', "S408") | regexm(`var', "S4081") | regexm(`var', "S409") | regexm(`var', "S500") | regexm(`var', "S501") | regexm(`var', "S508") | regexm(`var', "S5081") | regexm(`var', "S509") | regexm(`var', "S5181") | regexm(`var', "S5182") | regexm(`var', "S600") | regexm(`var', "S601") | regexm(`var', "S602") | regexm(`var', "S608") | regexm(`var', "S6081") | regexm(`var', "S609") | regexm(`var', "S700") | regexm(`var', "S701") | regexm(`var', "S709") | regexm(`var', "S800") | regexm(`var', "S801") | regexm(`var', "S808") | regexm(`var', "S8081") | regexm(`var', "S809") | regexm(`var', "S8181") | regexm(`var', "S8182") | regexm(`var', "S900") | regexm(`var', "S901") | regexm(`var', "S902") | regexm(`var', "S903") | regexm(`var', "S908") | regexm(`var', "S9081") | regexm(`var', "S909") | regexm(`var', "T001") | regexm(`var', "T018") | regexm(`var', "T019") | regexm(`var', "T0901") | regexm(`var', "T0902") | regexm(`var', "T0903") | regexm(`var', "T0904") | regexm(`var', "T0905") | regexm(`var', "T0908") | regexm(`var', "T091") | regexm(`var', "T092") | regexm(`var', "T1400") | regexm(`var', "T1401") | regexm(`var', "T1402") | regexm(`var', "T1403") | regexm(`var', "T1404") | regexm(`var', "T1405") | regexm(`var', "T1408") | regexm(`var', "T200") | regexm(`var', "T201") | regexm(`var', "T202") | regexm(`var', "T210") | regexm(`var', "T2100") | regexm(`var', "T2101") | regexm(`var', "T2102") | regexm(`var', "T2103") | regexm(`var', "T2104") | regexm(`var', "T2105") | regexm(`var', "T2109") | regexm(`var', "T211") | regexm(`var', "T2110") | regexm(`var', "T2111") | regexm(`var', "T2112") | regexm(`var', "T2113") | regexm(`var', "T2114") | regexm(`var', "T2115") | regexm(`var', "T2119") | regexm(`var', "T2121") | regexm(`var', "T2122") | regexm(`var', "T2123") | regexm(`var', "T2124") | regexm(`var', "T2125") | regexm(`var', "T220") | regexm(`var', "T2200") | regexm(`var', "T2201") | regexm(`var', "T2202") | regexm(`var', "T221") | regexm(`var', "T2210") | regexm(`var', "T2211") | regexm(`var', "T2212") | regexm(`var', "T222") | regexm(`var', "T2220") | regexm(`var', "T2221") | regexm(`var', "T2222") | regexm(`var', "T230") | regexm(`var', "T231") | regexm(`var', "T232") | regexm(`var', "T240") | regexm(`var', "T241") | regexm(`var', "T242") | regexm(`var', "T250") | regexm(`var', "T251") | regexm(`var', "T252") | regexm(`var', "T260") | regexm(`var', "T263") | regexm(`var', "T264") | regexm(`var', "T290") | regexm(`var', "T291") | regexm(`var', "T292") | regexm(`var', "T300") | regexm(`var', "T301") | regexm(`var', "T302") | regexm(`var', "T310") | regexm(`var', "T33") | regexm(`var', "T330") | regexm(`var', "T331") | regexm(`var', "T332") | regexm(`var', "T333") | regexm(`var', "T334") | regexm(`var', "T335") | regexm(`var', "T336") | regexm(`var', "T337") | regexm(`var', "T338") | regexm(`var', "T339") | regexm(`var', "T353") | regexm(`var', "T354") | regexm(`var', "T355") | regexm(`var', "T68")

*

gen maxais2bodyreg0`var'= regexm(`var', "S078")

