

**INTRAVENOUS FLUID RESUSCITATION: SURVEILLANCE OF PENETRATING
INJURY IN THE PRE-HOSPITAL ENVIRONMENT**

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DECLARATION

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ABSTRACT

Physical injury is a major cause of premature death and disability worldwide (WHO, 2015). Mortality statistics for South Africa indicate that approximately half of all injury-related deaths were intentionally inflicted, often as a result of sharp-force injuries (Donson 2009). Cape Town is reputed to be a violent city (Nicol et al., 2014). Pre-hospital emergency care providers are often the first medical contact for injured patients. Previously, it was understood that high volume crystalloid administration would improve survival and was standardised in the management of shock (Santry & Alam 2010). However, over-administration of crystalloid fluid can cause patient harm by potentially worsening injuries and can be detrimental to a patients survival. Current evidence supports the practice of lower volume crystalloid intravenous fluid administration- permissive hypotension. Little is known about pre-hospital emergency care providers intravenous fluid management practices for penetrating injury. Injury surveillance data for victims of penetrating injury is also scarce with the majority of current data taken from mortality sources. Surveilling pre-hospital cases may yield opportunities for prevention from premature mortality and morbidity.

The aim of this study is to undertake surveillance of penetrating injury and related intravenous fluid resuscitation in the pre-hospital emergency care environment.

A prospective observational descriptive survey was conducted in the Cape Metropole¹. Over three consecutive months, emergency care providers documented parameters related to mechanism of injury, scene vital signs, hospital vital signs, intravenous fluid resuscitation and basic patient demographic information for patients with penetrating injury. A predetermined inclusion and exclusion criteria was used to sample patients.

¹ The Cape Metropole was delineated to four major sectors serviced by four major provincial ambulance divisions in the Western Cape. The geographic map as seen in Annexure G. Using Cape Town as a central point of reference, the metropole extends from Cape Town CBD to Bloubergstrand, Durbanville and Kraaifontein in the Northern Suburbs, Macassar in the Eastern Suburbs, Fish Hoek to the South and Houtbay and Green Point to the West.

Over the three-month data collection period, 147 cases were recorded of which 143 was eligible for data analysis. The chest (35.7%), upper-limbs (31.5%) and the lower limbs (23.1%) were the most common anatomical areas for penetrating traumatic injuries. The estimated mean crystalloid fluid volume administered for all cases was 901mL, with a mean fluid volume of 1010.6ml for penetrating abdominal injuries and a mean fluid volume of 925.3mL administered for penetrating chest injuries. Fluids were administered over a mean time period of 18 minutes. A statistically significant result was observed for systolic and diastolic blood pressure, heart rate capillary refill time, level of consciousness estimation from the incident of the scene to the hospital after intravenous fluid administration. The incidents were most likely to occur between the hours of 20h00 and 02h00, with 56% of all incidents occurring during this six-hour interval.

The intravenous fluid management by pre-hospital emergency care providers, for patients with penetrating traumatic injuries relating to fluid volume, exceeded current clinical recommendations for chest and abdominal injuries in terms of the intravenous fluid volume. Further research is needed to regulate the clinical decision making processes on the challenges and contextual factors concerning the intravenous fluid management practices. The data collection tool demonstrated an alternative data collection method, documenting important variables related to patient demographics, clinical presentation and clinical management specific to intravenous fluid therapy. The number of incorrectly completed sheets in comparison to the correctly completed sheets is suggestive of ease of completion. The data collection instrument presents an opportunity for more accurate and reputable surveillance for penetrating trauma, whilst simultaneously documenting practitioner accountability for shock management.

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DEDICATION

For

My Parents Akbar and Roshan Zalgaonker

List of Abbreviations

AEA	Ambulance Emergency Assistant
ALS	Advanced life support
ATLS®	Advanced Trauma Life Support
BAA	Basic Ambulance Assistant
BLS	Basic life support
EBP	Evidence Based Practice
EC	Emergency Care
ECT	Emergency Care Technician
ECP	Emergency Care Practitioner
EMS	Emergency Medical services
HPCSA	Health Professions Council of South Africa
ILS	Intermediate Life Support

Definitions

Ambulance Emergency Assistant (AEA): An individual trained in the delivery of intermediate emergency care in the pre-hospital environment within the capabilities and scope as determined by the Health Professions Council of South Africa. The capabilities and scope of practice of AEA, referred to as Intermediate Life Support (ILS) in the pre-hospital environment of South Africa includes the delivery of specific skills in medical assessment, medication administration and clinical procedures which are over and above those of an Basic Ambulance Assistant but not at the clinical level of an Emergency Care Technician (ECT) or Emergency Care Practitioner (ECP).

Advanced Life Support (ALS): ALS refers to an advanced level of emergency care practised/ delivered in the pre-hospital environment within the capabilities and scope as determined by the Health Professions Council of South Africa. An individual trained at the level of an ECT, ECP or holds a registration status as a Paramedic by the Health Professions Council of South Africa.

Cape Metropole: The Cape Metropole was delineated to four major sectors serviced by four major provincial ambulance divisions in the Western Cape. The geographic map as seen in Annexure G. Using Cape Town as a central point of reference, the metropole extends from Cape Town CBD to Bloubergstrand, Durbanville and Kraaifontein in the Northern Suburbs, Macassar in the Eastern Suburbs, Fish Hoek to the South and Houtbay and Green Point to the West.

Emergency Care (EC): Emergency Care is the provision of a diagnostic assessment, clinical procedure and or medication administration by a trained health professional in order to prevent loss of life or further injury.

Emergency Care Technician (ECT): An individual trained as a mid-level worker in the delivery of emergency care in the pre-hospital environment within the capabilities and scope as determined by the Health Professions Council of South Africa. The capabilities and scope of practice of Emergency Care Technicians includes the delivery of specific advanced skills in medical assessment, medication administration and clinical procedures which are over and above those of an Ambulance Emergency Assistant and Basic Ambulance Assistant but not at the clinical level of an Emergency Care Practitioner.

Emergency Care Practitioner (ECP): An individual trained in the delivery of emergency care in the pre-hospital environment within the capabilities and scope as determined by the Health Professions Council of South Africa. The capabilities and scope of practice of Emergency Care Practitioners is the highest in South Africa and includes the delivery of advanced skills in medical assessment, medication administration and clinical procedures which are over and above those of an Emergency Care Technician, Ambulance Emergency Assistant and Basic Ambulance Assistant.

Emergency Medical Services (EMS): EMS is an essential health care service rendered to individuals in need of emergency health care which includes emergency care in the pre-hospital environment and transportation to a health care facility.

Fluid Resuscitation and Fluid Therapy: The administration of intravenous fluid by a healthcare provider with the aim of restoring and/or maintaining acceptable physiological levels sustaining life within the body as a result of medical disease or acute injury/illness from a variety of mechanism or causes. Fluid resuscitation often takes place in the acute setting, often within the first few hours after injury whereas fluid therapy may continue for days to weeks depending on the severity of illness, illness type and intended clinical outcome.

Health Professions Council of South Africa (HPCSA): The HPCSA is a statutory body consisting of 12 Professional Boards that are responsible for determining standards of professional education and training, and setting and maintaining standards of ethical and professional practice.

Penetrating Injury: Physical damage to the bodily structures when an object strikes the external surface of the body, breaking the skin and creating an open wound. The severity of the penetrating injury is determined by internal bodily factors which includes the type of tissue injured (muscle, soft tissue, blood vessel damage or bone), depth of tissue penetration, as well as external factors which is not limited to the type of projectile, rate of energy applied via penetrating object, physical properties of the object, trajectory pattern, quantity of penetrating strikes to the body to name a few.

Pre-Hospital Environment: Any setting outside of a medical facility or hospital.

Pre-Hospital Emergency Care Provider (PECP): A trained individual registered by the Health Professions Council of South Africa providing emergency medical care in the pre-hospital environment.

Surveillance: The process of monitoring, observing or describing an event(s) or activity (ies). In the context of this study, fluid therapy and penetrating trauma was observed.

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CHAPTER ONE

BACKGROUND

1.1 Introduction

Traumatic injuries are known to be major causes of premature death and disability worldwide, with a greater incidence in low-to middle-income countries. The most recent injury related mortality statistics for South Africa revealed that approximately half of all injury-related deaths were intentionally inflicted often as a result of sharp force injuries/stabbing, gunshot injuries or blunt-force injuries. Current epidemiological data for sharp force injuries/stabbing, gunshot injuries is determined using mortality data. Little epidemiological and clinical data is available for penetrating injuries in the pre-hospital context.

The clinical care provided by pre-hospital emergency care providers plays a pivotal role in patient survival outcome. Premature deaths, as a result of trauma, are caused by mechanisms involving circulatory collapse, prolonged shock and insufficient end-organ perfusion. Many clinical interventions are provided in the pre-hospital environment for patients with traumatic injuries for which, intravenous fluid resuscitation is one of the cornerstones in patient management. Over the last two decades, many recommendations have been made concerning the type of fluid, volume of fluid as well as clinical parameters and endpoints during fluid resuscitation for penetrating injury (Revell et al., 2002; Revell et al., 2003; Perkins & Beekley 2012; McDermid 2014). The major change in intravenous fluid resuscitation involves the administration of reduced intravenous crystalloid² fluids over previously favoured large fluid volume administration as well as the administration of crystalloids over colloid³ fluids. However, there is still a debate amongst clinicians concerning the type of fluid as well as the endpoints for intravenous fluid resuscitation for trauma.

The scarcity of epidemiological and clinical data for penetrating injury and intravenous fluid resuscitation highlights the need for a surveillance study for penetrating injury and intravenous fluid resuscitation in the pre-hospital emergency environment.

² Crystalloids fluids are composed of inorganic ions and small organic molecules dissolved in water. The main solute is either glucose or sodium chloride and the solutions may be isotonic, hypotonic or hypertonic when compared to plasma fluid(Gan 2011). Crystalloids commonly used in the clinical setting includes 0.9% Sodium Chloride and Ringer's Lactate

³ Colloid fluids contain large molecules or ultra-microscopic particles of one substance dispersed through a second substance of which the particles do not settle and cannot be separated out by ordinary filtering or centrifuging(Gan 2011). Colloids commonly used in the clinical setting includes Dextrans and Hydroxyethyl starches and solutions containing gelatins

1.2 Penetrating injury- An Epidemiological Perspective

According to the World Health Organisation (World Health Organization (WHO) 2014), every six seconds someone in the world dies as a result of an injury caused by acts of violence against others or oneself, road traffic crashes, burns, drowning or falls and other types of accidents causing physical injury. Physical injury is a major cause of premature death and disability worldwide (World Health Organization (WHO) 2005). Furthermore, the number of deaths (5.8 million) caused by injury each year is more than the number of fatalities due to malaria, tuberculosis and HIV/AIDS combined (World Health Organization (WHO) 2010). Although certain population groups may be at higher risk, injury is not specific to age, gender, income nor geographic location (Krug et al., 2000).

South Africa has a mortality profile, including infectious diseases (e.g. Tuberculosis and HIV), non-communicable diseases (e.g. diabetes, coronary artery disease) and injury/ trauma from external sources (e.g. motor-vehicle accidents). Firearm-related injuries, pedestrian injuries and blunt force trauma are among the main causes of external deaths⁴ in South Africa (Donson, 2009). South Africa has a global reputation for high rates of violence (Mattes 2006; Centre for the Study of Violence and Reconciliation 2009; Clowes & Lazarus 2010; Hardcastle et al., 2012).

Since 2001, the National Injury Mortality Surveillance System (NIMSS) has been providing epidemiological data of unnatural deaths based on mortality data from medico-legal laboratories across South Africa (South African Medical Research Council 2012). Donson (2009)⁵ showed the close link of penetrating injury, leading external cause of death (manner preceding death) as result of sharp-objects followed by fire-arm related injuries (Donson 2009). Sharp-object injuries were reported as the leading cause of death particularly in South Africans between the ages of 15-44 years, with majority of patients being males (Swart, et al., 2008; Donson, 2009).

The mortality profile described above and the nature of penetrating injuries are not exclusive to the South African context. A 16-year review of penetrating injury in London, found that 86.6% (N=1564) of the penetrating injuries were managed by pre-hospital emergency care

⁴ The external cause of death refers to the mechanism, circumstance or event that preceded the death which includes firearms, stabbing, motor vehicle collisions, drowning, burns and poisonings, all of which may result in injury and eventually death (Matzopoulos & Niekerk 2007).

⁵ The recent results released by the National Injury Mortality Surveillance System (NIMSS) where cause of death has been clearly specified as sharp object.

workers (Crewdson et al., 2009). A trauma surveillance in Cape Town, South Africa analysing 9236 consecutive trauma centre admissions found the common mechanism of injury was assault with a sharp object (1933 cases [20.9%]) and 1571 cases blunt object [17.0%]) (Nicol et al., 2014). In Pietermaritzburg, South Africa, an analysis of the mechanism of injury revealed 1,081 (40.7 %) penetrating injury, of which stab wounds (858 cases) were a frequent cause of penetrating traumatic injury followed by gunshot (202 cases) wounds impalements (14 cases), animal injuries (4 cases) and unspecified (3 cases). In Turkey, a four-year retrospective review of penetrating thoracic injury revealed that stab wounds were the most frequent mode of injury comprising 89 cases which represented 89.9% of the total injury presentation (Yazici et al., 2012). Thus, the epidemiological profiles for penetrating traumatic injuries raise local and international concern.

1.3 The Socio-economic Impact of Trauma in South Africa

The socioeconomic status and its dynamic components have a great influence on injury in South Africa. The World Bank has classified South Africa as an upper-middle-income country (2013). The World Health Organisation indicated that 90% of deaths resulting from injury occurred in low-to middle-income countries (World Health Organization (WHO) 2010). According to Butchart & Engstro (2002), most studies that investigated economic indicators for violence, models of sex and age-specific homicide rates showed higher homicide rates in countries with lower per capita gross domestic product while others show no relationships. A long-term ecological study confirmed that rates of penetrating injury increased with increased unemployment rates (Reed et al., 2003). Although a relationship between injury and economic status has been made, the factors underlying the trend between socio-economics and injury has not been fully understood (Madan et al., 2007; Kacker, et al., 2016)

South Africa's socio-political past has contributed to the current determinants of violence in the country. The determinants of violence in South Africa has included the legacy of Apartheid: income inequality, poverty, high unemployment, rapid social change, gender inequalities, family breakdown, corruption and poor rule of law (Norman et al., 2007) in addition to moral breakdown. Traumatic injuries have great economic impact on individuals and societies at large (Allard & Burch 2005). Furthermore, Allard & Burch (2005) mention that in 2005, the cost of serious abdominal gunshot injuries was at least 13-fold more than the annual per capita South African government expenditure on health. Furthermore, gang violence and easy firearm availability have been identified as leading factors of homicides, while drugs and alcohol have been reported to be leading contributors to injuries related to

interpersonal violence in South Africa (Norman et al., 2007). While national averages of mortality from firearm violence indicate an abnormality across the nation (national average Firearm-related homicides at a rate 27/100 000 people compared to Johannesburg 63/100 000, Durban 48/100 000 and Cape Town 40/100 000), some large South African urban areas have higher fatalities than the national average (Allard & Burch 2005).

The impact of a traumatic injury is not limited to the physical injury sustained during the traumatic ordeal. After experiencing a traumatic injury the probability for the development of mental and physical health problems is increased (Centers for Disease Control 2011), and in the context of South Africa raises major public health issues (Norman, et al., 2007).

1.4 Management of Trauma in the Pre-Hospital Environment of South Africa

1.4.1 An Overview of Pre-Hospital Emergency Medical Services

In South Africa, pre-hospital emergency care providers (PECPs) practice emergency care under the relevant scope of practice independently, without direct supervision of a medical doctor. PECPs perform their duties as defined by the scope of practice regulated by the Health Professions Council of South Africa (HPCSA 2011). The pre-hospital emergency services in South Africa have rapidly developed over the past 20 years with the advanced level of training comparable to the best in the world (MacFarlane et al., 2005).

The national number pre-hospital emergency care providers can be seen in Table 1.1 below. The table provides an overview into the number of active practitioners registered by the Professional Board for Emergency Care. The practitioners within each professional register listed in the table below have intravenous fluid therapy as an independent capability within their scope of practice.

Table 1.1 Active Registrations from 01 April 2010 to 31 March 2015 Professional Board for Emergency Care Health Professions Council of South Africa (Health Professions Council of South Africa 2015)

Professional Register	2010	2011	2012	2013	2014	2015
Ambulance Emergency Assistant	6 508	6 934	7 536	7 992	8 507	8 882
Paramedic	1 316	1 396	1 490	1 573	1 598	1 593
Emergency Care Practitioner	89	127	166	222	287	372
Emergency Care Technician	86	303	397	595	778	942
Total Practitioners Per Year	7 999	8 760	9 589	10 382	11 170	11 789

The clinical oversight of PECPs and other health care providers is nationally regulated by the HPCSA. On the contrary, the delivery of pre-hospital emergency medical services is a regional responsibility, often managed by government agencies (provincial or municipal). Depending on the regional needs, the emergency medical service may also include other specialist services such as fire-fighting, motor vehicle rescue, wilderness search and rescue and various forms of aquatic rescue, implying cost-intensive specialist interventions.