*

gen maxais2bodyreg1`var'= regexm(`var', "S020") | regexm(`var', "S0268") | regexm(`var', "S029") | regexm(`var', "S033") | regexm(`var', "S040") | regexm(`var', "S041") | regexm(`var', "S042") | regexm(`var', "S043") | regexm(`var', "S044") | regexm(`var', "S045") | regexm(`var', "S046") | regexm(`var', "S047") | regexm(`var', "S048") | regexm(`var', "S049") | regexm(`var', "S0600") | regexm(`var', "S0601") | regexm(`var', "S0602") | regexm(`var', "S0603") | regexm(`var', "S066") | regexm(`var', "S071") | regexm(`var', "S097") | regexm(`var', "S100") | regexm(`var', "S110") | regexm(`var', "S1101") | regexm(`var', "S1102") | regexm(`var', "S111") | regexm(`var', "S120") | regexm(`var', "S121") | regexm(`var', "S122") | regexm(`var', "S1221") | regexm(`var', "S1222") | regexm(`var', "S1223") | regexm(`var', "S1224") | regexm(`var', "S1225") | regexm(`var', "S127") | regexm(`var', "S131") | regexm(`var', "S1310") | regexm(`var', "S1311") | regexm(`var', "S1313") | regexm(`var', "S1314") | regexm(`var', "S1315") | regexm(`var', "S1316") | regexm(`var', "S1317") | regexm(`var', "S1318") | regexm(`var', "S133") | regexm(`var', "S136") | regexm(`var', "S142") | regexm(`var', "S143") | regexm(`var', "S146") | regexm(`var', "S1470") | regexm(`var', "S1503") | regexm(`var', "S151") | regexm(`var', "S16") | regexm(`var', "S178") | regexm(`var', "S179") | regexm(`var', "S197") | regexm(`var', "T0201") | regexm(`var', "T040") | regexm(`var', "T080") | regexm(`var', "T902") | regexm(`var', "T904") | regexm(`var', "T905")

*

gen maxais2bodyreg2`var'= regexm(`var', "S220") | regexm(`var', "S2200") | regexm(`var', "S2201") | regexm(`var', "S2202") | regexm(`var', "S2203") | regexm(`var', "S2204") | regexm(`var', "S2205") | regexm(`var', "S2206") | regexm(`var', "S222") | regexm(`var', "S224") | regexm(`var', "S2242") | regexm(`var', "S2243") | regexm(`var', "S229") | regexm(`var', "S231") | regexm(`var', "S2310") | regexm(`var', "S2311") | regexm(`var', "S2312") | regexm(`var', "S2313") | regexm(`var', "S2314") | regexm(`var', "S2315") | regexm(`var', "S2316") | regexm(`var', "S2317") | regexm(`var', "S242") | regexm(`var', "S255") | regexm(`var', "S270") | regexm(`var', "S274") | regexm(`var', "S276") | regexm(`var', "S278") | regexm(`var', "S2781") | regexm(`var', "S279") | regexm(`var', "S298") | regexm(`var', "S299") | regexm(`var', "T270") | regexm(`var', "T271") | regexm(`var', "T272") | regexm(`var', "T273")

*

```
gen maxais2bodyreg3`var'= regexm(`var', "S2181") | regexm(`var', "S221") | regexm(`var', "S2240") | regexm(`var', "S228") | regexm(`var', "S246") | regexm(`var', "S3183") | regexm(`var', "S320") | regexm(`var', "S3200") | regexm(`var', "S3201") | regexm(`var', "S3202") | regexm(`var', "S3203") | regexm(`var', "S3204") | regexm(`var', "S3205") | regexm(`var', "S331") | regexm(`var', "S3310") | regexm(`var', "S3311") | regexm(`var', "S3312") | regexm(`var', "S3313") | regexm(`var', "S3314") | regexm(`var', "S333") | regexm(`var', "S342") | regexm(`var', "S344") | regexm(`var', "S360") | regexm(`var', "S3602") | regexm(`var', "S3603") | regexm(`var', "S361") | regexm(`var', "S3612") | regexm(`var', "S362") | regexm(`var', "S3620") | regexm(`var', "S3622") | regexm(`var', "S3623") | regexm(`var', "S363") | regexm(`var', "S364") | regexm(`var', "S3640") | regexm(`var', "S3641") | regexm(`var', "S3649") | regexm(`var', "S365") | regexm(`var', "S3650") | regexm(`var', "S3651") | regexm(`var', "S3652") | regexm(`var', "S3653") | regexm(`var', "S3659") | regexm(`var', "S366") | regexm(`var', "S368") | regexm(`var', "S3681") | regexm(`var', "S369") | regexm(`var', "S370") | regexm(`var', "S3700") | regexm(`var', "S3701") | regexm(`var', "S3703") | regexm(`var', "S371") | regexm(`var', "S372") | regexm(`var', "S3720") | regexm(`var', "S3722") | regexm(`var', "S373") | regexm(`var', "S3730") | regexm(`var', "S3732") | regexm(`var', "S3733") | regexm(`var', "S379") | regexm(`var', "S380") | regexm(`var', "S382") | regexm(`var', "T0210") | regexm(`var', "T041") | regexm(`var', "T911") | regexm(`var', "T912") | regexm(`var', "T914")

*

gen maxais2bodyreg4`var'= regexm(`var', "S317") | regexm(`var', "S321") | regexm(`var', "S322") | regexm(`var', "S323") | regexm(`var', "S324") | regexm(`var', "S325") | regexm(`var', "S328") | regexm(`var', "S3282") | regexm(`var', "S3289") | regexm(`var', "S332") | regexm(`var', "S3616") | regexm(`var', "S3617") | regexm(`var', "S3618") | regexm(`var', "S3621") | regexm(`var', "S3654") | regexm(`var', "S3682") | regexm(`var', "S3688") | regexm(`var', "S420") | regexm(`var', "S4200") | regexm(`var', "S4201") | regexm(`var', "S4202") | regexm(`var', "S4203") | regexm(`var', "S421") | regexm(`var', "S4210") | regexm(`var', "S4211") | regexm(`var', "S4212") | regexm(`var', "S4213") | regexm(`var', "S4214") | regexm(`var', "S4219") | regexm(`var', "S422") | regexm(`var', "S4220") | regexm(`var', "S4221") | regexm(`var', "S4222") | regexm(`var', "S4223") | regexm(`var', "S4224") | regexm(`var', "S4229") | regexm(`var', "S423") | regexm(`var', "S424") | regexm(`var', "S4240") | regexm(`var', "S4241") | regexm(`var', "S4242") | regexm(`var', "S4243") | regexm(`var', "S4244") | regexm(`var', "S4245") | regexm(`var', "S4249") | regexm(`var', "S430") | regexm(`var', "S4300") | regexm(`var', "S4301") | regexm(`var', "S4302") | regexm(`var', "S4303") | regexm(`var', "S4308") | regexm(`var', "S431") | regexm(`var', "S432") | regexm(`var', "S450") | regexm(`var', "S451") | regexm(`var', "S452") | regexm(`var', "S520") | regexm(`var', "S5200") | regexm(`var', "S5201") | regexm(`var', "S5202") | regexm(`var', "S5209") | regexm(`var', "S521") | regexm(`var', "S5210") | regexm(`var', "S5211") | regexm(`var', "S5212") | regexm(`var', "S522") | regexm(`var', "S5220") | regexm(`var', "S5221") | regexm(`var', "S523") | regexm(`var', "S5230") | regexm(`var', "S5231") | regexm(`var', "S525") | regexm(`var', "S5250") | regexm(`var', "S5251") | regexm(`var', "S5252") | regexm(`var', "S5253") | regexm(`var', "S5259") | regexm(`var', "S526") | regexm(`var', "S529") | regexm(`var', "S559") | regexm(`var', "S570") | regexm(`var', "S578") | regexm(`var', "S620") | regexm(`var', "S621") | regexm(`var', "S6210") | regexm(`var', "S6211") | regexm(`var', "S6212") | regexm(`var', "S6213") | regexm(`var', "S6214") | regexm(`var', "S6215") | regexm(`var', "S6216") | regexm(`var', "S6217") | regexm(`var', "S622") | regexm(`var', "S6220") | regexm(`var', "S6221") | regexm(`var', "S6222") | regexm(`var', "S6223") | regexm(`var', "S6224") |
```

regexm(`var', "S623") | regexm(`var', "S6230") | regexm(`var', "S6231") | regexm(`var', "S6232") | regexm(`var', "S6233") | regexm(`var', "S6234") | regexm(`var', "S6302") | regexm(`var', "S670") | regexm(`var', "S680") | regexm(`var', "S730") | regexm(`var', "S7300") | regexm(`var', "S7301") | regexm(`var', "S7302") | regexm(`var', "S740") | regexm(`var', "S741") | regexm(`var', "S751") | regexm(`var', "S770") | regexm(`var', "S771") | regexm(`var', "S772") | regexm(`var', "S820") | regexm(`var', "S821") | regexm(`var', "S8211") | regexm(`var', "S822") | regexm(`var', "S823") | regexm(`var', "S8231") | regexm(`var', "S824") | regexm(`var', "S8240") | regexm(`var', "S8242") | regexm(`var', "S8249") | regexm(`var', "S825") | regexm(`var', "S826") | regexm(`var', "S828") | regexm(`var', "S8281") | regexm(`var', "S8282") | regexm(`var', "S829") | regexm(`var', "S831") | regexm(`var', "S8310") | regexm(`var', "S8311") | regexm(`var', "S8312") | regexm(`var', "S8313") | regexm(`var', "S8314") | regexm(`var', "S832") | regexm(`var', "S834") | regexm(`var', "S8340") | regexm(`var', "S8341") | regexm(`var', "S8342") | regexm(`var', "S835") | regexm(`var', "S8350") | regexm(`var', "S8351") | regexm(`var', "S8352") | regexm(`var', "S840") | regexm(`var', "S841") | regexm(`var', "S850") | regexm(`var', "S855") | regexm(`var', "S861") | regexm(`var', "S862") | regexm(`var', "S863") | regexm(`var', "S868") | regexm(`var', "S869") | regexm(`var', "S870") | regexm(`var', "S878") | regexm(`var', "S920") | regexm(`var', "S921") | regexm(`var', "S922") | regexm(`var', "S9220") | regexm(`var', "S9221") | regexm(`var', "S9222") | regexm(`var', "S9223") | regexm(`var', "S923") | regexm(`var', "S929") | regexm(`var', "S930") | regexm(`var', "S942") | regexm(`var', "S959") | regexm(`var', "S960") | regexm(`var', "S961") | regexm(`var', "S962") | regexm(`var', "S968") | regexm(`var', "S970") | regexm(`var', "S971") | regexm(`var', "S978") | regexm(`var', "S981") | regexm(`var', "S982") | regexm(`var', "S983") | regexm(`var', "T081") | regexm(`var', "T093")