In South Africa, pre-hospital emergency care is primarily delivered via PECPs using road ambulances and response vehicles via the country's road infrastructure. However, budgetary allocations, geographical and health care needs of the region may also include the use of alternative transport platforms and specialist services. In the Western Cape of South Africa, one example alternative transport platform and specialist services is Red Cross Air Mercy Service (air ambulance), which provides inter-facility transport, primary emergency medical response and rescue services using an aviation platform (Red Cross Air Mercy Services 2014).

1.4.2 Clinical Management of Trauma in the South African Pre-hospital Environment

The care provided in the pre-hospital environment can range from simple basic life support interventions such as oxygen administration to complex advanced life support procedures involving the independent interpretation of 12-lead electrocardiograms to the administration of a thrombolytic agents. PECPs in South Africa are accustomed to the clinical management of trauma (MacFarlane et al., 2005). Under the regulations set by the Health Professions Council of South Africa (2011), intravenous cannulation and the administration of intravenous fluids are listed as capabilities in the scope of practice of intermediate and advanced life

support providers. Crystalloid fluid administration is limited to intermediate life support providers, while advanced life support providers can additionally administer colloid fluids intravenously (Naidoo et al., 2014).

Oddly, in South Africa, pre-hospital emergency care providers have no set protocols or specific fluid resuscitation guidelines for patients who have sustained penetrating injuries. A general guideline for fluid therapy is available, but is not penetrating injury or other injury specific (HPCSA 2003). Thus, providers may be following recommendations set by: Advanced Trauma Life Support^{®6} (ATLS[®]); a traditional approach to normalize systolic blood pressure to physiological values; other injury-specific fluid resuscitation guidelines; or may manage patients as they see fit in the absence of any recommendations.

The level of care provided to a patient with a traumatic injury is directly related to the clinical need, level of qualification (capabilities and scope as stipulated by the HPCSA) and the resources at the practitioners disposal. Thus, minor and major differences can be seen in the management of trauma patient. For example, a patient with a stab wound to the neck will be managed by an intermediate life support provider's application of an occlusive dressing to stop bleeding, the administration of oxygen via a face mask, the administration of an intravenous fluid in the event of haemodynamic instability⁷ and the management of pain which is limited to the administration of Nitrous Oxide. Intermediate life support providers may also provide basic airway management (oropharyngeal airway and bag valve mask ventilation) should the patient require ventilatory support. However, in addition to the above patient management, advanced life support providers, where appropriate, may independently administer intravenous analgesics (opioids, dissociative anaesthetics), sedate and provide ventilator support via a mechanical ventilator. Thus a range of clinical procedures in the management of a trauma patient can be seen in the pre-hospital environment, comparable to acute care provided in an emergency department.

⁶ The Advanced Trauma Life Support[®] (ATLS[®]) was developed by the American College of Surgeons (ACS) Committee on Trauma (COT) and was first introduced in the US and abroad in 1980. The program designed for health care providers, teaches a systematic concise approach to the resuscitation and stabilisation of the trauma patient.

⁷ Haemodynamic instability refers to a change in one or more of a patient's vital signs and or a change in the patient's signs & symptoms which indicate poor tissue perfusion.

1.4.3 Intravenous Fluid Therapy for Trauma

Previously (1960-1974), it was understood that high-volume crystalloid administration for traumatic injuries would improve survival; in addition, high-volume crystalloid administration was standardised as part of the clinical management for patients with physical signs (low blood pressure) of haemorrhagic shock (Santry & Alam 2010).

Since 2000, evidence generated from human and animal studies has led to a debate around fluid resuscitation regarding choice of fluid type, fluid volume, injury specific end-points for cessation of fluid and time spent on scene. The debate continued with critical evaluation of previous and current fluid resuscitative practices for trauma (Alam & Velmahos 2007). At the start of the 21st century, recommendations for fluid resuscitation have been similar (Cotton et al., 2009). Guidelines for fluid resuscitation for penetrating injury allude to the potential for unfavourable compensatory (increase in blood chloride levels, dilution of clotting factors and clot dislodgement to name a few) physiological changes. Patients may experience effects such as reversal of vasoconstriction, clot dislodgement, dilution of coagulation factors, cooling and visceral swelling (Revell et al., 2003; Kirkpatrick et al., 2008). Some of the matters related to management of trauma remain elusive due to practical and ethical limitations (Spahn et al., 2007).

Hußmann, et al., (2011) viewed fluid resuscitation as a main option of primary treatment in many rescue situations. Alternatively, inappropriate fluid resuscitation may worsen injury and can be detrimental to a patient's survival (Revell et al., 2003; Napolitano 2005; Alam & Rhee 2007; Hußmann et al., 2011; Hussmann et al., 2013). Consensus guidelines for pre-hospital fluid resuscitation have been reached for certain types of penetrating injuries (Revell et al., 2002). There is minimal research regarding pre-hospital fluid resuscitation for penetrating injury in South Africa.

Fluid resuscitation protocols in hospital may vary in relation to the type of injury (penetrating versus blunt trauma) and volume of intravenous fluid administered, but most often are based on Advanced Trauma Life Support® (ATLS®) guidelines (John, 2015). Furthermore, there is limited infrastructure in place dedicated to the collection of clinical data for specific evaluation (demographic profile, fluid evaluation, patient outcome) in the pre-hospital environment. Limited databases in the pre-hospital environment have various implications for the individual and population, health-economics and patient safety.

Using the considerations above as informed by the evolution of intravenous fluid therapy for trauma, determining intravenous fluid practices in the pre-hospital setting is of importance in the context of patient safety. Thus, the aim of this study is to determine the pre-hospital intravenous fluid management practices for penetrating injury.

1.5 Contextualising the Problem

According to Kurt (2009), despite the large body of knowledge around homicides, literature regarding sharp object related injuries is not easily found. However, the few studies relating to penetrating injuries have produced noteworthy findings in the management of penetrating injuries as well as demographic data (Meel 2003; Degiannis et al., 2006; Kurt 2009). Furthermore Henry & Reingold (2012) report that the majority of deaths in the developing world occurs in the pre-hospital environment. As trauma is a public health concern, emphasis has been placed on the understanding and characteristics of the problem including pre-hospital care for injured persons (Krug et al., 2000). In the last decade, there has been the development and implementation of trauma databases and trauma registries in South Africa (Clarke, et al., 2014; Laing, et al., 2014a). The development and implementation of a local database as mentioned by Clarke, et al., (2014) has provided essential epidemiological data points aiding in the improvement and quality of healthcare.

The alarming mortality data for sharp object injury, the scarcity of epidemiological and intravenous fluid practice data for penetrating injury (in light of the documented adverse effects of inappropriate intravenous resuscitation) raises patient safety and injury surveillance concerns. Thus, an observational surveillance study into penetrating injury and intravenous fluid therapy was conceptualised.

1.6 Research Aim

The aim of this study is to undertake surveillance of penetrating injury and associated with intravenous fluid therapy in the pre-hospital emergency care environment.

The satisfaction of this aim is likely to inform emergency care clinicians, policy makers and educators on the population at risk of penetrating injury, current treatment modalities and injury prevention opportunities. Further, this study aims to highlight the need for

epidemiological surveillance of penetrating injury as a burden of pre-hospital emergency care⁸ and the challenges associated with the emergency care of penetrating injury.

1.7 Research Objectives

The primary objective was to development of a surveillance instrument for the purpose of penetrating injury and associated intravenous fluid therapy surveillance.

Through this surveillance instrument, the secondary objectives were:

- 1.7.1 To provide a clinical description of the pre-hospital fluid management practices associated with penetrating injury⁹ with reference to: fluid type, volume of fluid administered, time period of fluid administration, number of intravenous attempts, number of intravenous cannula placements and cannula size (bore).
- 1.7.2 To identify the clinical indications/ indicators¹⁰ used in pre-hospital emergency care for fluid resuscitation.
- 1.7.3 To describe the clinical end-points, in relation to the clinical indicators, used by pre-hospital emergency care providers for fluid resuscitation.
- 1.7.4 To determine the clinical presentation of the penetrating traumatic injury/ injuries with reference to anatomical location(s) of penetrating injury/injuries, number of penetrating, presence of other injuries/wounds the systolic blood pressure, heart rate and capillary-refill-time upon scene arrival as well as the systolic blood pressure, heart rate and capillary refill-time upon hospital arrival.
- 1.7.5 To describe the basic demographic profile of the penetrating trauma patient including age and gender.

1.8 Chapter One Summary

The information provided in chapter one describes the current major disease burdens and the current locus of trauma worldwide. An epidemiological perspective on intentional trauma initiated by means of a sharp object is contextualised to South Africa, alongside recent mortality statistics. The impact of trauma on South Africa's socio-economic status as well as

⁸ Emergency Care (EC) refers to the emergency care profession that is located in the out of hospital setting (although not exclusively)

⁹ The penetrating trauma type is delineated to the Cape Metropole due to its high incidence (Donson 2009) in this locale and is further explained in Chapter Three.

¹⁰ Clinical indicators refer to objective measures/ vital signs within the logistical and scope limitations of the pre-hospital emergency care profession.

other variables aiding trauma related injuries are presented. A brief presentation in the major determinants of violence in South Africa is presented as penetrating injury.

The clinical role of pre-hospital emergency care providers is defined for traumatic injury care, with emphasis to intravenous fluid therapy post penetrating traumatic injury. Intravenous fluid management is one of the key therapies pre-hospital emergency care providers can initiate and cease at their own discretion. Recognising that pre-hospital emergency care providers may often be the first link in the chain of clinical care, incorrect intravenous fluid therapy post penetrating traumatic injury has a great potential to cause numerous deleterious effects on human physiology and ultimately negatively alter the patients clinical outcome.

Data from human and animal studies demonstrated the harmful effects on human physiology after the administration of large intravenous volumes in the presence of penetrating and non-penetrating traumatic injuries.

In conclusion, penetrating injuries raises epidemiological concerns from a public health care perspective. The scarcity of literature in the intravenous fluid management therapies for penetrating injury raised concerns around patient safety and quality of care rendered in relation to current evidence based practices. The absence of a pre-hospital clinical practice guideline or protocol for penetrating injuries seen in the African context supported the need for a study of this nature.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Intravenous cannulation and the subsequent administration of intravenous fluid is a common practice in patient care. Intravenous fluid administration post vein cannulation in trauma, commonly referred to as 'IV's, Drips or Fluid Resuscitation' is an integral practice in the emergency care setting, and is often a critical component in simple and complicated clinical interventions for all patient age groups. In certain clinical manifestations, along with other therapies and clinical interventions, intravenous fluid administration could also make the difference between life and death. However, it has also been recognised that intravenous fluid administration in trauma is not completely innocuous.

In the pre-hospital setting, intravenous fluid management practices are essential components to emergency care providers in their delivery of patient care. Over the last two decades, various clinical-practice recommendations, for the developed world, have been made for intravenous fluid resuscitation post traumatic injury. However, little is known on the pre-hospital fluid resuscitation practices and patient demographics, as limited literature exists in the South African and other developing world contexts.

This chapter will review the literature on the evolution of fluid resuscitation up to the latest trends, penetrating injury, and pre-hospital emergency care patient demographics (gender, age, injury location and time of incident) to name a few. A brief aspect of the physiological mechanisms in shock has been included. The concept of intravenous fluid management includes the time, volume and type of fluid administration will be critically discussed.

2.2 The Epidemiology of Penetrating Injury

Trauma is the leading cause of mortality worldwide with a greater incidence in low-to middle-income countries (Peden et al., 2002). Injuries, whether unintentional or intentional, raises major public health concerns due to the potential for a life changing disability or death. Previously, it was understood that injuries were unavoidable and random events. Injury is now viewed as preventable cause of injury particularly after the introduction of injury

specific¹¹ preventative measures at a secondary and tertiary level (Katzenellenbogen & Hoffman 2007).

Injury has been found to be a major cause of premature death and disability worldwide (World Health Organization (WHO) 2005). In 2002, road traffic-related injuries, self-inflicted injuries, interpersonal violence, burns and drowning were among the 15 leading causes of death occurring among people between 5 years and 44 years of age (World Health Organization (WHO) 2005). Injuries and violence destabilize social cohesion and social and economic development, and are sources of considerable burden of preventable mortality and physical and emotional disability (Mock & Cherian, 2008; Schuurman, et al., 2015). It is estimated that in 2020, 8.4 million people will die every year due to injury compared to 5.1 million in 1990 (Murray & Lopez 1997).

Traumatic injuries in South Africa has been described by Muckart (1991) as an epidemic with numerous attributable causes, most of which are unique to Third World countries (WHO, 2005; Seedat, et al., 2009). More so, unintentional injuries encompasses significantly higher proportion of years of life lost than total deaths, as injuries occur primarily in young individuals and thus, result in a larger number of years of life lost compared to diseases that cause a higher number of deaths which predominantly affect older population groups (Chandran et al., 2010).

The most recent¹² (2015) injury related mortality statistics for South Africa indicates that approximately half of all injury-related deaths were intentionally inflicted (48.6%; 25 499/52 493), with the of homicide attributed deaths caused by sharp force injuries/stabbing, gunshot injuries or blunt-force injuries (Matzopoulos et al., 2015). A retrospective review of 35 176 penetrating and blunt trauma hospital cases by Ottochian et al., (2009) found the overall mortality of penetrating injury to be 2.63 times that of blunt trauma (11.0% vs. 4.2%, RR 2.63; 95% CI: 2.42, 2.85, p<0.0001). Furthermore, when compared to blunt trauma, the relationship between age and mortality in penetrating injury is similar except that the relative mortality in penetrating injury is significantly 2.63 times higher for each age group (11.0% vs. 4.2%, RR 2.63; 95% CI: 2.42, 2.85, p<0.0001).

¹¹ Injury specific measures may vary depending on the type of injury. Effective injury preventative measures included the provision of early childhood education and family counseling to prevent violence and the use of seat belts, car seats for children (Holder et al., 2001).

¹² The latest mortality statistics available for South Africa

Groenewald et al., (2010) investigated the leading causes of mortality and premature mortality in Cape Town and its sub-districts. Although, Groenewald et al., (2010) found that mortality rates in Cape Town are lower than the national average, the pattern of mortality observed in Cape Town displayed a quadruple burden of disease observed in the national cause-of-death profile, with a high mortality from violence and injuries among young adults. Furthermore, they also concluded that homicide rates were highest in the Khayelitsha sub-district, where the rate for males (242.4 per 100 000 individuals) was 17 times the global average and that for females (36.6 per 100 000 individuals) almost 9 times the global average. The above investigation also found 40% of homicides in the Cape Town Metro district were committed with firearms (Groenewald et al., 2010).

In South Africa, the overall injury death rate due to violence and injuries is 157.8 per 100 000 population (for the year 2000), which is nearly twice the global average, and the rate of homicide of women by intimate partners is six times the global average (Seedat et al., 2009). Males in Africa and in low- and middle-income countries of Europe, and females in Africa and India, have the highest injury-related mortality rates worldwide. Disproportions in male to female deaths due to fatal violence in the Western Cape were also observed elsewhere (Meel 2004; Matzopolous et al., 2007; Mirza et al., 2010).

Traumatic injuries, documented through injury surveillance systems involving pathology services and police reports, where recent findings suggested that the highest cause of deaths are related to sharp object injury (Donson 2009; Matzopoulos et al., 2010). High burdens of trauma have been identified in many geographical locations/ provinces across South Africa (Clarke et al., 2014). Violence was the leading cause of death (30.5%, n=3204) with firearm-related deaths accounted for almost one-third of homicides for the Gauteng province in South Africa, for the year 2011(MRC-UNISA 2013). In the same population, more than half of the victims (n = 3 037) were between the ages of 20-34 years, with 84.8% of the victims being male and 14.2% female. In 2008, 40% of the 9831 violent deaths in South Africa were inflicted by sharp objects, 29.4% by firearms, and 20.4% (n=2005) as a result of blunt force injuries, the remainder of deaths were as a result of suicide, transport related deaths and other mechanisms such as burns and drowning-incidents. Similar demographic findings were found by Kutcher et al., (2013) and Swaroop et al., (2013).