*

gen maxais2bodyreg5`var'= regexm(`var', "S023") | regexm(`var', "S024") | regexm(`var', "S0267") | regexm(`var', "S028") | regexm(`var', "S030") | regexm(`var', "S052") | regexm(`var', "S053") | regexm(`var', "S057") | regexm(`var', "S070") | regexm(`var', "S327") | regexm(`var', "S3283") | regexm(`var', "S3351") | regexm(`var', "S337") | regexm(`var', "S3683") | regexm(`var', "S3721") | regexm(`var', "S3728") | regexm(`var', "S3731") | regexm(`var', "S3738") | regexm(`var', "S3783") | regexm(`var', "S3784") | regexm(`var', "S3788") | regexm(`var', "S396") | regexm(`var', "S397") | regexm(`var', "S4181") | regexm(`var', "S4182") | regexm(`var', "S4209") | regexm(`var', "S427") | regexm(`var', "S428") | regexm(`var', "S437") | regexm(`var', "S447") | regexm(`var', "S457") | regexm(`var', "S467") | regexm(`var', "S5219") | regexm(`var', "S524") | regexm(`var', "S527") | regexm(`var', "S528") | regexm(`var', "S5318") | regexm(`var', "S547") | regexm(`var', "S557") | regexm(`var', "S6181") | regexm(`var', "S6182") | regexm(`var', "S6219") | regexm(`var', "S624") | regexm(`var', "S627") | regexm(`var', "S628") | regexm(`var', "S6308") | regexm(`var', "S647") | regexm(`var', "S657") | regexm(`var', "S666") | regexm(`var', "S667") | regexm(`var', "S678") | regexm(`var', "S682") | regexm(`var', "S683") | regexm(`var', "S697") | regexm(`var', "S7181") | regexm(`var', "S7182") | regexm(`var', "S7208") | regexm(`var', "S727") | regexm(`var', "S7308") | regexm(`var', "S7318") | regexm(`var', "S757") | regexm(`var', "S764") | regexm(`var', "S767") | regexm(`var', "S797") | regexm(`var', "S807") | regexm(`var', "S8221") | regexm(`var', "S8228") | regexm(`var', "S8238") | regexm(`var', "S8241") | regexm(`var', "S827") | regexm(`var', "S8288") | regexm(`var', "S8318") | regexm(`var', "S837") | regexm(`var', "S847") | regexm(`var', "S867") | regexm(`var', "S897") | regexm(`var', "S9181") | regexm(`var', "S9182") | regexm(`var', "S9228") | regexm(`var', "S927") | regexm(`var', "S932") | regexm(`var', "S9334") | regexm(`var', "S9338") | regexm(`var', "S9348") | regexm(`var', "S947") | regexm(`var', "S957") | regexm(`var', "S967") | regexm(`var', "S997") | regexm(`var', "T0220") | regexm(`var', "T0230") | regexm(`var', "T0231") | regexm(`var', "T0240") | regexm(`var', "T0250") | regexm(`var', "T0251") | regexm(`var', "T026") | regexm(`var', "T0260") | regexm(`var', "T0261") | regexm(`var', "T0270") | regexm(`var', "T0280") | regexm(`var', "T0281") | regexm(`var', "T0290") | regexm(`var', "T0291") | regexm(`var', "T030") | regexm(`var', "T031") | regexm(`var', "T032") | regexm(`var', "T033") | regexm(`var', "T034") | regexm(`var', "T038") | regexm(`var', "T039") | regexm(`var', "T042") | regexm(`var', "T043") | regexm(`var', "T047") | regexm(`var', "T048") | regexm(`var', "T100") | regexm(`var', "T101") | regexm(`var', "T112") | regexm(`var', "T120") | regexm(`var', "T121") | regexm(`var', "T132") | regexm(`var', "T133") | regexm(`var', "T136") | regexm(`var', "T138") | regexm(`var', "T139") | regexm(`var', "T262") | regexm(`var', "T921") | regexm(`var', "T922") | regexm(`var', "T923") | regexm(`var', "T924") | regexm(`var', "T925") | regexm(`var', "T926") | regexm(`var', "T928") | regexm(`var', "T931") | regexm(`var', "T932") | regexm(`var', "T933") | regexm(`var', "T934") | regexm(`var', "T935") | regexm(`var', "T936") | regexm(`var', "T938") | regexm(`var', "T939") | regexm(`var', "T940") | regexm(`var', "T941")