It has been estimated that 3.5 million South Africans seek medical assistance every year for non-fatal injuries (Peden & Butchart 1999), half of which have been initiated by acts of violence (Matzopoulos et al., 2006). The burden of violence is made up of multiple causes not limited to transport related deaths such as motor-vehicle and pedestrian vehicle accidents, violence involving a sharp object or firearm, burns and drowning incidents (Donson 2009). The number of deaths in South Africa due to injuries has been said to be one part of a triple burden. The other two elements of the burden includes causes related to poverty and the development of the chronic disease (Norman 2007).

Norman (2007) investigated revised age- and sex-specific estimates of injury mortality rates, calculating age and sex-specific Disability Adjusted Life Years (DALYs) for selected types of injuries, and comparing the burden with Africa and global estimates. Injuries were responsible for an estimated 2.3 million DALYs; the male burden was three times that of the female. Interpersonal violence (6.5%) and road traffic injuries (3.0%) respectively ranked second and fourth leading causes of all disability-adjusted life year (DALY) in South Africa in 2000 (Norman, et al., 2006; Norman, 2007).

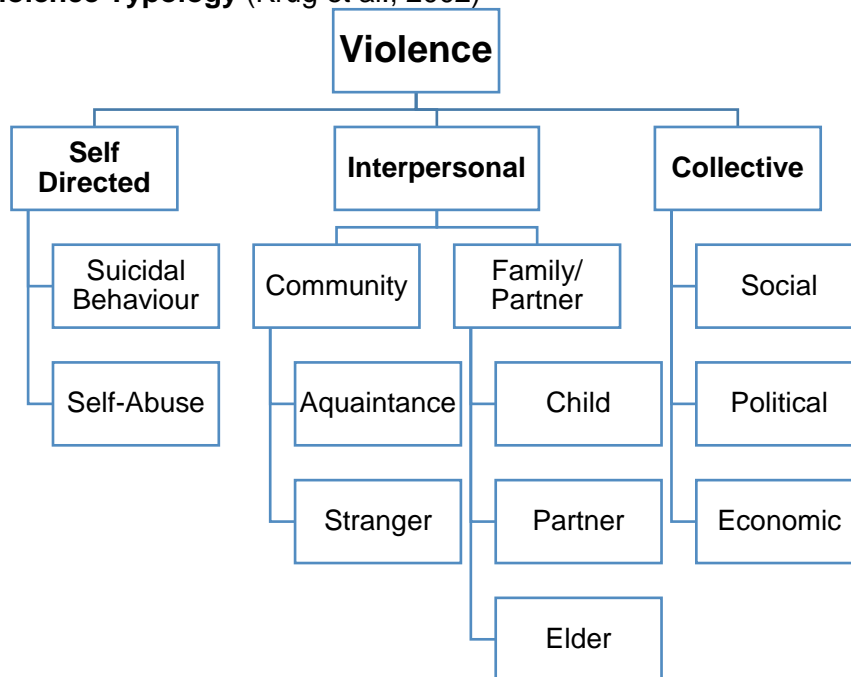
The nature of physical violent¹³ acts, irrespective of its typology¹⁴ is a major component in the origin of traumatic injuries (Krug, et al., 2002; Donson, 2009). As seen in Figure 2.1, penetrating injury can be caused by physical violence has the potential to influence in all categories depicted in typology by Krug et al., (2002).

Although a scarcity on injury patterns and patient demographics for trauma in developing countries is present (Lewis & Wood 2015), the data obtained by the National Injury Mortality Surveillance System (NIMSS) 2008, reported violence to be the leading manner of death, accounting to 31.5% (n=9831) of the 31177 non-natural deaths recorded.

¹³ Violence is defined by the WHO as "The intentional use of physical force or power, threatened or actual, against oneself, another person, or against a group or community, that either results in or has a high likelihood of resulting in injury, death, psychological harm, mal-development or deprivation"(World Health Organization (WHO) 1996)

¹⁴ The proposed typologies of violence have divided into three broad categories according to characteristics of those committing the violent act (i. self-directed violence ii. interpersonal violence and iii. collective violence) (Krug et al. 2002)

Figure 2.1 Violence Typology (Krug et al., 2002)



2.3 Injury Surveillance for Injury Identification and Prevention

Injury surveillance plays a vital role a healthcare system, providing data informing preventative efforts, monitoring intervention effectiveness, and describing epidemiological information aiding in the understanding of fatal violence patterns, risk factors and at risk groups (Matzopoulos et al., 2010). In the 1940's John Gordon (1949), one of the pioneers using scientific approaches (underpinned in epidemiology) investigated the epidemiology of accidents. He suggested that advances for injury prevention could be made by approaching injury in the same manner as the prevention of other diseases, advocated by the use of data to quantify the burden of injury burden, establish of causative factors, guide development of preventive measures, and enable periodic evaluation of the effectiveness of instituted prevention programs (Gordon 1949). For decades epidemiologists largely relied on mortality data in determining the burden on injury on a population (Bull 1978). However, (Segui-Gomez & MacKenzie (2003) argued that documenting the burden of injury should not be limited only to mortality data, but should include data metrics¹⁵ assessing the burden of fatal injuries, non-fatal injuries and integrated measures of fatal and nonfatal injury consequences.

¹⁵ Data metrics in this context would include health and health-related quality of life specifically after injury integrated with mortality, disability, and quality-of-life consequences

Data collection informing preventative efforts is described an important first step in the public health approach to prevent injuries and violence (National Center for Injury Prevention and Control & Control 2014). Additionally, clearly understanding injury patterns for fatal and non-fatal injury is critical as preventative efforts can be clearly guided accordingly.

Holder, et al., (2001) highlighted injury prevention as an issue predominantly addressed in wealthier countries, while the highest death rates and incidence of permanent disability due to injury are to be found in the poorer nations. Thus injury surveillance informing injury prevention is a concerning issue as there are few continuing injury surveillance systems for collection and analysis of injury data (National Center for Injury Prevention and Control & Control 2014). Holder, (2001) describes effective injury prevention strategies, injury surveillance systems in developing countries should be that are appropriate (account the complexities of the problem), cost-efficient, effective, the availability of resources and intervention measures have been shown to work elsewhere. Furthermore, Holder, (2001) addresses the need better information including the numbers and types of injuries and the circumstances in which those injuries occur.

The International Classification of Diseases (ICD-10), a key epidemiologic tool, is used to categorize diseases, injuries, and external causes of injury, enabling uniform reporting, storage and retrieval of data from health and other vital records to produce mortality and morbidity statistics (McKenzie et al., 2012). Although widely adopted in various healthcare settings globally including South Africa, the ICD has its limitations¹⁶. As an epidemiologic tool, these limitations may pose challenges and inconsistencies not just in reporting external injury but also injury prevention initiatives.

Furthermore, other key elements deficient in the ICD reporting of external injury (to aid injury prevention) are the causal mechanism(s), objects involved, intent of the injured person or perpetrator (for assault), place or setting of the incident, and the activity of the injured person at the time of the injury (e.g., work related, during sporting activity) not using a single code (McKenzie et al., 2012). Notwithstanding the deficiencies of the ICD, the use of inconsistent injury definitions and associated ICD codes also poses obstacles to injury

¹⁶ Some limitations related to external causes of injury have included difficulty in selecting all codes referring to the same mechanism (e.g., falling or drowning) across all intent blocks. Additionally, some mechanism blocks are specific, with titles providing a good indication of their contents (e.g., Accidental drowning and submersion), while other titles are more abstract or lack detail (e.g., Exposure to inanimate mechanical forces) (McKenzie et al. 2012).

surveillance, development of targeted interventions and evaluation of the intervention effectiveness.

In light of the challenges, limitations and deficiencies of ICD for injury reporting, the United States of America (Hauschild et al., 2017) and Australia (Australian Consortium for Classification Development 2017) have expanded on the base ICD system to provide more comprehensive morbidity coding. These expansions include clinical modifications aimed at enhancing country-specific public health surveillance and hospital utilization data.

Despite the addition of more codes to the ICD coding system, alternative classification systems have also been developed. The International Classification of External Causes of Injury (ICECI)¹⁷ is a system of classifications to enable systematic description of how injuries occur and is also designed to assist injury prevention. Both the ICECI and the External Causes chapter of the ICD provide ways to classify and code external causes of injuries. The ICECI unlike the ICD is multi-axial¹⁸, modular¹⁹ and hierarchical²⁰ addressing intent, mechanism(s), object/substance used, place of occurrence, activity when injured, alcohol use, and psychoactive drug or substance use (ICECI Coordination and Maintenance Group 2004; McKenzie et al., 2012). Furthermore, the development of the ICECI is to expand the role of protective equipment, first aid and emergency care, and measurement of long term consequences (Rogmans et al., 1998).

Another tool injury classification tool is the NOMESCO (Nordic Medico-Statistical Committee) Classification of External Causes of Injury (NCECI). The Nordic countries through the Nordic Medico- Statistical Committee developed the first multidimensional classification, known as the NOMESCO Classification of External Causes of Injury in 1984 to monitor emergency room patients (McKenzie et al., 2012). Since its inception the NCECI has been actively used

¹⁷ The ICECI was originally designed for use in settings in which information is recorded in a way allowing for statistical reporting. E.g. injury surveillance based on collection of information about cases attending a sample of hospital emergency departments.

¹⁸ Enabling numerous factors to be recorded independently of one another E.g. Objects or a substance involved in the occurrence of an injury is possible irrespective of how, or whether, other items have been coded.

¹⁹ Grouping sets of items which are likely to be used together. E.g. the sports module includes items that might be used when sports injury is a special focus of a data collection items that are generally useful for injury surveillance.

²⁰ Allowing users to choose from up to three levels of detail for data collection and reporting. The level used can differ between items and modules

as a basis for injury prevention and control building on long standing experience from many different sectors²¹ of society (Jørgensen et al., 2007).

Despite the presence of various injury collection tools, systematic data on non-fatal injuries is said to be limited in or not available in most low and middle-income countries (National Center for Injury Prevention and Control & Control 2014) and evident in the South African context (Schuurman et al., 2015)- supporting the need for an injury surveillance study.

2.4 Financial Impact of Trauma

Bowman et al., (2010), estimated the cost of injuries in South Africa. They identified gunshot wounds as the most expensive to treat (ZAR 6395.65 per case) and the most common of the injury types in South Africa. Although the investigators faced many challenges (injury combinations, elusive cost items, patient follow-up difficulties) in conducting a study of this nature in the South African health-system, it indubitably provides a glimpse of the magnanimity regarding the cost of injuries in South Africa. The cost of injuries provided guidance for healthcare expenditure and injury prevention. Additionally, estimating the cost of injuries has been classified as one of the five core research investments and capacity development, particularly in low-and-middle income countries (Chandran et al., 2010).

Norberg et al, (2009) determined the average cost per bullet to the South African health care system to range from \$196 - \$19 600 per patient. While the total cost for bullet related injuries for the 3-month study period was \$US285 824. More so, the greatest cost (64%) was affiliated to admission and duration of general ward and ICU stay, including ambulance transport and haemodialysis. The above-mentioned costing figures were the minimum per patient costs and excluded staff salaries, laboratory and pharmacy related costs. It was also found that on average, gunshot injuries were the most expensive to treat at \$US 2 230 per case (Norberg et al., 2009).

Traumatic injuries have many consequences on individuals, groups and communities. Certain consequences are visible and can be quantified and enumerated, while other consequences such as grief and pain cannot be cost for. Traumatic injuries have great economic impact on individuals and societies, as the cost of injuries are vast, both in the

²¹ The NCECI has elements devised and refined during practical application in many settings e.g. hospitals, emergency rooms, outpatient clinics, trauma centres, road traffic safety agencies, occupational health agencies, consumer product safety programs, public health research institutions

financial impact of the injury and to the nation at large (Allard & Burch, 2005). In 2005, the cost of serious abdominal gunshot injuries was at least 13-fold more than the annual per capita South African government expenditure on health (Allard & Burch 2005).

2.5 The Evolution Intravenous Fluid Therapy and Fluid Resuscitation for Trauma

2.5.1 History of Fluid Therapy

The historical written documents of traumatic injury can be traced back to 3000 BC with one of the first cases of penetrating thoracic injury can be found in the Edwin Smith Surgical Papyrus (Patterson 2003). Although procedures related intravenous therapies were not present at the time, the nature of thoracic injuries in years to come would provide a basis for the progression and development of medicine. More recently, exsanguinating haemorrhage was found to be the leading cause of death in severely injured trauma patients (Engels et al., 2014), with existing treatment strategies aimed at achieving haemostasis, replacing lost intravascular volume with intravenous fluids and blood, and treating coagulopathy (Chesters, Roberts & Harris, 2013; Engels, et al., 2014).

The first saline (crystalloid) infusion was practiced in 1832 on an elderly woman and in 1833, successful saline infusions were carried out on multiple patients (Barsoum & Kleeman 2002). As time progressed, several key components in the administration equipment development, biochemistry and physiology were also either discovered or improved upon (Barsoum & Kleeman 2002).

During the 1960's, the fluid resuscitation practice was the administration of large volumes (as much as three times the volume of blood lost) of crystalloid fluid and which was thought to improve survival, replace intra-vascular volume and interstitial deficits. Large volume intravenous fluid administration became the practice during the Vietnam War (Alam & Velmahos 2011). Patients who were treated with the above fluid regime later presented with 'shock-lung', now termed as acute respiratory distress syndrome (ARDS) (Alam & Velmahos 2011). Research in the latter 20th century by Shoemaker, Appel & Kram (1988) suggested that an oxygen debt was created during a traumatic injuring, requiring a restoration to physiological equilibrium. In the clinical setting (intensive care units), this physiological abnormality was corrected via the infusion of large volumes of intravenous fluid, which was thought to maximise cardiac output and ultimately reducing the oxygen debt- which was attempted with different types intravenous fluids (Al-Khafaji & Webb 2004).

As intravenous fluid resuscitation progressed, the characteristics of the ideal intravenous fluid for trauma (in the clinical setting) has been described as a fluid that is safe, effective, cheap; easy to store and transport; has the capacity to carry oxygen and nutrients to the cells and be able to protect cells from resuscitation injury (Alam, 2007). In the absence of the ideal intravenous fluid, a decision is required by the health care provider as to which fluid(s) to administer.

The 1980's, and 1990's animal studies found that hyper-chloremic metabolic acidosis and increased mortality was associated with large volumes of isotonic sodium chloride intravenous fluid administration. Large volume isotonic sodium chloride administration subsequently led to the emergence of Ringer's Lactate which was then the crystalloid of choice for resuscitation post-Vietnam War (Santry, 2010). The development of hyper-chloremic metabolic acidosis and increase in mortality raised concerns during the post-Vietnam War era, which led to an interest in hypertonic intravenous fluids as alternative intravenous fluids (Santry & Alam 2010). Hoste et al., (2014) claim that inappropriate fluid resuscitation is still practiced in the present-day in the United Kingdom with inappropriate fluid therapy, although rarely reported, may occur in as many as one in five patients in hospitals.

In 1990, it was estimated that more than 85% of patients hospitalised in the United States required intravenous access and intravenous fluid therapy (Barsoum & Kleeman 2002). Post millennium, the Advanced Trauma Life Support® (ATLS®) group which guides pre-hospital clinical practices, was a major contributing entity in the standardisation of trauma care. They recommended large crystalloid fluid administration volumes (2 litres) for patients experiencing haemorrhagic shock (Santry & Alam 2010). Subsequently, crystalloid fluid administration became a common clinical practice in both pre and in-hospital settings (Alam & Velmahos 2011). Additionally, the use of blood products and intravenous fluid therapy is considered routine therapy (Barsoum & Kleeman 2002).

Evidence from human and animal studies have led to the practice of large intravenous fluid volumes being questioned, and in some instances, highly discouraged (Hatoum et al., 2002; Revell et al., 2002; Alam & Rhee 2007; Haut et al., 2011; Balogh & McKinley 2003; Lobo et al., 2006; Hußmann et al., 2011). Some of these studies have found no evidence in pre-hospital intravenous fluid administration being beneficial and report that they may in fact be harmful when compared to patients where intravenous fluid was withheld (Dretzke et al.,

2004). Hoste, et al., (2014) mentions that many physicians prescribing fluid therapy appear to lack appropriate expertise for its potential to cause harm due to the physiological complexity of the considerations underpinning the use of fluid resuscitation. Santry & Alam (2010) have questioned the method of fluid administration as contributing factors to patient harm rather than fluid composition itself. However, it is important to note that certain intravenous fluid resuscitative studies on human participants are difficult to conduct due to logistical and ethical problems (Wang et al., 2014).

Along with the intravenous fluid therapy developments in the laboratory setting, many developments arose from military surgery and medicine as physicians were presented with new problems in war. In-turn these developments resulted in therapies and devices such as damage control resuscitation tourniquets and haemostatic agents that are later introduced to civilian settings (Manring, et al., 2009; Byers, 2010).