*

gen maxais2bodyreg6`var'= regexm(`var', "S3180") | regexm(`var', "S3181") | regexm(`var', "S3182") | regexm(`var', "S410") | regexm(`var', "S411") | regexm(`var', "S510") | regexm(`var', "S518") | regexm(`var', "S610") | regexm(`var', "S611") | regexm(`var', "S710") | regexm(`var', "S711") | regexm(`var', "S810") | regexm(`var', "S818") | regexm(`var', "S910") | regexm(`var', "S911") | regexm(`var', "S912") | regexm(`var', "S913") | regexm(`var', "T058") | regexm(`var', "T203") | regexm(`var', "T2131") | regexm(`var', "T2132") | regexm(`var', "T2133") | regexm(`var', "T2134") | regexm(`var', "T2135") | regexm(`var', "T223") | regexm(`var', "T2230") | regexm(`var', "T2231") | regexm(`var', "T2232") | regexm(`var', "T233") | regexm(`var', "T253") | regexm(`var', "T293") | regexm(`var', "T3100") | regexm(`var', "T311") | regexm(`var', "T34") | regexm(`var', "T340") | regexm(`var', "T341") | regexm(`var', "T342") | regexm(`var', "T344") | regexm(`var', "T346") | regexm(`var', "T347") | regexm(`var', "T349") | regexm(`var', "T750") | regexm(`var', "T754")

*

gen maxais3bodyreg1`var'= regexm(`var', "S021") | regexm(`var', "S0604") | regexm(`var', "S0605") | regexm(`var', "S061") | regexm(`var', "S063") | regexm(`var', "S0630") | regexm(`var', "S0631") | regexm(`var', "S0632") | regexm(`var', "S0633") | regexm(`var', "S0634") | regexm(`var', "S064") | regexm(`var', "S065") | regexm(`var', "S112") | regexm(`var', "S1121") | regexm(`var', "S1122") | regexm(`var', "S128") | regexm(`var', "S129") | regexm(`var', "S130") | regexm(`var', "S1312") | regexm(`var', "S140") | regexm(`var', "S1478") | regexm(`var', "S150") | regexm(`var', "S1500") | regexm(`var', "S1501") | regexm(`var', "S157") | regexm(`var', "T060") | regexm(`var', "T061") | regexm(`var', "T281") | regexm(`var', "T71")

*

gen maxais3bodyreg2`var'= regexm(`var', "S027") | regexm(`var', "S2241") | regexm(`var', "S225") | regexm(`var', "S230") | regexm(`var', "S240") | regexm(`var', "S251") | regexm(`var', "S252") | regexm(`var', "S253") | regexm(`var', "S254") | regexm(`var', "S258") | regexm(`var', "S259") | regexm(`var', "S260") | regexm(`var', "S269") | regexm(`var', "S271") | regexm(`var', "S273") | regexm(`var', "S2731") | regexm(`var', "S2732") | regexm(`var', "S275") | regexm(`var', "T751")

*

gen maxais3bodyreg3`var'= regexm(`var', "S2183") | regexm(`var', "S2188") | regexm(`var', "S2244") | regexm(`var', "S2412") | regexm(`var', "S2470") | regexm(`var', "S2471") | regexm(`var', "S2472") | regexm(`var', "S2473") | regexm(`var', "S2474") | regexm(`var', "S2475") | regexm(`var', "S2476") | regexm(`var', "S2477") | regexm(`var', "S257") | regexm(`var', "S2681") | regexm(`var', "S2738") | regexm(`var', "S2782") | regexm(`var', "S2783") | regexm(`var', "S2788") | regexm(`var', "S297") | regexm(`var', "S330") | regexm(`var', "S340") | regexm(`var', "S343") | regexm(`var', "S351") | regexm(`var', "S352") | regexm(`var', "S353") | regexm(`var', "S354") | regexm(`var', "S355") | regexm(`var', "S359") | regexm(`var', "S3600") | regexm(`var', "S3611") | regexm(`var', "S3702") | regexm(`var', "S381") | regexm(`var', "T065") | regexm(`var', "T913")

*

gen maxais3bodyreg4`var'= regexm(`var', "S3281") | regexm(`var', "S334") | regexm(`var', "S357") | regexm(`var', "S3601") | regexm(`var', "S3608") | regexm(`var', "S3610") | regexm(`var', "S3614") | regexm(`var', "S367") | regexm(`var', "S581") | regexm(`var', "S589") | regexm(`var', "S684") | regexm(`var', "S720") | regexm(`var', "S7200") | regexm(`var', "S7201") | regexm(`var', "S7202") | regexm(`var', "S7203") | regexm(`var', "S7204") | regexm(`var', "S7205") | regexm(`var', "S721") | regexm(`var', "S7210") | regexm(`var', "S7211") | regexm(`var', "S722") | regexm(`var', "S723") | regexm(`var', "S724") | regexm(`var', "S7240") | regexm(`var', "S7241") | regexm(`var', "S7242") | regexm(`var', "S7243") | regexm(`var', "S7244") | regexm(`var', "S728") | regexm(`var', "S729") | regexm(`var', "S750") | regexm(`var', "S759") | regexm(`var', "S789") | regexm(`var', "S881") | regexm(`var', "S889") | regexm(`var', "S980") | regexm(`var', "T915")

*

gen maxais3bodyreg5`var'= regexm(`var', "S3315") | regexm(`var', "S688") | regexm(`var', "S689") | regexm(`var', "S857") | regexm(`var', "S984") | regexm(`var', "T116")

*

gen maxais3bodyreg6`var'= regexm(`var', "S018") | regexm(`var', "T243") | regexm(`var', "T3110") | regexm(`var', "T3111") | regexm(`var', "T312") | regexm(`var', "T343") | regexm(`var', "T345") | regexm(`var', "T348")

*

gen maxais4bodyreg1`var'= regexm(`var', "S062") | regexm(`var', "S0620") | regexm(`var', "S0621") | regexm(`var', "S0622") | regexm(`var', "S0623") | regexm(`var', "S0628") | regexm(`var', "S1502")

*

gen maxais4bodyreg2`var'= regexm(`var', "S250") | regexm(`var', "S272") | regexm(`var', "S281")

*

gen maxais4bodyreg3`var'= regexm(`var', "S2688") | regexm(`var', "S350") | regexm(`var', "S358") | regexm(`var', "S3613")

*

gen maxais4bodyreg4`var'= regexm(`var', "S3470") | regexm(`var', "S3471") | regexm(`var', "S3472") | regexm(`var', "S3473") | regexm(`var', "S3474") | regexm(`var', "S3475") | regexm(`var', "S3604") | regexm(`var', "S3615") | regexm(`var', "S480") | regexm(`var', "S481") | regexm(`var', "S489") | regexm(`var', "S580") | regexm(`var', "S780") | regexm(`var', "S781") | regexm(`var', "S880")

*

gen maxais4bodyreg5`var'= regexm(`var', "S3476") | regexm(`var', "T055")

*

gen maxais4bodyreg6`var'= regexm(`var', "T3120") | regexm(`var', "T3121") | regexm(`var', "T3122") | regexm(`var', "T313")

*

gen maxais5bodyreg1`var'= regexm(`var', "S141") | regexm(`var', "S1410") | regexm(`var', "S1411") | regexm(`var', "S1412") | regexm(`var', "S1413") | regexm(`var', "S1471") | regexm(`var', "S1472") | regexm(`var', "S1473") | regexm(`var', "S1474") | regexm(`var', "S1475") | regexm(`var', "S1476") | regexm(`var', "S1477") | regexm(`var', "S170")

*

gen maxais5bodyreg2`var'= regexm(`var', "S241") | regexm(`var', "S2410") | regexm(`var', "S2411") | regexm(`var', "S280") | regexm(`var', "T790")

*

gen maxais5bodyreg3`var'= regexm(`var', "S2682") | regexm(`var', "S2683") | regexm(`var', "S341") | regexm(`var', "S3629") | regexm(`var', "S383")