Recent resuscitative strategies are aimed at titrating intravenous fluid administration to various clinical parameters of the injured patient and not solely based on the chemical properties of the administered fluid. Some popular terms for intravenous fluid administration strategies include hypotensive resuscitation, delayed fluid resuscitation and damage control resuscitation. These resuscitation strategies have been developed in conflict zones such as those in the Middle East region. One of the newest strategies is remote damage control resuscitation that emphasizes the early use of blood products and restriction of other fluids, in order to support coagulation and tissue oxygenation (Medby 2014). Alam & Velmahos (2011) described a similar strategy known as damage control resuscitation which aims to: avoid crystalloid resuscitation; allow permissive hypotension whenever possible; prevent coagulopathy through early use of blood products; aggressively break the vicious cycle of acidosis, coagulopathy, and hypothermia.

According to Schmidt et al., (2012), permissive hypotension, also referred to as hypotensive resuscitation was described, more than ninety years ago, as part of an initial resuscitation strategy in the acute phase of traumatic haemorrhage. The aim of permissive hypotension is to reduce bleeding in patients experiencing haemorrhage until haemorrhage can be appropriately treated in the hospital environment (Bahrami, et al., 2006). Schmidt et al. (2012) clinically defined permissive hypotension as a mean arterial pressure between 50-65 mmHg. Permissive hypotension has become widely accepted as normal practice in many

recommendations and protocols on the basis of theoretical grounds (physiology) and on experimental evidence (Revell et al., 2002; Dretzke et al., 2004).

Individualising fluid therapy based on patients in special clinical considerations has also been explored (Mythen, et al., 2012). The above concept involves the choice of intravenous fluid (and other clinical treatments) based on specific cause of hypovolemia, cardiovascular state, renal functioning and serum osmolality and the coexisting acid–base and electrolyte disorders of the patient (Liamis et al., 2015).

Other approaches have been described, but are not aimed at the addressing the acute stages fluid resuscitation post trauma. One of these strategies has been mentioned by Finfer, Vincent, Vincent & De Backer, (2013) in which four distinct phases or stages of resuscitation after injury are discussed: Rescue, Optimization, Stabilization, and De-escalation (ROS-D). These four different clinical phases of fluid therapy, occur over a prolonged time course in which patients experience a decrease in illness severity and includes the administration (and weaning off) of vasoactive agents. Although important, only selected treatments across the four phases can be carried out in the pre-hospital setting. Similar intravenous fluid administration processes have been described by Holcomb et al., (2007), Perkins & Beekley (2012) and has been successfully implemented in a civilian setting (Campion et al., 2013). However, a vastly dissimilar mechanism of injury and emergency care systems between the battlefield and civilian settings has to be acknowledged and the direct application of resuscitation principles and models from the military to civilian settings may not always be appropriate (Mabry & McManus 2008).

Besides the development of pharmacological agents and therapeutic strategies, other advances included the questioning commonly known classification of shock (Mutschler et al., 2013) as well as the addition of other clinical measures to identifying shock and stratifying patients for advanced interventions (Manuel et al., 2013). One of the recent studies by (Vandromme & Griffin 2010) found that blood lactate was a better predictor for blood transfusion compared to systolic blood pressure in victims of shock. Others (Mutschler et al., 2014) found current pre-hospital trauma life support recommendations to be substantial deficit in adequately risk-stratifying trauma patients with hypovolemic shock.

Alluding to the dangers and potential for adverse changes to the physiological response to injury, Murugan & Kellum, (2012) and Myburgh & Mythen, (2013) recommends intravenous fluid therapy be rendered with the same considerations similar to that of any other prescribed pharmacological agents- as literature indicates that the adverse effects of intravenous fluids are similar depending on the type and dose administered.

2.5.2 Fluid Choice for Resuscitation: Crystalloids versus Colloids

Fluid resuscitation has been described as a process aimed at restoring tissue perfusion and obtaining haemodynamic stability (Spahn et al., 2007; Kortbeek, et al., 2008) and although empirical, it is an important clinical intervention for the treatment shock (Marik, et al., 2011). Fluid resuscitation is widely understood to be the administration of intravenous fluid(s) via a cannulated vein with the intention to increase intravascular volume to augment cardiac output and organ perfusion. Resuscitative fluids can be broadly classified as colloid, crystalloid solutions, with each category of fluid types having their specific chemical and physical characteristics altering human physiology (Myburgh, 2013; Smorenberg, 2013).

The debate around the choice of intravenous fluid type for patients with trauma is not new (Annane et al., 2013). The areas of debate has included the choice of fluid for resuscitation in the intensive care unit (Phillips et al., 2013), the role of colloids versus crystalloids in shock (Hillman 2004; Orbegozo Cortes et al., 2014), crystalloids and colloid fluid in the critically ill patient (Roche & James 2009) as well as colloids versus crystalloids for fluid resuscitation in critically ill patients (Perel & Roberts 2012) . Each study had different study methodologies comparing specific crystalloids, intravenous crystalloid and colloid types to differences in end-goal achievements. Traditional resuscitative practices have not included the use of normal saline due to its potential for acidosis with Ringer's lactate being the preferred crystalloid intravenous fluid (Davis et al., 2014). Compared to crystalloids, less colloid is needed for the same expansion of intravascular volume. Pre-hospital fluid resuscitation is considered to be a standard of care, but there is little clinical evidence supporting the use of either crystalloids or colloids (Midwinter, 2009).

Normal Saline, also referred to as physiological Saline, was described and applied since 1831, although dissimilar to the initial composition of 0.9%. Saline is the most widely used intravenous fluid in the hospital environment (Smorenberg, 2013; Awad, et al., 2008). Hypertonic intravenous fluids were thought to be the ideal intravenous fluid for resuscitation based on studied animal models (Velasco et al., 1989; Junger, et al., 2012). Chudnofsky,

Dronen, Syverud, Zink & Hedges, (1989) found benefit in Hypertonic Saline (7.5% without Dextran), particularly in the attenuation of post-traumatic neutrophil and endothelial cell activation in haemorrhagic shock, but no overall reduction in multi-organ-dysfunction syndrome- the leading cause of death in intensive care units (Brattstrom et al., 2010).

Controversy regarding the optimal choice and composition of resuscitation fluids is ongoing in various trauma related clinical studies, with recent strategies suggesting the limitation of crystalloid fluids in favour of blood components during the initial resuscitation (Feinman, et al., 2014a; Kutcher, 2013). A small volume resuscitation rat-model study with severe haemorrhagic shock by Bahrami et al., (2006) found that hypotensive resuscitation with normal saline caused a significant increase in plasma interleukin (IL)-1beta, IL-6, IL-2, interferon gamma (IFNgamma), IL-10, and granulocyte-macrophage colony stimulating factor (GM-CSF). Furthermore, on the seventh day post shock, animals treated with hypertonic saline had a markedly, but not significantly, lower survival rate than that of normal saline treated animals (47% versus 63%, respectively). In summary, the authors found that hypotensive resuscitation with hypertonic fluids may reduce the inflammatory response but not lung tissue damage or mortality after severe haemorrhagic shock (Bahrami, 2006). A multi-centre, randomized, blinded clinical trial (852 patients of which 38% sustained penetrating injury) in the pre-hospital environment involving the administration of hypertonic fluids for trauma was stopped early after the recommendation from a data and safety monitoring board, for futility and potential safety concerns (Bulger et al., 2011).

A randomised trial compared the use of colloids and crystalloids among intensive care patients presenting hypovolemia either due to sepsis, trauma, or hypovolemic shock without sepsis or trauma. The primary outcome of the study was death within 28 days and a secondary outcome including 90-day mortality; and days alive and not receiving renal replacement therapy, mechanical ventilation, or vasopressor therapy. According to the authors, “the use of colloids versus crystalloids did not result in a significant difference in 28-day mortality” with a lower 90-day mortality among patients receiving colloids” (Annane et al., 2013:1809).

On the contrary, a trauma specific multicentre randomized blinded clinical trial, conducted over two years across 114 emergency services in North America whereby patients with penetrating (38%) and blunt (62%) injuries were enrolled. No difference in overall 28-day survival was noted between hypertonic saline/dextran, normal saline or hypertonic saline

fluid types. Accounting for the above, the study was stopped at 23% of proposed sample size for concerns of futility and patient safety (Bulger et al., 2011).

When comparing crystalloids to colloids, Pablo Perel, Roberts, & Ker, (2013) identified 78 eligible trials of which 70 trials presented mortality data. The mortality trials compared Albumin, Hydroxyethyl Starch, Modified Gelatin, Dextran and Isotonic crystalloids. The authors included studies where intravenous fluid was administered for patients with burns, trauma, patients undergoing surgery and other critical conditions. The results from the systematic review concluded that there is no evidence for risk-of-death reduction for colloid fluid resuscitation compared to crystalloid fluid resuscitation (Perel et al., 2013). On the contrary, a multi-centre study across three continents by Annane et al., (2013) found no difference in 28 day mortality amongst heterogeneous intensive care patients presenting with hypovolemia when crystalloids versus colloids were used.

A randomised control trial has found benefit in the use of colloids for penetrating injury. Hydroxyethyl starch provided better lactate clearance and less renal injury when compared with 0.9% saline for patients with traumatic injuries. However, no significance between any of the patient and fluid groups in time to recovery of bowel function or mortality was found (James et al., 2011).

Cellular injury caused by haemorrhagic shock can be exacerbated and the type of fluid used for resuscitation plays an important role in this injury pattern. Thus, fluid resuscitation can adversely affect a patient if not performed correctly. Annane et al., (2013), found colloid intravenous resuscitation was associated with more rapid weaning from life-support treatments as shown by significantly more days alive without mechanical ventilation or vasopressor therapy and no evidence for a colloid-related increase in the risk for renal replacement therapy. These findings differ to those by Perel et al., (2013) and Zarychanski et al., (2013). Annane, (2013) alluded their findings to the dose regime of hydroxyethyl starch which never, exceeded the regulatory agencies, the exclusion of patients with severe, chronic renal failure and colloid administration leading to a significant reduction in cardiovascular and respiratory failure resulting in a reduced need for vasopressor and mechanical ventilation. A recent systematic review investigating intravenous Gelatin (colloid) administration for hypovolaemia found that Gelatin solutions increase the risk of anaphylaxis and may be harmful by increasing mortality, renal failure and bleeding, which could be due to extravascular uptake and coagulation impairment (Moeller et al., 2016). The authors further

recommend the until well-designed randomised controlled trials show Gelatin is safe, they caution against the use of Gelatins since cheaper and safer fluid alternatives are available (Moeller et al., 2016).

The resuscitative effects (hemodynamics, metabolic responses, and coagulation) of normal saline and Ringer's Lactate was studied by Martini, Cortez, & Dubick (2013), in an animal model with severe haemorrhage (60% of estimated blood volume). Both Ringer's Lactate and normal saline had the same resuscitative effects on oxygen metabolism and haemodynamics. However, normal saline was found to be overall inferior to Ringer's Lactate due to its vasodilatory effects (lower peripheral resistance and higher stroke volume) and the risk of metabolic acidosis and hyperkalaemia (Martini et al., 2013).

In a patient model, Davis et al., (2014) studied the demographic details, vital signs, 'blood work parameters', and fluid intake over 24 hours for 410 patients stratified into a Ringer's Lactate cohort (207 patients) and a normal saline cohort (203 patients). The overall findings indicated that normal saline was a safe and viable alternative to Ringer's Lactate for intravenous fluid resuscitation for trauma and may also have potential cost savings (Davis et al., 2014).

Young et al., (2014) compared three fluids (0.9% saline, Plasma-Lyte A and a calcium-free balanced crystalloid solution) for initial fluid resuscitation in a randomised double-blind, parallel-group trial. The primary outcome was mean change in base excess from 0 to 24 hours. They found that Plasma-Lyte A resulted in improved acid-base status and less hyperchloremia at 24 hours post-injury. However the authors requested that further studies to evaluate whether resuscitation with Plasma-Lyte A improves clinical outcomes (Young et al., 2014).

2.6 Intravenous Fluid Dynamics on Human Physiology

The physiology of intravenous fluids is directly related to the inherent fluid composition of crystalloid and colloid solutions and its interaction within the spaces of the human body (Myburgh & Mythen 2013). When administered intravenously, each fluid (crystalloid or colloid), behaves differently with respect to physiological pressures and distribution (Cotton et al., 2006). Colloids remain longer in the circulatory system by increasing the colloid-osmotic-pressure and may have a three to four fold greater plasma expanding capability for a given fluid volume compared to crystalloids (Smorenberg et al., 2013). Crystalloids tend to

distribute much quicker into the extra-cellular space compared to colloids and therefore larger volumes are needed to maintain intravascular volume (Griffel & Kaufman 1992). The choice of intravenous fluid used by clinicians is based on the compartment model (intracellular, interstitial and intravascular compartments) and the factors dictating fluid distribution across them (Myburgh & Mythen 2013).

Crystalloid fluids that have similar chemical properties to that of the extra-cellular fluid in the human body have been termed as 'balanced' or 'physiologic' solutions (Table 2.3) (Myburgh & Mythen 2013). These authors stated that crystalloids were merely derivatives of the original Hartmann's and Ringer's solutions, while Guidet et al., (2010) argued that these balanced solutions were neither physiological nor plasma adapted. Alluding to the physiological differences exerted by intravenous fluids (crystalloids and colloids), colloid fluids do not offer substantive advantages over crystalloid fluids with respect to hemodynamic effects (Myburgh & Mythen 2013). Each intravenous fluid type has inherent deleterious effects, the most reported being that of hydroxyethyl starch solutions which have been associated with increased rates of renal-replacement therapy and adverse events as seen in intensive care patients (Annane et al., 2013).

Major blood loss often accompanies physical injury (Mc Swain et al., 2011). One of the clinical goals of managing patients that have sustained intravascular fluid losses is the replacement of these intravascular constituents. Intravenous fluid therapy serves as a medium for maintaining circulatory volume, aiding organ perfusion and reducing ischemia. Crystalloid and colloid based fluid have no oxygenation transportation capabilities and only serve in the maintenance of circulatory volume. Blood and blood derived products serve as both. However, blood and blood products are expensive and carry potential patient risk. Research investigating haemoglobin-oxygen-based carriers and other oxygen carrying substitutes are underway and are in advance stages of development, with properties aimed at preserving microvascular and organ function, reducing the inherent or potential toxicity of the material used to carry oxygen, and treating pathologies initiated by anaemia and hypoxia (Cabrales & Intaglietta 2013). Majority of these products do not have the same limitations as blood (no cross match required, free of viral and bacterial infections and have similar dissociation curves to natural blood)(Nolan 2001). However, most of these products have failed Federal Drug Administration approval (Mc Swain et al., 2011).

The safety and efficacy of 7.5% sodium chloride in 6% dextran 70 (HSD) in post-traumatic hypotension was evaluated by Mattox, et al., (1991) in a multicentre, blinded, prospective randomized trial. The authors compared 250 mL of HSD versus 250 mL of normal crystalloid solution administered before routine pre-hospital and emergency centre resuscitation. Among 422 patients enrolled, 72% were victims of penetrating injury. The total amount of fluid administered, white blood cell count, arterial blood gases, potassium, or bicarbonate also were identical between groups. The HSD group had an improved blood pressure ($p = 0.024$). Haematocrit, sodium chloride, and osmolality levels were significantly elevated in the emergency centre. Although no difference in overall survival was demonstrated, the HSD group requiring surgery did have a better survival ($p = 0.02$). The HSD group had fewer complications than that of the standard treatment group (7 versus 24). A greater incidence of adult respiratory distress syndrome, renal failure, and coagulopathy occurred in the standard treatment group. Neither anaphylactoid nor Dextran-related coagulopathies occurred in the HSD group. Although the above trial demonstrated trends supportive of HSD in hypotensive patients with haemorrhagic shock requiring surgery, a larger sample size will be required to establish which subgroups of trauma patients might maximally benefit from the pre-hospital use of a small volume of hyperosmolar solution. Thus this study Mattox, et al., (1991) demonstrated the safety of administering 250 mL 7.5% HDS to post-traumatic hypotensive patients.

Similarly, the administration of normal saline has been associated with the development of metabolic acidosis and acute kidney injury (Myburgh & Mythen 2013). The administration of large intravenous fluid (crystalloid or colloid) may have detrimental effects on normal physiology (Morgan & Venkatesh, 2003) and may lead to secondary injury such as Systemic Inflammatory Response Syndrome (SIRS) as described by Junger et al., (2012). The development of SIRS may require the administration of other pharmacological agents to maintain tissue perfusion and thus cellular life (Alam & Velmahos 2011).

Shoemaker, Appel & Kram (1988) suggests that an oxygen-debt is created during a traumatic injuring, requiring a restoration to physiological equilibrium. In the clinical setting, the oxygen-debt is corrected via the infusion of intravenous fluid, aimed at maximising cardiac output, restoring tissue perfusion and ultimately obtaining haemodynamic stability (Spahn et al., 2007; Kortbeek, et al., 2008).