*

gen maxais5bodyreg6`var'= regexm(`var', "T212") | regexm(`var', "T2120") | regexm(`var', "T2129") | regexm(`var', "T213") | regexm(`var', "T2130") | regexm(`var', "T2139") | regexm(`var', "T3130") | regexm(`var', "T3131") | regexm(`var', "T3132") | regexm(`var', "T3133") | regexm(`var', "T314") | regexm(`var', "T3140") | regexm(`var', "T3141") | regexm(`var', "T3142") | regexm(`var', "T3143") | regexm(`var', "T3144") | regexm(`var',

```
"T315") | regexm(`var', "T3150") | regexm(`var', "T3151") | regexm(`var', "T3152") | regexm(`var', "T3153") | regexm(`var', "T3154") | regexm(`var', "T3155") | regexm(`var', "T316") | regexm(`var', "T3160") | regexm(`var', "T3161") | regexm(`var', "T3162") | regexm(`var', "T3163") | regexm(`var', "T3164") | regexm(`var', "T3165") | regexm(`var', "T3166") | regexm(`var', "T317") | regexm(`var', "T3170") | regexm(`var', "T3171") | regexm(`var', "T3172") | regexm(`var', "T3173") | regexm(`var', "T3174") | regexm(`var', "T3175") | regexm(`var', "T3176") | regexm(`var', "T3177") | regexm(`var', "T318") | regexm(`var', "T3180") | regexm(`var', "T3181") | regexm(`var', "T3182") | regexm(`var', "T3183") | regexm(`var', "T3184") | regexm(`var', "T3185") | regexm(`var', "T3186") | regexm(`var', "T3187") | regexm(`var', "T3188")

*

gen maxais6bodyreg1`var'= regexm(`var', "S0638") | regexm(`var', "S18")

*

gen maxais6bodyreg6`var'= regexm(`var', "T319") | regexm(`var', "T3190") | regexm(`var', "T3191") | regexm(`var', "T3192") | regexm(`var', "T3193") | regexm(`var', "T3194") | regexm(`var', "T3195") | regexm(`var', "T3196") | regexm(`var', "T3197") | regexm(`var', "T3198") | regexm(`var', "T3199")

}


forval i = 1/4 {

forval j = 1/6 {

gen MAXAIS_BODYREGION`i'_`j'=" "

forval k = 1/48 {

replace MAXAIS_BODYREGION`i'_`j'= "`i'.`j'" if maxais`i'bodyreg`j'nmds_a1==1

replace MAXAIS_BODYREGION`i'_`j'= "`i'.`j'" if maxais`i'bodyreg`j'nmds_b`k'==1

}

}

}


foreach j of numlist 1 2 3 6 {

gen MAXAIS_BODYREGION5_`j'=" "
```

```
forval k = 1/48 {

replace MAXAIS_BODYREGION5_`j'= "5.`j'" if maxais5bodyreg`j'nmds_a1==1

replace MAXAIS_BODYREGION5_`j'= "5.`j'" if maxais5bodyreg`j'nmds_b`k'==1

}

}


foreach j of numlist 1 6 {

gen MAXAIS_BODYREGION6_`j'=" "

forval k = 1/48 {

replace MAXAIS_BODYREGION6_`j'= "6.`j'" if maxais6bodyreg`j'nmds_a1==1

replace MAXAIS_BODYREGION6_`j'= "6.`j'" if maxais6bodyreg`j'nmds_b`k'==1

}

}

drop maxais1bodyreg1nmds_a1- maxais6bodyreg6nmds_b48


forval i = 1/4 {

forval j = 1/6 {

destring MAXAIS_BODYREGION`i'_`j', replace

}

}


foreach j of numlist 1 2 3 6 {

destring MAXAIS_BODYREGION5_`j', replace

}
```

```
foreach j of numlist 1 6 {

destring MAXAIS_BODYREGION6_`j', replace

}


gen region_1=max(MAXAIS_BODYREGION1_1, MAXAIS_BODYREGION2_1, MAXAIS_BODYREGION3_1, MAXAIS_BODYREGION4_1, MAXAIS_BODYREGION5_1, MAXAIS_BODYREGION6_1)

gen region_2=max(MAXAIS_BODYREGION1_2, MAXAIS_BODYREGION2_2, MAXAIS_BODYREGION3_2, MAXAIS_BODYREGION4_2, MAXAIS_BODYREGION5_2)

gen region_3=max(MAXAIS_BODYREGION1_3, MAXAIS_BODYREGION2_3, MAXAIS_BODYREGION3_3, MAXAIS_BODYREGION4_3, MAXAIS_BODYREGION5_3)

gen region_4=max(MAXAIS_BODYREGION1_4, MAXAIS_BODYREGION2_4, MAXAIS_BODYREGION3_4, MAXAIS_BODYREGION4_4)

gen region_5=max(MAXAIS_BODYREGION1_5, MAXAIS_BODYREGION2_5, MAXAIS_BODYREGION3_5, MAXAIS_BODYREGION4_5)

gen region_6=max(MAXAIS_BODYREGION1_6, MAXAIS_BODYREGION2_6, MAXAIS_BODYREGION3_6, MAXAIS_BODYREGION4_6, MAXAIS_BODYREGION5_6, MAXAIS_BODYREGION6_6)


gen region1= floor(region_1)

gen region2= floor(region_2)

gen region3= floor(region_3)

gen region4= floor(region_4)

gen region5= floor(region_5)

gen region6= floor(region_6)


drop MAXAIS_BODYREGION* region_*

gen region_1=region1
```

```
gen region_2=region2

gen region_3=region3

gen region_4=region4

gen region_5=region5

gen region_6=region6


egen max1=rowmax(region1-region6)

gen nmax1=0

quietly forval j = 1/6 {

  replace nmax1= nmax1 + (region`j'==max1) if region`j'!=.

}

foreach x of varlist region1-region6{

  replace `x'=. if `x'==max1

}


egen max2=rowmax(region1-region6)

replace max2=max1 if nmax>=2

gen nmax2=0

quietly forval j = 1/6 {

  replace nmax2= nmax2 + (region`j'==max2) if region`j'!=.

}

foreach x of varlist region1-region6{

  replace `x'=. if `x'==max2

}
```

```
egen max3=rowmax(region1-region6)

replace max3=max1 if nmax1>=3

replace max3=max2 if nmax2>=2


drop region1-region6 nmax*


gen max1_2=max1^2

gen max2_2=max2^2

gen max3_2=max3^2

gen iss_algorithm=max1_2+max2_2+max3_2

replace iss_algorithm=max1_2+max2_2 if iss_algorithm==.

replace iss_algorithm=max1_2 if iss_algorithm==.

replace iss_algorithm=75 if max1==6 | max2==6 | max3==6
```

Appendix 3: Systematic review paper

Epidemiology of major trauma in New Zealand: a systematic review

Luisa Montoya, Bridget Kool, Bridget Dicker, Gabrielle Davie

ABSTRACT

BACKGROUND: Physical injuries are one of the major causes of disability and death worldwide and have an immense impact on population health. In New Zealand, an estimated 8% of total health loss from all causes is attributed to injuries.

AIM: To describe the incidence and characteristics of major trauma in New Zealand.

METHODS: A systematic review based on a MEDLINE search strategy was performed using the databases PubMed, EMBASE, CINAHL and Scopus. Search terms included: "Wounds and Injuries," "Fatal Injuries," "Injury Severity Score," "Major Trauma," "Severe Trauma," "Injury Scale," "Epidemiology," "Incidence," "Prevalence" and "Mortality." Studies published in English up to September 2021 reporting the incidence of major trauma in New Zealand were included. The quality of studies was assessed using the GATE LITE™ tool.

RESULTS: Thirty-nine studies fulfilled the inclusion criteria. The majority of studies were descriptive observational studies (n=37). The incidence of fatal trauma was highest among those injured from motor vehicle crashes (MVCs) or falls, Māori males and those sustaining head injuries. The incidence of non-fatal major trauma was highest among young Māori males. MVCs and falls were the most common mechanism of injury among trauma patients across all age groups. Length of hospital stay was greatest in patients with the highest Injury Severity Scores.

CONCLUSIONS: The incidence of major trauma varies by age, sex and ethnicity. This review highlights the need for further analytical studies that can explore factors that may impact survival from major trauma.

Trauma, defined as any serious physical injury to the body that requires medical attention,[1] is one of the major causes of disability and death worldwide.[2,3] More than one quarter of the five million global deaths from physical injuries annually are the result of motor vehicle crashes (MVCs).[4] New Zealand (NZ) is a high-income country with a population of approximately 5.1 million.[5] Māori, the Indigenous people of New Zealand, account for 16.5% of the total population.[6] Around 50,000 people are hospitalised as a result of injury in New Zealand annually, with an economic cost estimated at NZ$10.2 billion per year.[7] An additional NZ$5.7 million is the estimated economic burden per fatality.[8] The New Zealand Ministry of Health (MoH) reported in 2016 that an estimated 8% of total health loss from all causes was attributed to injuries.[3] However, little is known about the incidence of injuries that have the potential to cause death or long-term disability (major trauma).[9]

Major trauma is commonly defined in terms of injury severity. Although there is not an internationally recognised definition of major trauma,[10] it has been variably defined as an Injury Severity Score (ISS) greater than 15, which is associated with a mortality risk of 10%.[11–14] Since the introduction of the Abbreviated Injury Scale (AIS) AIS-2005-Updated 2008, an ISS>12 is also considered as major trauma.[10,15–17]

In order to reduce morbidity and mortality resulting from major trauma, it is important to understand how major trauma is distributed in terms of time, geographic location and population groups. Therefore, this systematic review of the literature aimed to describe the incidence and characteristics of major trauma in New Zealand.

Methods

Inclusion criteria

Studies describing the incidence of major trauma in New Zealand published up to September 2021 were included. For the purposes of this review, "major trauma" was defined as death or an ISS greater than 12 or greater than 15, depending on the AIS version used at the time the injuries were coded.[11,17] The AIS is an anatomical scoring system used internationally to rank the severity of individual injuries by body region on a scale of 1 (minor) to 6 (un-survivable injury).[18,19] The AIS is the basis of the ISS, which is used to determine the

2022 Feb 25; 135(1550). ISSN 1175-8716
www.nzma.org.nz/journal