Table 2.1 Recommendations For Fluid Resuscitation In Acutely Ill Patients (Myburgh & Mythen 2013)

<p>Fluids should be administered with the same caution used when administering any intravenous drug</p> <ul style="list-style-type: none"> • Consider the type, dose, indications, contra-indications, potential for toxicity and cost
<p>Fluid resuscitation is a component of a complex physiological process</p> <ul style="list-style-type: none"> • Identify the fluid that is most likely to be lost and replace the fluid lost in equal volumes • Consider serum sodium, osmolarity, and acid base status when selecting a resuscitation fluid • Consider cumulative fluid balance and actual body weight when selecting the dose of resuscitation fluid • Consider the early use of catecholamines as a concomitant treatment of shock
<p>Fluid requirements change over time in critically ill patients</p> <ul style="list-style-type: none"> • The cumulative dose of resuscitation and maintenance fluids is associated with interstitial oedema • Pathological oedema is associated with an adverse outcome • Oliguria is a normal response to hypovolemia and should not be solely used as a trigger or end point for fluid resuscitation, particularly in the post resuscitation period • The use of fluid challenge in the post resuscitation period phase (>24 hours) is questionable • The use of hypotonic maintenance fluid is questionable once dehydration has been corrected.
<p>Specific Considerations apply to different categories of patients</p> <ul style="list-style-type: none"> • Bleeding patients require control of haemorrhage and transfusion with red cells and blood components as indicated • Isotonic, balanced salt solutions are pragmatic initial resuscitation fluid for the majority of acutely ill patients • Consider saline in patients with hypovolemia and alkalosis • Consider albumin during the early resuscitation of patients with severe sepsis • Saline or isotonic crystalloids are indicated in patients with traumatic brain injury • Albumin is not indicated in patients with traumatic brain injury • Hydroxyethyl starch is not indicated in patients with sepsis or those at risk for acute kidney injury • The safety of other semi-synthetic colloids has not been established, so the use of these solutions is not recommended • The safety of hypertonic saline has not been established • The appropriate type and dose and resuscitation fluid in patients with burns has not been determined

Two animal studies have also demonstrated a decrease in blood loss and lower mortality from haemorrhagic shock when controlled (fluid administered at $2 \text{ mL} \times \text{kg}^{-1} \times \text{min}^{-1}$), turned on or off to maintain a mean arterial pressure of 40, 80, or 100 mm Hg) intravenous resuscitation was practiced compared to normotensive resuscitation or no fluid administration (Burriss, et al., 1999; Li, et al., 2011) and maintains equivalent organ perfusion (Schmidt, 2012). One animal study even found improved hepatic stability, the presence of urine output, decreased Interleukin-6 levels, and significantly lowers mortality when intravenous fluids were given early after haemorrhagic shock. The authors attribute the conflicting results to

excessive fluid resuscitation (100 ml/kg) which resulted in an increased inflammatory cytokine level and mortality (Santibanez-Gallerani, et al., 2001).

In light of the above, Alam & Rhee (2007) suggested that in the absence of traumatic brain injury, permissive hypotension with systolic pressures greater than 80 mmHg, consciousness, or palpable pulse are reasonable goals until haemorrhage has been controlled. In an animal study, Li et al., (2011) found that the ideal targeted blood pressure for uncontrolled haemorrhagic shock is 60-90mmHg with a tolerance time of 90 minutes. They also found that 120 minutes of hypotension can cause significant organ damage (Li et al., 2011). Similarly, hypotensive resuscitation strategy was found to cause less intra-abdominal bleeding than normotensive resuscitation while maintaining equivalent organ perfusion (Schmidt, 2012). Onat et al., (2011) found that patients with significantly lower (+/- 42mmHg) systolic blood pressure died on presentation at an emergency room compared to those that had a higher systolic blood pressure (+/- 82mmHg). The findings by Onat et al., (2011) support the practice of permissive hypotension previously suggested by Revell et al., (2003) a recommended fluid resuscitative guideline for penetrating injury.

Three different mean-arterial pressure readings were studied (60 mmHg, 80 mmHg, and 100 mmHg) in an animal study with hypovolemic shock caused by trauma. The animals underwent hypotensive resuscitation and surgical intervention. The best haemodynamic stability, tissue perfusion, and organ function was seen in the 80mmHg group compared to the other groups (Bai, et al., 2015).

A retrospective review of patients that increased pre-hospital volume replacement (more than 1501ml) resulted in increased need for transfusion as well as the inability to coagulate. Additionally, excessive fluid (not specified by the authors and assumed to be more than 1500ml) resulted in an increase in mortality (Hussmann, et al., 2013). In the context of blunt trauma, Brown et al., (2013) found that severely injured hypotensive patients with, pre-hospital administration of more than 500ml crystalloid was associated with worse outcome compared to those without hypotension. They also found that more than 500ml crystalloid administration was associated with corrected pre-hospital hypotension (Brown, et al., 2013). Similarly, Geeraeds, et al., (2014) found that fluid volumes were associated with a decrease of the likelihood of shock, while increasing fluid volumes were associated with an increase in the likelihood of receiving blood transfusion. Furthermore, Geeraedts, et al., (2014) advocates for a tailored approach to individual situations based on the above mentioned findings.

2.7 Hypovolemic Shock

2.7.1 Hypovolemic Shock Pathophysiology

The recognition of and management of shock has been said to be one of the most challenging tasks in the initial assessment of trauma patients (Mutschler et al., 2013). According to Moore & Murtaugh (2001) "shock is a momentary pause in the act of death". Marx et al., (2013) argued that in the emergency medicine context, a shock results from the widespread failure of the circulatory system to oxygenate and nourish the body adequately, with haemorrhagic shock resulting from a rapid reduction in blood volume, which causes baroreceptor activation and leads to vasoconstriction, increased strength of cardiac contraction, and increased heart rate. In the context of a traumatic injury, shock has been described as the driver of coagulopathy in conjunction with direct tissue trauma (Hess et al., 2008) and in the context of homeostasis, it is described as "as the as the inadequate delivery of nutrients to the cells of the body" (Moore & Murtaugh 2001:1115).

Two basic mechanisms for bleeding after trauma have been described. The first mechanism involves bleeding as a direct result of a physical insult such as a penetrating injury, while the second involves the disturbance of the coagulation system with diffuse microvascular bleeding (Ganter & Pittet 2010). The loss of intravascular volume due to blood loss triggers a systemic physiological response mediated by local vascular signalling as well as the neuro-endocrine system (Dutton 2007). The pathophysiology of shock describing in a chronological manner using concepts such as Starling's Law and fight and flight response (Dutton 2007). Hypovolemic shock, if left untreated, will ultimately result in cell death due to cellular ischemia, decreased cardiac output and a cascade of cellular signalling and response mechanism resulting in organ and system failure (Dutton 2007; Ganter & Pittet 2010). However, intravenous fluid administration does not come without any risks. Animal studies have positively indicated an increase in apoptosis in intestinal mucosa, smooth muscle, liver and lung tissue (Deb et al., 1999).

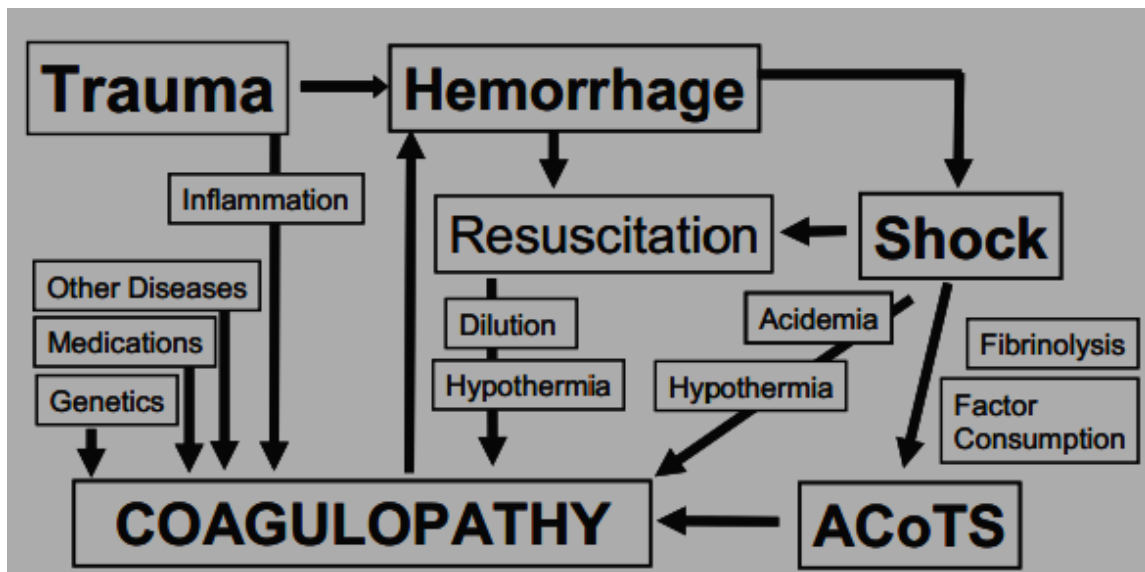
2.7.1.1 The Lethal Triad

The 'Lethal Triad' comprises of three major components namely hypothermia, acidosis and coagulopathy often seen in severe traumatic injuries. Each component has deleterious effects on normal physiological functioning of the human body and can adversely affect the body's response after an injury is sustained (Thorsen & Ringdal 2011). Intravenous fluid

management whether administered in or out of hospital has a direct influence on the patient's temperature (hypothermia), acid base balance (acidosis) and coagulopathic status.

Schreiber (2004) describes a lethal triad, due to uncontrolled haemorrhage. The combination of uncontrolled haemorrhage and iatrogenic interventions results in a 'the bloody vicious cycle' which lead to death unless haemorrhage is ceased and abnormalities corrected (Schreiber 2004).

Figure 2.2 Mechanism leading to coagulopathy (Hess et al., 2008)



2.7.1.2 Hypothermia in the Lethal Triad

Hypothermia is defined as a core body temperature below 35°C (Thorsen & Ringdal (2011). Hypothermia post trauma can be caused by the environmental exposure or the administration of intravenous fluids (Ganter & Pittet 2010). The energy needed by the body to warm two litres of colloid fluids infused at room temperature of 25°C within one hour exceeds the energy that can be delivered by common warming methods in one hour (Schreiber, 2005; Lier & Krep 2008).

According to Schreiber (2004), the greatest heat loss can be observed secondary to fluid resuscitation aetiologies of hypothermia in trauma. Alterations in body temperature has an influence on the body's haemostatic ability, with lower temperature ranges (34°C or less)

impairing haemostasis (Lier et al., 2008), enzyme activity slowing, decreased platelet function (Watts et al., 1998) and shifts the oxygen dissociation curve, and making oxygen less readily available (Byers 2010). Mabry & McManus (2008) found that hypothermia may be caused by prolonged scene times and the administration of cold intravenous fluid.

Shafi et al., (2005) found no protective effect of hypothermia for patients with traumatic injuries, further indicating that hypothermia itself, irrespective of its association with shock, injury severity, and other cofactors significantly increases patient mortality (Shafi et al., 2005) (Mabry, 2008; Inaba, et al., 2009). Another factor of major consideration is the presence of clinical coagulopathy and acidosis frequently occurring in the presence of hypothermia (Martini et al., 2005).

2.7.1.3 Acidosis in the Lethal Triad

Metabolic acidosis in trauma occurs secondary to tissue hypoxia and subsequent inadequate tissue perfusion in the context of hypovolemia (Thorsen & Ringdal 2011) and as a result of lactate production from anaerobic metabolism (Schreiber, 2004). Acidosis may also impair the functioning of plasma proteases, increased degradation of fibrinogen (Hess et al., 2008) and noticeably impair haemostasis at a pH <7.1 or base excess of -12.5 or less (Lier et al., 2008). Furthermore, Hess et al., (2008), indicated that acidosis can be corrected by the administration of intravenous buffer solutions, but does not correct the coagulopathy. Acidosis is recognized as a marker of inadequate resuscitation and impending organ failure (Thorsen & Ringdal 2011). Recently, blood lactate has been shown to be a better predictor for mortality as well as transfusion compared to systolic blood pressure (Vandromme & Griffin 2010) even in scenarios without clinical signs of shock (Burša & Pleva 2014).

One of the end results of hypovolemic shock is acidosis with detrimental effects such as altered myocardial contractility, reduced inotropic response to catecholamines, and ventricular arrhythmias (Schreiber 2004). An animal study by Martini & Holcomb (2007) found that an acidotic physiological state compromises the clotting process and accelerates fibrinogen consumption with no effect on fibrinogen production. The above physiological process ultimately results in a decreased fibrinogen availability (Martini & Holcomb 2007). The combination of acidosis and hypothermia may also cause a clinical coagulopathy with different kinetics in the generation of thrombin (Martini et al., 2005). The physiological effects of acidosis and hypothermia are deleterious and may result in significant bleeding despite the administration of adequate blood, plasma, and platelet replacement (Ferrara et al., 1990).

2.7.1.4 Coagulopathy in the Lethal Triad

Coagulopathy is defined as “a condition in which the blood ability to clot is impaired” (Meier et al., 2014: 2152) or “any flaw in the coagulation system, leading to either increased bleeding time or increased formation of clots” (Thorsen & Ringdal 2011:898). Coagulopathy is found in 10–34% of injured patients (Thorsen & Ringdal 2011). Six key initiators of coagulopathy in trauma patients are tissue trauma, shock, haemodilution, hypothermia, acidemia, and inflammation (Hess et al., 2008).

Shock reduces intravascular hydrostatic pressure resulting in a fluid shift deficient in coagulation factors (hypo- coagulable) from the cellular and interstitial spaces to the plasma (Hess et al., 2008). While Schreiber (2005), suggests that coagulation post traumatic injury may result in either a hypo-coagulable or a hyper-coagulable state depending on the severity of injury, degree of haemorrhage and the nature of the resuscitation. A patient with either coagulable is said to be in a state of coagulopathy which can be exacerbated by acidosis, hypothermia, or both causes (Martini, 2005; Lier, 2008).

It has been suggested that the choice of fluid may also influence a patient’s coagulation status (Schreiber, 2005). Blood loss as a result of haemorrhage may be increased with an incorrect coagulopathic state. Abnormal coagulation factors can be found in 25% of trauma patients with major injuries and patients presenting with coagulation abnormalities upon hospital admission have worse clinical outcome (Ganter & Pittet 2010). Coagulopathy post-acute traumatic injury serves as an independent predictor for mortality (MacLeod & Lynn, 2003;Brohi, et al., 2008).

Trauma-induced coagulopathy has both endogenous and exogenous components. The endogenous components are associated with shock and hypo-perfusion and the exogenous components are a consequence of dilution from intravenous fluid resuscitation as they lack clotting factors (Schreiber 2004). Bickell et al., (1994) indicates that the administration of intravenous fluid may also alter blood viscosity. The finding above by Bickell et al., (1994) has been supported by Maegele et al., (2007), showing that 50% of patients who were given high volume intravenous fluid(more than 3 litres) in the pre-hospital phase of care had coagulopathy. Similarly, fluid resuscitation with Hypertonic Saline and Dextran (7.5% NaCl/6% Dextran 70) may worsen the imbalance between pro-coagulation/anticoagulation and pro-fibrinolysis/anti-fibrinolysis, resulting in increased hypo-coagulable and hyper-

fibrinolytic states after haemorrhagic shock in trauma (Delano et al., 2015) However, Brohi et al., (2003), indicated that traumatic coagulopathy may not be related to intravenous fluid administration, but rather an indicator of injury severity as the authors found no relationship between fluid administration and the incidence of coagulopathy when they administered 550 ml of intravenous fluid. A randomised study by Gan et al., (1999), found that patients who were fluid resuscitated with 6% Hetastarch in a balanced electrolyte solution had significantly lower blood loss compared to those who were resuscitated with 6% Hetastarch in saline. The study above was conducted in the context of major elective surgeries and not in the context of acute penetrating traumatic injuries in the pre-hospital setting. Similar findings to that found by Gan et al., (1999) have been documented by MacLeod & Lynn (2003) and Brohi et al., (2007), noting that patients with acute coagulopathy due to trauma were four times more likely to die compared to those without an acute coagulopathy.

2.7.1.5 Tissue trauma Predisposing Shock

Tissue trauma can be expected with any physical injury, however the amount of tissue damaged during a traumatic insult may vary depending on the mechanism of injury (Hess et al., 2008).

Penetrating injury results from the abrupt, direct application of a mechanical force to a focal area (Kuhajda et al., 2014). A knife or projectile produces tissue damage by stretching and crushing the tissues in its path, resulting in a physical injury is usually confined to the path of tissue penetration. The severity of the internal injury depends on the organ penetrated and on how vital the organ is. In the context of gunshot injuries, the quantity of tissue damaged is directly related to the amount of energy exchanged between the object causing the injury, the body part to which the injury is sustained and the tissue density (Kuhajda et al., 2014). Table 2.2 lists the potential anatomical sites of exsanguinating haemorrhage as well as the confirmatory diagnostic modalities.

According to Schreiber (2005), tissue damage as a result of a traumatic injury triggers the clotting cascade together with the body's inherent inflammatory as well as the suppression of fibrinolytic pathways and produces hypercoagulability state. Tissue trauma may also result in haemorrhage and shock. A retrospective study in South Africa found that increased number of wounds was associated with decreased blood loss (Lockyer et al., 2013). The authors alluded the above finding to the attack type involving multiple superficial slash-type injuries rather than stab injuries that are deep (Lockyer et al., 2013).

Table 2.2. Potential sites of Exsanguinating Haemorrhage (Dutton 2007)

Site of Bleeding	Diagnostic Modality
Chest	Physical Examination (Breath sounds, bruises, or abrasions) Radiograph Thoracostomy Tube CT scan
Abdomen	Physical Examination (Distension, Pain) Ultrasound (FAST) CT with contrast Peritoneal lavage
Retro-peritoneum	Physical examination (unstable pelvic ring) Pelvic Radiograph CT with contrast Angiography
Long Bones	Physical Examination Plain radiographs
Outside the body	Medic's or bystander's report Physical examination
<i>Abbreviation:</i> FAST, Focused Assessment by Sonography in Trauma	

2.7.2 Hypovolemic Shock Classification and Identification

Currently, shock is clinically diagnosed in the pre-hospital environment using the patient's clinical presentation which includes the measurement of vital signs such as heart rate, blood pressure and Glasgow Coma Scale (Burša & Pleva 2014). These measurements are supported by the Advanced Trauma Life Support (ATLS®) guidelines. Common signs and symptoms of haemorrhagic shock identification can be seen in Table 2.5. The ATLS® shock classification compares independent vital signs within predetermined target ranges to classify shock. However, alternative methods using vital signs have also been used to classify shock. The Shock Index was introduced by Allgöwer and Burri in 1967, and is defined as the ratio of heart rate to systolic blood pressure (Manuel Mutschler et al., 2013). It has been found to be useful in diagnosing early haemorrhage compared to heart rate and blood pressure alone (Birkhahn et al., 2005). The shock index has been used in the pre-hospital environment as an index to facilitate the identification of patients that are in compensated shock and are at risk of being under-triaged. Manuel Mutschler et al., (2014) tested the validity of the Pre-Hospital Trauma Life Support's (PHTLS) classification of hypovolemic shock and found that the classification displayed substantial deficits in adequately risk-stratifying trauma patients. Vandromme et al., (2010) indicated that standard haemodynamic evaluation of patients in shock may underestimate severity of haemorrhage.

Table 2.3 Signs and Symptoms of Haemorrhagic Shock (Dutton 2007)

Appearance Pale, Diaphoretic
Injuries Open wounds, bruising, or bony instability consistent with blood loss
Mental Status Progressive deterioration from normal to agitated to lethargic to comatose
Vital Signs Decreased systolic SBP(<100mmHg), narrow pulse pressure, tachypnea, non-functional pulse oximeter, progressive hypothermia
Pulse Diminished or absent, poor capillary refill
Renal Diminished urine output
Laboratory Decreased pH, abnormal base deficit, elevated lactate, elevated osmolarity, elevated prothrombin time (PT)
Response Increased systolic blood pressure with fluid administration (fluid responsiveness), exaggerated decrease with analgesics or sedatives

Blood pressure is one of many clinical parameters used by health care providers to measure a patient's physiological status and is useful in the diagnosis of shock. The measurement of blood pressure is an important parameter in the determination of the patients clinical status and as blood pressures lower than 110mmHg have been associated with higher mortality in patients with penetrating traumatic injuries (Hasler et al., 2012). Poloujadoff et al., (2006) found that patients who recover their blood pressure with pre-hospital interventions prior to hospital administration have better outcomes. Healthcare facilities (trauma or specialist care centres) require blood pressure as one of many criteria for admission. A systolic blood pressure of 90mmHg has been described as the threshold for hypotension (Hasler et al., 2012). Bruns et al., (2008) indicated that the above criterion (systolic blood pressure of 90mmHg) should be redefined with a pre-hospital systolic blood pressure of less than 110mmHg for triage.

Non-invasive blood pressure monitoring is used in the pre-hospital environment to measure systolic and diastolic blood pressure. The value often in millimetres of mercury is used along with other diagnostic techniques to guide clinical therapy. It was found that non-invasive blood pressure measurements taken at the arm was accurate when compared to invasive blood pressure measurement (Lakhal et al., 2012). In the context of blood loss and blood pressure, Frank et al., (2010), found that higher volumes of blood loss were estimated by paramedics and physicians for patients with lower blood pressures and higher heart rates (Poloujadoff et al., 2006).

It is understood that pre-hospital emergency healthcare providers are usually first on scene and have the benefit of obtaining information that has contributed to the patient's clinical condition. Other than vital signs, demographic data, information obtained by pre-hospital emergency care providers may also include the estimated blood-loss experienced by the patient. However, Frank et al., (2010) found that instability of the patients vital signs (low blood pressure and increased heart rate) led to higher estimation of blood loss by both paramedics and physicians, while small blood volumes were over-estimated and large blood volumes underestimated. Frank et al., (2010) also found that neither gender, occupational status (paramedic or physician) nor level of experience influenced the accuracy of estimated blood loss. Poloujadoff et al., (2006) found that hypotension on arrival at hospital amongst other clinical features was significantly associated with increased mortality. The factors contributing to blood loss estimation should be noted when clinically diagnosing and categorising a patient within a specific stage of shock in the pre-hospital environment.

Recommendations of lower than normal blood pressures (permissive hypotension or hypotensive resuscitation), while balancing organ perfusion due to the risk of re-bleeding has been mentioned by Kortbeek et al., (2008) and Revell et al., (2002). Hypotensive fluid resuscitation strategies such as permissive hypotension have been used to prevent worsening of uncontrolled bleeding and according to Medby (2014), which is largely supported by animal studies. Most clinical evidence suggests that restricting fluid therapy is associated with improved outcome. Advanced Trauma Life Support® Guidelines (ATLS®) indicates the traditional practice of persistent infusions of large intravenous fluid volumes in an attempt to achieve a normal blood pressure is not a substitute for definitive control of bleeding (Kortbeek et al., 2008). Some authors like (Smorenberg, 2013) suggested that intravenous fluid management for hypovolemia or shock should be limited to rapid infusions of 500ml to 1000ml of crystalloids (Smorenberg et al., 2013), while others (Revell et al., 2002) stated that fluid should not be given to trauma victims before haemorrhage control, if a radial pulse can be felt. However, it has to be noted that Revell et al., (2002) do not provide specific details regarding injury types and intravenous fluid parameters for these patients with other injuries. Restricted intravenous fluid therapies has been defined by Smorenberg et al., (2013) as the administration of less than 7ml/Kg intravenous fluid. An over restrictive fluid management therapy may result in a sequelae of physiological events which can include gastrointestinal hypo-perfusion, intra-abdominal hypertension, abdominal compartment

syndrome, hyperchloremic metabolic acidosis and contributing to hyperkalaemia and death (Balogh, 2003; Smorenberg, 2013).

2.8 Timing and Volume of Intravenous Fluid Administration

Time and volume components in intravenous fluid management contribute to many intravenous fluid management strategies. Alterations in time and volume variables associated with intravenous fluid management may have direct impact on the vital signs and other physiological parameters of a patient.

Hampton et al., (2013) studied fluid management in the pre-hospital environment. Eighty-four percent (84%, n=1009) of patients were given fluid and sixteen percent (16%, n=191) were given no fluid. They found that a decrease in hospital mortality was found in trauma patients that were given intravenous fluid in the pre-hospital environment compared to those patients that were given no fluid in the pre-hospital environment. Carley (2013) commented on the article above indicating that the overall mortality described in the study as not statistically different and which was based on observational data that is likely prone to selection bias.

Retrospectively analysing a trauma database at a Level 1 trauma centre in Los Angeles Yaghoubian et al., (2007) determined whether a policy of intravenous fluids restriction is being followed and whether the volume of pre-hospital and emergency department intravenous fluids affects outcome. Patients with penetrating truncal injury and field hypotension (systolic blood pressure less than 90 mm Hg) along with multiple variables, including originating EMS agency, mechanism of injury, transport time, Injury Severity Score, field and emergency department vital signs, and intravenous fluid volume infused, complications, and mortality were compared. Of the 194 patients median pre-hospital IV fluid was 500 ml with only 25 % receiving less than 100 ml of intravenous fluid. There were no differences in the amount of intravenous fluid administered by the degree of field hypotension or by emergency services.

In light of the clinical data from animal and human studies, best practice have been suggested in fluid management for penetrating injury, with other practices such as large volume fluid resuscitation discouraged (Hatoum et al., 2002; Revell et al., 2002; Alam & Rhee 2007). Similarly, other best practices have also been suggested which includes not delaying scene time for intravenous cannulation, transport to nearest appropriate medical

facility and emphasis on infection control for intravenous cannulation, to name a few (Maki et al., 2006; Seamon et al., 2007; Funder et al., 2011; O'Grady et al., 2011).

However, effective monitoring processes should also be in place as Yaghoubian et al., (2007) found that Los Angeles County EMS did not adhere to guidelines of intravenous fluid restriction for patients with penetrating truncal injuries and field (pre-hospital) hypotension (systolic blood pressure less than 90mmHg).

A recent systematic review and meta-analysis of randomized controlled trials and observational studies by Wang et al., (2014: 954) found that liberal fluid resuscitation strategies may be associated with higher mortality in injured patients. However, it has to be mentioned that "available studies are subject to a high risk of selection bias and clinical heterogeneity".

In the in-hospital environment Ley, Clond, & Srour, (2011) prospectively analysed crystalloid fluid administration amongst the elderly (older than 70 years) and non-elderly (younger than 70 years). Multivariate logistic regression analysis and found that fluid volumes greater than 1.5L or more was associated with mortality in elderly (odds ratio [OR]: 2.89, confidence interval [CI] [1.13–7.41], $p = 0.027$) and non-elderly patients (OR: 2.09, CI [1.31–3.33], $p = 0.002$). The authors concluded that crystalloid administration in the emergency department of 1.5L or more was an independent risk factor for mortality.

Schreiber, et al., (2015) assessed the feasibility and safety of controlled resuscitation versus standard resuscitation in hypotensive trauma patients. Patients in the controlled resuscitation group received 250 mL of intravenous fluid if they had no radial pulse or a systolic blood pressure lower than 70 mm Hg and additional 250-mL boluses to maintain a radial pulse or an SBP of 70 mm Hg or greater. Patients in the standard resuscitation group received 2 litres of intravenous fluid initially and additional intravenous fluid as needed to maintain a systolic blood pressure of 110 mm Hg or greater. The above protocol was maintained until haemorrhage was controlled or 2 hours after hospital arrival. Their primary findings from a total of 192 patients (randomized 97 patients in controlled resuscitation group and 95 patients in standard resuscitation group), indicated that there was no difference among patients with penetrating injury (9% vs. 9%; adjusted odds ratio, 1.93; 95% CI, 0.19–19.17). Additionally at 24 hours after admission, 5 deaths (5%) occurred in the controlled resuscitation group and 14 (15%) in the standard resuscitation group (adjusted odds ratio,

0.39; 95% CI, 0.12-1.26). Based on these findings, the authors concluded that controlled resuscitation is achievable in the pre-hospital and hospital environments and may offer an early survival advantage to patients with blunt traumatic injuries (Schreiber et al., 2015).

Aggressive intravenous administration strategies have been said to be associated with an increase cardiac and pulmonary complications, gastrointestinal dysmotility, coagulation disturbances, and immunological and inflammatory mediator dysfunction (Cotton et al., 2006).

A randomized controlled trial involving human patients that were in hemorrhagic shock showed that hypotensive resuscitation is safe strategy to use for patients with trauma and also resulted in decrease in blood products and intravenous fluid usage (Morrison et al., 2011). Furthermore, the application of military contributions to civilian contexts extends further than just the Vietnam War (Santry & Alam 2010) and has included a concept called damage control resuscitation (Campion et al., 2013). Damage control resuscitation as a clinical strategy is a two-step process incorporating hypotensive resuscitation (permissive hypotension) and haemostatic resuscitation (use of blood products) which is aimed at combat acidosis, hypothermia, coagulopathy and hypo-perfusion (Byers, 2010; Curry & Davis, 2012). In the continuity of patient care, damage control surgery has been described by Inan (2012), as a five step process incorporating 1) correct triage within one hour post injury, 2) theatre admission with the aim of controlling haemorrhage and cleaning the wound, 3) intensive care admission, 4) definitive surgery and lastly, 5) reconstruction and rehabilitation. However, it must be stated that the five steps above have certain end-goals and targets that are described in detail by Inan (2012).

Inan (2012), further mentions that physicians should manage patients in terms of their physiological state rather than using approaches that uses pre-defined protocols. A certain degree of individualised patient management can only be done in the pre-hospital environment. Comprehensive individualised patient management strategies can be unattainable in the pre-hospital environment due to limitations of diagnostic and advanced monitoring equipment.

2.9 Early Versus Delayed fluid administration

Permissive hypotension is a strategy that prioritises haemostasis over tissue perfusion and includes the administration of intravenous fluid that is titrated to maintain perfusion of the cardiac and cerebral circulations, but not to restore normal circulatory volume (Chesters et al., 2013).

Bickell et al., (1994) determined the effects of delaying intravenous fluid resuscitation until of operative intervention (surgery) in hypotensive patients with penetrating injuries to the torso. 289 patients received delayed fluid intravenous resuscitation, of which 70% (203 patients) survived and were discharged from the hospital compared to 62% (193 of 309 patients) who received immediate fluid resuscitation. The authors concluded that delay of aggressive intravenous fluid resuscitation until operative intervention improves the outcome for hypotensive patients with penetrating torso injuries (Bickell et al., 1994).

Turner, et al., (2000) investigated two treatment protocols via randomisation of paramedics (and not patients) in the pre-hospital environment for patients that sustained traumatic injuries. The first protocol allowed for intravenous fluid administration on scene to all trauma patients, while the in the second protocol, intravenous fluids were withheld until hospital arrival unless hospital arrival was likely to be more than one hour. The mortality was 73/699 (10.4%) in the early (first protocol) as compared to 60/610 (9.8%) in the delayed/no fluid administration group (second protocol). Mortality is said to be an important clinical outcome and end-point in clinical research, but its measurement may be prone to measurement error and reporting bias (Kwan et al., 2009)

Dutton, Mackenzie, & Scalea, (2002) studied 110 patients that presented with haemorrhagic shock. Patients were randomised to two protocols (55 patients per protocol). One protocol allowed for a targeted systolic blood pressure of more than 100mmHg as an end-point, while the other protocol had a targeted systolic blood pressure of 70mmHg as an end-point. The investigators found a titration of lower than normal blood pressure (70mmHg) during active haemorrhage did not affect mortality. They substantiated the overall mortality findings and the lack of differentiation between groups to improvements in diagnostic and therapeutic technology, the heterogeneous nature of human traumatic injuries, and the imprecision of SBP as a marker for tissue oxygen delivery (Dutton et al., 2002).

An evidence synopsis by Liu (2014) found that delayed fluid resuscitation prior to surgery is safe and is associated with better survival and shorter hospital stay compared to immediate fluid resuscitation in the setting of haemorrhagic shock from penetrating torso injuries requiring surgical intervention. However, it is mentioned that these findings should not be applied to all patients and patient groups such as pregnant patients, to hypotensive patients with blunt trauma or severe head injuries, or to rural trauma care settings Liu (2014).

The effects of early versus delayed, and larger versus smaller volume of fluid administration in trauma patients with bleeding was assessed in a Cochrane Review by Kwan et al . (2009:3) found “no evidence from randomised controlled trials for or against early or larger volume of intravenous fluid administration in uncontrolled haemorrhage”.

A retrospective cohort study of 776 734 patients from a national trauma databank found the administration of intravenous fluid in the pre-hospital environment was associated with increased mortality (odds ratio 1.1 95% confidence interval 1.05-1.17).

2.10 Pre-hospital Scene Time and Clinical Care for Trauma

Pre-hospital scene times have been compared with patient survival, patient outcome as well as time to definitive care to name a few (Swaroop et al., 2013). A systematic review and meta-analysis assessing the effectiveness of pre-hospital trauma systems in developing countries found that pre-hospital trauma systems (particularly middle income countries) reduces mortality (Henry & Reingold 2012).

Swaroop et al., (2013) retrospectively researched total pre-hospital times for urban victims of penetrating thoracic trauma. The study documented 908 patients presenting to the emergency room following thoracic trauma with 79% of the patients surviving. They also found that longer pre-hospital times for hypotensive patients were associated with a higher patient mortality. In a time-to-death study, it was found that 35% of patients died in the first 24 hours after sustaining a traumatic of which thoracic injuries from penetrating injury were most common (Acosta et al., 1998).

Band et al., (2014) compared mortality associated with the transportation of patients that sustained penetrating traumatic injuries by emergency services and police to a Level I or Level II trauma centre. In un-adjusted analysis, there was a higher mortality with patients transported by police to hospital compared to emergency ambulance services (29.8% versus

26.5%; OR 1.18; 95% confidence interval [CI] 1.00 to 1.39). However, in the adjusted models, there was no significant difference in mortality between the two modes of transportation to hospital (odds ratio [OR] 0.78; 95% CI 0.61 to 1.01). Interestingly, the subgroup analysis showed that patients with gunshot, stab wounds or with an injury severity score of more than 15 were more likely to survive if transported by police (Band et al., 2014).

Funder et al., (2011) studied on-scene time and patient outcome after penetrating injury. The observational cohort study registered 467 patients of which 442 (94%) were included at the 30-day survival end-point. A higher mortality rate was found among patients treated in the pre-hospital environment with an on-scene time greater than 20 min ($p=0.0001$).

Over a 14 year period, McCoy & Menchine, (2013) studied emergency medical services out-of-hospital scene and transport times and their association with mortality (primary outcome) in trauma patients presenting to an urban Level I trauma centre. 84% (16170) of the injuries were blunt, with 596 (3.7%) deaths, while 16% (2 997) were penetrating, with 269 (9%) deaths. Their final conclusions indicated an increase in the odds for mortality among patients with penetrating traumatic injuries with scene times greater than 20 minutes (McCoy & Menchine 2013).

Seamon et al., (2007) retrospectively analysed 180 charts of patients that sustained penetrating traumatic injuries and underwent a thoracotomy in the emergency department. They hypothesised that survival of critically injured patients that sustained penetrating injuries requiring emergency department thoracotomy would be improved if procedures were restricted until arrival to the trauma bay. Their findings displayed the performance of pre-hospital procedures in critical, penetrating injury victims had a negative impact on survival after emergency department thoracotomy and recommended that paramedics should adhere to a minimal or 'scoop and run' approach to pre-hospital transportation in this setting (Seamon et al., 2007). The 'scoop and run' idea may be a simple idea but it requires careful consideration which includes pre-hospital emergency care system, rural and urban environments skills performed in the field which includes the differentiation between advanced life support and basic life support (Smith & Conn 2009). However, Beuran et al., (2012) endorses a more balanced approach between the scoop and run approach versus the stay and play approach (staying on scene to perform procedures necessary prior to scene departure) in patients that have sustained trauma accounting also for the mechanism of injury, distance to the nearest trauma centre and resource availability.

When comparing pre-hospital resuscitative interventions for penetrating traumatic injury patients performed by Basic and Advanced Life Support providers (BLS and ALS respectively), Seamon, Doane, & Gaughan, (2013) found that ALS providers have longer scene times compared BLS providers, but did not significantly increase total pre-hospital time.

A valuable point was raised by Revell et al., (2002: 497), and is one of consensus view: “The on scene time should not be prolonged by attempts to gain a line” and “A limit of two attempts en-route is reasonable”. Accounting for all of the evidence above, a meta-analysis compiled for Emergency Services in the United States of America identified no empirically defined average pre-hospital time intervals and provide points of reference for pre-hospital time intervals for inter-emergency service comparison as well as national comparison (Carr et al., 2006).

2.10.1 Intravenous Cannulation for Fluid Administration and Scene Time

Intravenous cannulation involves the placing of catheter in the vein of a patient for drug or intravenous fluid administration (Revell et al., 2002). Inappropriate use and technique may result in infection and increased pain (Iqbal et al., 2009). Intravenous cannulation is a procedure that can be performed by South African Ambulance Emergency Assistants and Emergency Care Technicians and Emergency Care Practitioners (HPCSA 2011). Scene time increases when pre-hospital emergency care providers perform procedures such as intravenous cannulation and endotracheal intubation on patients that have sustained traumatic injuries (Carr et al., 2008).

Intravenous cannulation for a trauma patient may save time in hospital, but repeated unsuccessful attempts and venous access with incorrect gauge size may also delay care (Revell et al., 2002). Gonzalez, Cummings, Phelan, Mulekar, & Rodning (2008), found a mean time of 14.5 minutes was spent on scene in the urban setting for single intravenous cannulation and 15.8 minutes when two attempts are made by pre-hospital emergency care providers. Carr et al., (2008) found that the additional time associated with intravenous access in isolation was approximately 2 minutes and 3.17 and 5.08 minutes when intravenous access was accompanied with another procedure. Kuzma et al., (2009) studied intravenous utilization in the pre-hospital emergency environment and patient presentation. They found that high intravenous utilization were associated with hypotension, bradycardia,

bradypnea, and abnormal skin signs. Similar findings regarding scene times were reported by Eckstein et al., (2000) regarding time spent on scene by pre-hospital emergency care providers. The difficulties proved to be valid predictors of cannulation failure and exceedance of a two minute threshold with intravenous cannulation includes lighting, vein visibility and palpability (Prottengeier et al., 2015). A recent Cochrane systematic review investigating advanced life support services adapted for low –to-middle income countries found no evidence supporting advanced training (including intravenous cannulation amongst other clinical skills) benefiting patient outcomes (Jayaraman et al., 2014).

Engels et al., (2014) retrospectively analysed hospital charts of 208 patients at a trauma centre of which 81 % of the patients received intravenous lines in the field which resulted in 5 minute longer scene time (16.1 vs 11.4, $p < 0.01$). Furthermore, the time taken for intravenous cannulation in the emergency room for those that did not have intravenous lines in the pre-hospital environment was 21 minutes. However, Eckstein et al., (2000) also determined whether pre-hospital advanced life support care and not just intravenous cannulation improved the survival of major trauma patients. Despite the application of advanced clinical procedures, the authors found no overall improvement in patient survival.

To date, limited literature describes current pre-hospital intravenous cannulation practices for penetrating trauma. The above studies by (Revell et al., 2002; Kuzma et al., 2009) describe a harmful association between intravenous cannulation practices for trauma. However little is described regarding the health care systems and infrastructures in which the pre-hospital emergency care providers work within as well as the structures and processes present or absent, supporting or challenging pre-hospital emergency care providers. Jayaraman, (2014) describes accountability of the following factors when drawing comparatives in pre-hospital care interventions. Some of these factors includes: the impact of advanced life support related interventions on scene time; the mechanism of trauma (blunt versus penetrating); geographical location (distance from general hospital care and definitive care); injury severity, injury pattern, mode of pre-hospital transport; staff qualification on ambulances (doctors and/or paramedics); training in additional advanced life support certifications (ACLS, PHTLS, etc.) or postgraduate or specialist training in intensive care or anaesthesia, which may affect outcomes.

2.10.2 Evidence Based Practice and Intravenous Fluid Management

Patient care and clinical decision making in the pre-hospital environment making involves a thought processes not limited to, what to do, when and how to do it. These clinical decisions are based on guidelines and protocols supported by various forms of evidence. The ultimate aim of clinical guideline is to improve the quality of patient care (Woolf et al., 1999; Grimshaw et al., 1995).

Evidence based practice (EBP) because of the inadequacies of clinical-based-medicine, which emphasised “pathophysiological rationale, clinical experience and intuition as the cornerstones to good practice” (Kelly & Horsley 2000:116). In the practice of clinical based medicine, there may be a wide inter-clinician variability in practice, which may result in patients missing out on beneficial therapies due to delays from the time when treatments were proven to be beneficial by research and to the application in clinical practice (Kelly & Horsley 2000).

EBP guidelines have been developed for fluid management in the pre-hospital environment with an emphasis on penetrating traumatic injuries (Revell et al., 2002; Kortbeek et al., 2008). Little is known regarding intravenous fluid management practices of EBP guidelines in the South African. Simpson et al., (2012) found that paramedics with tertiary education and shorter length of service have positive expectations and perceptions and support for EBP.

Health practices may also have financial implications. Few studies are available evaluating the cost-effectiveness of intravenous fluid management specifically for trauma and more-so in the pre-hospital environment (Dretzke et al., 2004). In 2004, a clinical effectiveness and cost-effective study was conducted involving the administration of intravenous fluids for adults sustaining trauma in the pre-hospital environment. The authors found only four suitable randomized control trials of which, according them, was poorly designed and/ or conducted. Only one randomized control trial found that the administration of intravenous fluid for patients that have penetrating injuries may be harmful. In terms of cost-effectiveness, there was no difference in using intravenous fluids versus not using fluids (Dretzke et al., 2004). However, the contextual circumstances (budgetary allowances and their countries economic status) are different to South African pre-hospital emergency care setting, and there may be significant cost implications.

2.11 Chapter Two Summary

The chapter starts with brief synopsis of the origins of intravenous fluid therapy and the major developments since its inception. Literature from pre-hospital, in-hospital and laboratory studies (animal studies) were deliberated. In certain instances, fluid resuscitation strategies within the battlefield context were also included.

This chapter highlighted the burden of trauma and its impact on low to middle income countries, raising major public health concerns. An epidemiological perspective was also presented using injury related mortality statistics for South Africa and where applicable, attributed deaths caused by sharp force injuries/stabbing, gunshot injuries or blunt-force injuries were presented. The consequences of trauma on individuals, groups and communities were briefly touched on. The pathophysiology, clinical presentation and overall management strategies of shock as a result of penetrating trauma were presented. Recommendations from leading groups such as Advanced Trauma Life Support group were presented and discussed.

A greater portion of this chapter was dedicated to intravenous fluid therapy within the trauma context. Intravenous fluid therapy was discussed at length providing evidence supporting low intravenous fluid volumes for penetrating traumatic injuries. The harmful effects with the over-administration of intravenous fluids were also noted. As the debate around the choice of intravenous fluid type for patients with trauma is not new, key evidence was presented from human and animal studies with majority of the evidence discouraging the practice of large intravenous fluid volume administration for trauma (Hatoum et al., 2002; Revell et al., 2002; Alam & Rhee 2007; Haut et al., 2011; Balogh & McKinley 2003; Lobo et al., 2006; Hußmann et al., 2011). Key findings from human and animal studies described aggressive intravenous administration strategies associated with an increase cardiac and pulmonary complications, gastrointestinal dysmotility, coagulation disturbances, and immunological and inflammatory mediator dysfunction.

Alongside the recommended intravenous fluid volumes for trauma, the preferred intravenous fluid type was also presented. Alluding to cost, patient safety (allergy and fluid sensitivity) as well as patient safety post fluid administration, crystalloid intravenous fluids are recommended over colloid fluids when managing patients with trauma. The next chapter will provide an overview of the methodology used to achieve the objectives of this study.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The methodology described in this chapter was designed to meet the aim and objectives of this study. This chapter describes the methodology used for data collection; the processes related to sampling; delineation of research, assumptions and limitations. Ethical considerations concerning this study have also been included with supporting documents such as letters of consent, ethical approval and participant information forms listed as annexure items to this chapter.

3.2 Study Design

A non-experimental research design was used to investigate the objectives. An observational descriptive prospective survey was used to describe the clinical parameters and practitioner practices related to fluid management as well as patient demographics. Fouche & Bartley (2011), describes the quantitative methodology as one suited to describe trends or explain the relationship between variables either observed or measured. The quantitative descriptive approach had applicability in determining the intravenous fluid management practices for penetrating injury and quantifying other aspects of penetrating injury. The scarcity of data related to the intravenous fluid management practices for penetrating injury in the South Africa also provided a basis for a descriptive methodology. Although unsophisticated in its methodological construction, this methodology provided a pertinent structure for patient demographic data collection as patient demographic data is limited to mortality data collected by forensic pathology laboratories and/or mortuary services and pre-hospital information systems do not adhere to the study questions.

The Western Cape Provincial Health Research Committee requires research projects to be approved by an Ethics Committee prior to formal application to conduct the study within the organization. Ethical approval was given by Cape Peninsula University of Technology (CPUT), reference CPUT/HW-REC 2013/H28 (See Annexure A) and requisition to conduct the study was sent to the Western Cape Provincial Health Research Committee and Director of Western Cape Emergency Medical Services. In mid-December 2013, written approval was received from the Western Cape Provincial Health Research Committee to conduct the study (reference RP145/2013 Annexure B). One of the requirements by the Western Cape

Provincial Health Research Committee is that the Director of the Western Cape Emergency Medical Service be notified. The Emergency Medical Services Director was contacted and soon thereafter, and with his approval (Annexure C) the ambulance base managers were contacted to arrange suitable times to meet with emergency personnel to explain the research project (Annexure D), and obtain their consent (Annexure E) to participate in the study.

Emergency care personnel who met the inclusion criteria and gave consent via the completion of a consent form were given four sheets (Annexure F) containing the data collection tool and an information sheet describing the patient inclusion and exclusion criteria for the study, similar to the format seen in Table 3.1. Extra data collection sheets were placed at the ambulance bases at the data collection box (see section 8.2 data collection, management, protection and dissemination). Emergency Care providers had to be registered with the HPCSA as an Ambulance Emergency Assistants, Paramedic (either with a Critical Care Assistant or National Diploma Emergency Medical Care qualification), Emergency Care Technician or an Emergency Care Practitioner in order to participate in the study as described in Table 3.2. Further information regarding participant sampling can be seen in section 3.5.

The aim of this study was to undertake surveillance of penetrating injury and related intravenous fluid therapy in the pre-hospital emergency care environment. The satisfaction of this aim was intended to inform emergency care clinicians, policy makers and educators on the population at risk of penetrating injury, current treatment modalities and injury prevention opportunities. Further, this study aimed to highlight the need for epidemiological surveillance of penetrating injury as a burden of pre-hospital emergency care²² and the challenges associated with the emergency care of penetrating injury.

This study was partially funded by the Teaching Development Grant awarded by the Cape Peninsula University of Technology. The funds paid for printing costs, statistical consultations and poster presentations.

²² Emergency Care (EC) refers to the emergency care profession that is located in the out of hospital setting (although not exclusively)

3.3 Research Objectives

The primary objective was to develop a surveillance instrument for the purpose of penetrating injury and associated intravenous fluid therapy surveillance.

Through this surveillance instrument, the secondary objectives were:

- 3.3.1 To provide a clinical description of the pre-hospital fluid management practices associated with penetrating injury²³ with reference to: fluid type, volume of fluid administered, time period of fluid administration, number of intravenous attempts, number of intravenous cannula placements and cannula size (bore).
- 3.3.2 To identify the clinical indications/ indicators²⁴ used in pre-hospital emergency care for fluid resuscitation.
- 3.3.3 To describe the clinical end-points, in relation to the clinical indicators, used by pre-hospital emergency care providers for fluid resuscitation.
- 3.3.4 To determine the clinical presentation of the penetrating traumatic injury/ injuries with reference to anatomical location(s) of penetrating injury/injuries, number of penetrating, presence of other injuries/wounds the systolic blood pressure, heart rate and capillary-refill-time upon scene arrival as well as the systolic blood pressure, heart rate and capillary refill-time upon hospital arrival.
- 3.3.5 To describe the basic demographic profile of the patient including age and gender.

3.4 Data Collection Tool Development

The researcher had insider knowledge regarding the clinical management practices which included the strengths and weakness in the capturing of patient and clinical information in the pre-hospital environment. The research also observed a varying level of penetrating injury and specific intravenous therapy information recorded on patient report forms by pre-hospital emergency care providers. Thus, using the current patient record document as a data source will be a major limitation in meeting the study's objectives. Notwithstanding the insider knowledge and variances in the completing of patient report forms, the scarcity of penetrating injury and intravenous fluid therapy data as highlighted in the literature review highlighted the need for a data collection tool aimed at effectively and efficiently collecting the appropriate

²³ This trauma type is delineated to the Western Cape Metropole due to its high incidence (Donson 2009) in this locale and is further explained in Chapter Three.

²⁴ Clinical indicators refer to objective measures/ vital signs within the logistical and scope limitations of the pre-hospital emergency care profession.

information to survey penetrating injury and intravenous therapy in the pre-hospital environment.

Key modular information (mechanism of Injury, intent, type of injury, place of occurrence and patient demographics) from the International Classification of External Causes of Injuries (ICECI version 1.2) was used in the design of the data collection tool. The ICECI, a tool consisting of a set of classifications in a modular structure designed to be useful for injury surveillance. The designers of the tool mention that “depending on the objectives and setting of a data collection system, it will be necessary and feasible to collect all or some data elements from the ICECI”. ICECI data items focus on external causes of injury. These will normally be supplemented by other items, typically including demographic items (e.g. age, sex), dates and perhaps times (e.g. of injury), the nature of injury sustained”(ICECI Coordination and Maintenance Group 2004).

3.5 Validity of the Tool

To best knowledge of the researcher, the tool designed for data collection in this research study is the first of its kind and has not been statistically tested or validated. The tool meets the minimum requirements for face validity and content validity.

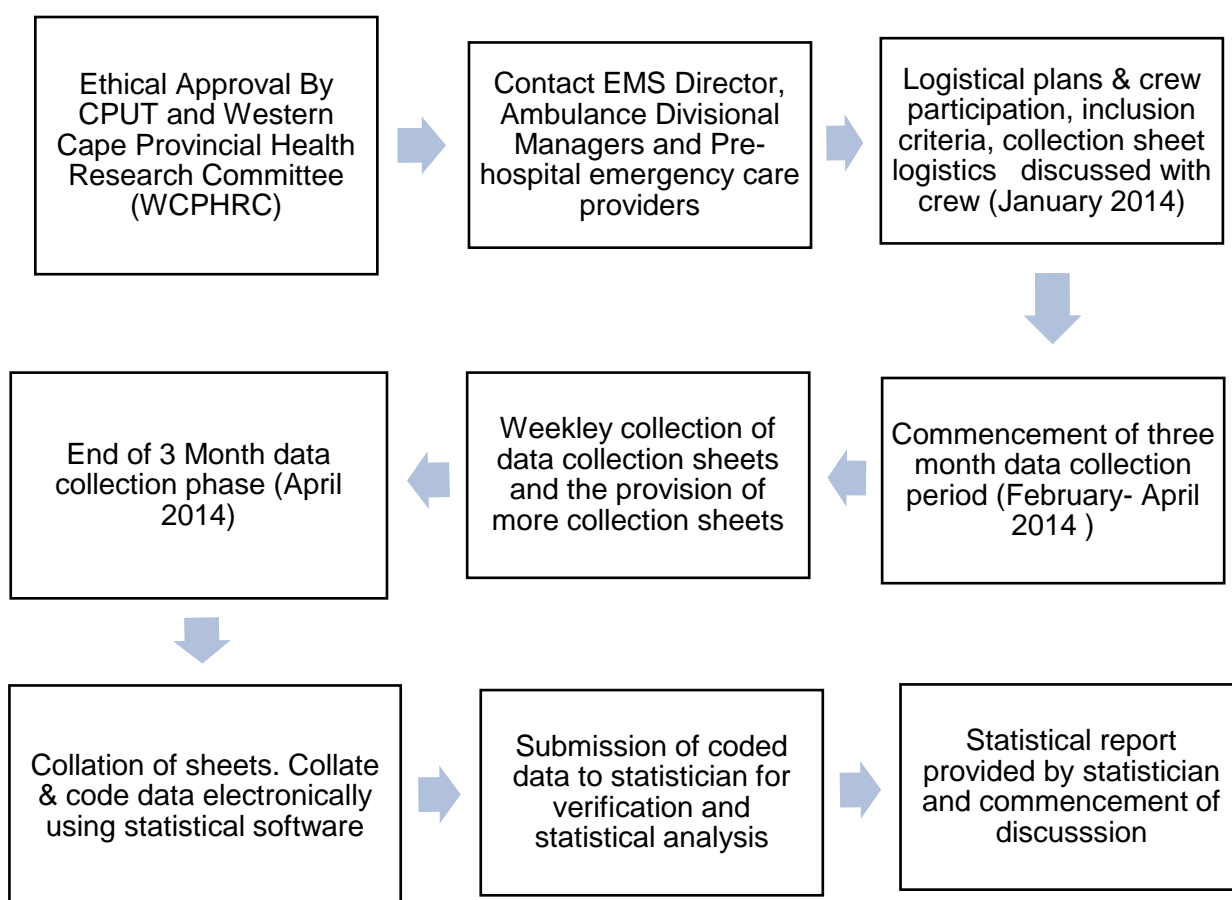
The contents of the data collection sheet are similar to that used by emergency care provider when completing a patient report form. However, there is no information on the data collection sheet that can link a data collection sheet with an emergency care provider or the patient. The sheet was designed by the primary investigator, during the transformation of the study objectives into the data collection tool. During the design process/phase, the data collection sheet was piloted by giving the form to a group of emergency care providers working in the field for their comment regarding the practical and logistical issues when completing the sheet. Alterations were made to the data collection tool to achieve the objectives of the study. The alterations to the data collection tool included rearranging data entry fields and formatting for easier use. The alterations were approved by the supervisor of the primary investigator.

The process for data collection involved the completion of a data collection sheet (Annexure F) by a data collector for patients that have sustained a penetrating traumatic injury. Prior to the commencement of the questionnaire, the patient had to comply with the inclusion criteria seen in Table 3.1.

Table 3.1: Inclusion Criteria for the study

Criteria		Description
1.	Penetrating traumatic Injury	The patient must have suffered a traumatic injury that was caused by a sharp object that may include, but is not limited to: glass objects (e.g. broken bottle), sharp metal object (knife or other improvised devices), bullet(s) or any other object that has a sharp edge, excluding needles.
2.	Patient Age	Patient is older than the age of twelve (12) years
3.	Injury or Wound Age	The wound/ injury should not be older than twenty four (24) hours prior to patient care.
4.	Primary Calls	Emergency Care Providers had to be the first to provide medical care. This excludes hospital/ inter-facility transfers that are classified as 'urgent'.
5.	Transportation	Patients have to be transported to a medical facility. Patients that refuse transportation are not eligible for inclusion in the study.
6.	Data Collection	Only one Pre-Hospital Penetrating injury and Fluid Management Survey Tool should be completed per patient. Incomplete forms should be handed to the researcher

Figure 3.1 Summary of Data Collection Process



3.6 Sampling

The sample in this study was the number of penetrating trauma cases seen by pre-hospital emergency care providers in the Cape Metropole. There are different pre-hospital emergency care qualifications in South Africa as seen in Table 3.2, with clinical capabilities varying from basic to advanced life support. In order to meet the objectives of the study, only intermediate and advanced life support emergency care providers were included in the data collection process. The number of practitioners listed in the table is based on the residential address of the practitioner upon registration and may not necessarily depict the actual province of employment or practice. Additionally practitioners may be registered in their respective categories, but may be working abroad in the clinical setting, health education, emergency medical service management or other sectors.

Basic life support emergency care providers were excluded as the practice of fluid management is not included in their scope of practice as per scope of practice regulations set by the HPCSA. Practitioners from the public sector were only selected as there are many private ambulance services in the Cape Metropole, each employing small staff cohorts in comparison to the public sector. This study had limited funding and including private ambulance services was not feasible.

Table 3.2 South African Pre-hospital Qualifications, Level of Care and Intravenous Capability

Qualification Name	Level of Care	Intravenous Fluid Therapy Capability
Basic Ambulance Assistant	Basic Life Support	No
Ambulance Emergency Assistant	Intermediate Life Support	Yes
Critical Care Assistant	Advanced Life Support	
National Diploma Emergency Medical Care		
Emergency Care Technician		
Emergency Care Practitioner		

In place of stratified sampling (or other random sampling techniques), non-random purposive sampling was used. The above sampling technique was chosen due to the nature of the problem being investigated as well as the factors described in the sampling frame which included qualification type which was linked to their scope of practice. Similarly, emergency care providers are unaware when traumatic incidents will occur or which emergency care provider at the ambulance division will respond to the emergency. Thus target sampling, quota sampling or other non-probability or probability sampling methods were unsuitable. Private emergency medical services and emergency medical care students (working under

clinical supervision) were excluded. A minimum response rate was not determined prospectively. Rather, the appropriateness of the sample size was calculated retrospectively after the three month data collection, using the sampled cases in relation to the total number of cases seen by the entire emergency medical service population. Additionally, to cross check the sample size appropriateness statistical methods using statistical task of estimation (estimating proportions) and statistical task of inference (Hypothesis testing) were used. A description of the statistical computation for appropriate sample size determination can be seen in the sections below.

3.6.1 Sample Size Determination

One of the basic requirements of the research is to estimate proportions from the study population, for instance, the percentage of trauma victims who have a certain demographic or clinical characteristic. Accordingly, the probabilistic properties of statistical estimation and inference concerning proportions were used to determine an appropriate sample size. There are two broad approaches to the determination of sample size. One is based on the statistical task of *estimation* and the other is based on the statistical task of *inference* (hypothesis testing). Both were used in order to cross-check that the sample size used was appropriate for both tasks. In this study, the study population (total number of trauma cases seen during the three-month period of the study, excluding deaths on scene, deaths in ambulance and patients refusing care) was $N=2884$.

3.6.1.1 Sample Size for Estimating a Proportion

To be conservative, it was assumed that the proportion to be estimated is actually 0.5 (50%) as this is the 'worst case scenario' yielding the maximum necessary sample size. The α value, that is, the probability allowing a 'bad sample' that does not yield an estimate within the margin of error. In this case $\alpha=0.05$ was used, which is typical. The margin of error e , that is, how close to the true value required in our estimate to be with probability $1-\alpha$. In this case $e=0.08$ was used. This means that, when estimating a proportion from the study population that is actually 50%, it will have a 95% probability of obtaining an estimate within $\pm 8\%$ of the true value, i.e. between 42% and 58%. The following formula gives us the smallest sample size necessary to achieve the desired margin of error:

$$n > \frac{\frac{z_{\alpha/2}^2 p(1-p)N}{e^2}}{\frac{z_{\alpha/2}^2 p(1-p)}{e^2} + N - 1}$$

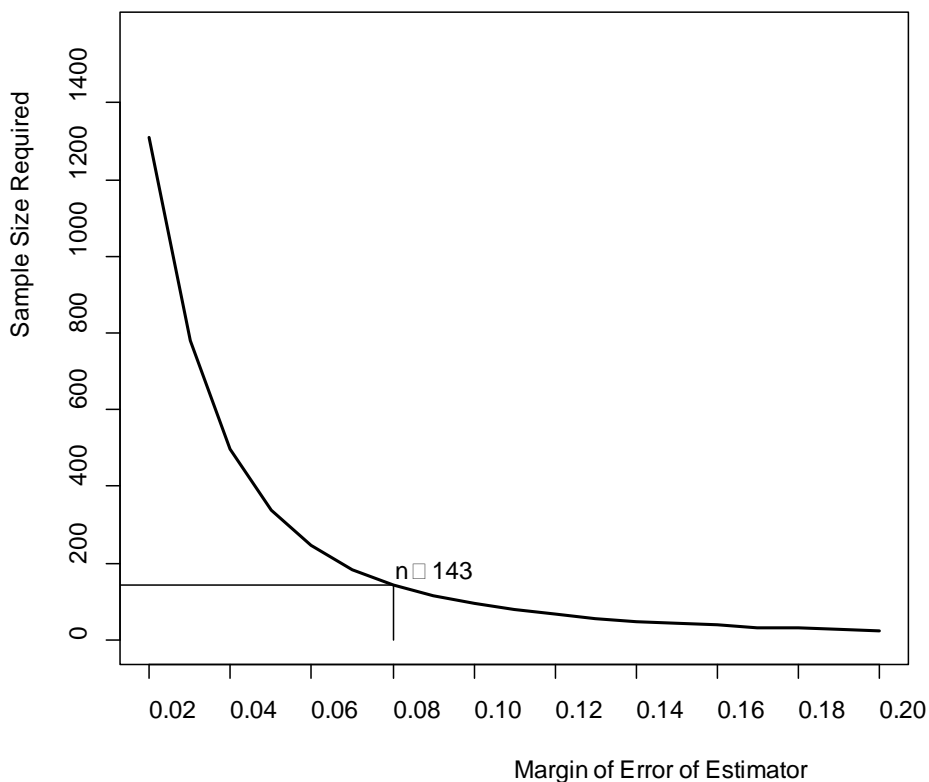
Since sample size must be an integer, when the formula gives a decimal value, the value was rounded up to the next integer, which will be the smallest integer-valued sample size that can achieve the desired margin of error. Here, $z_{\alpha/2}$ is the value of z that satisfies

$\Pr(Z > z) = \frac{\alpha}{2}$ where Z is a random variable following the standard normal distribution. N is

our population size (2884), p is the proportion to be estimated (conservatively set to 0.5) and e is the margin of error. The figure below shows the relationship between margin of error and required sample size in our case. With the margin of error set to 0.08, the necessary sample size is $n=143$.

Figure 2.4 Sample Size Vs. Margin of Error for Estimating Population Size

Sample Size vs. Margin of Error for Estimating $p = 0.5$
 where population size $N = 2884$, $\alpha = 0.05$



3.6.1.2 Sample Size for Testing a Hypothesis

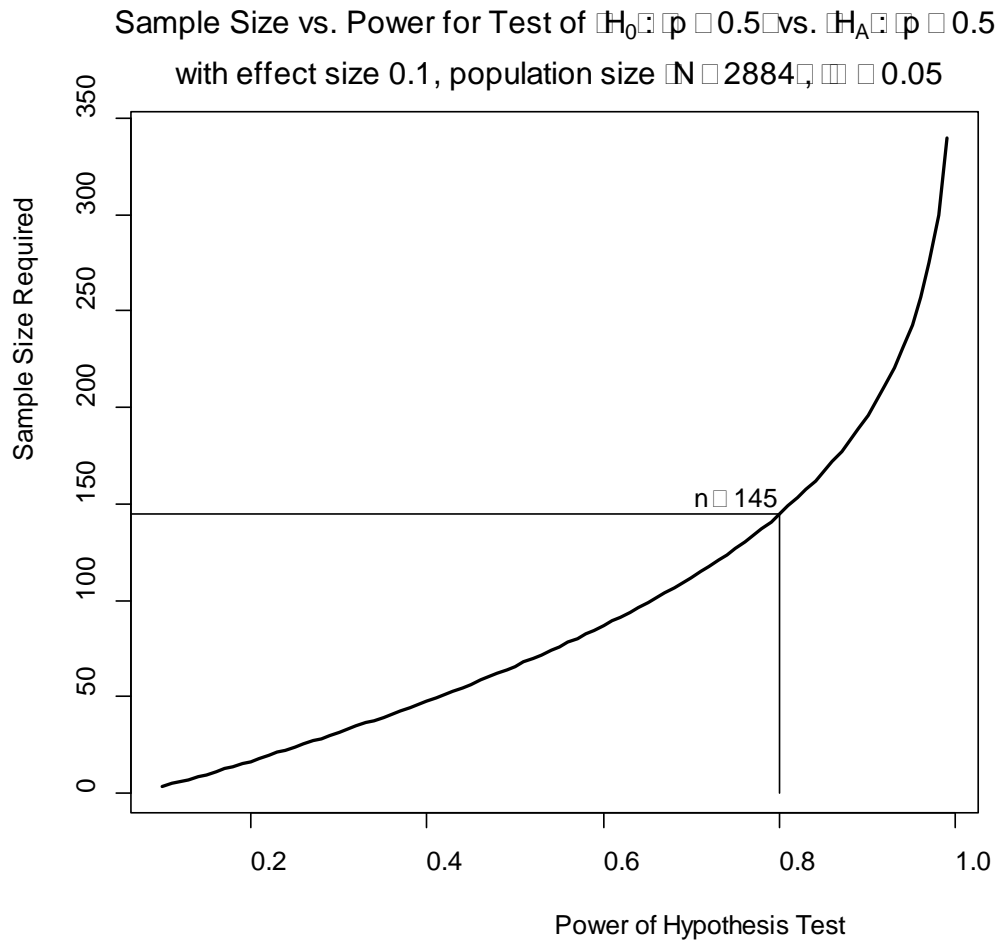
Under the sampling size calculation mentioned above, a minimum sample size needed to achieve a certain level of power $1-\beta$ in a statistical hypothesis test was determined. 'Power' in a statistical hypothesis test refers to the probability of rejecting the null hypothesis that is false; in other words, the probability of *not* committing a Type 2 error (which occurs with probability β). In the case of this study a hypothesis test that would test the null hypothesis $H_0 : p = p_0$ against the one-sided alternative hypothesis $H_A : p > p_0$ was setup. To determine the power, an effect size (η , i.e. the amount by which the true proportion exceeds p_0) was needed. In the case of this study, $p_0 = 0.5$ and $\eta = 0.1$, corresponding to testing the null hypothesis $H_0 : p = 0.5$ against the alternative hypothesis $H_A : p > 0.5$ when the null hypothesis is false and the true value of p is $p_1 = p_0 + \eta = 0.5 + 0.1 = 0.6$. As before, our population size is $N=2884$ and our α value is 0.05. In this case, α denotes the significance level of the hypothesis test, i.e. the probability willing to allow of committing a Type 1 error (rejecting a null hypothesis that is true).

The sample size needed to achieve a power of $1-\beta$ in this hypothesis test is given by the following formula:

$$n > \frac{N}{1 + \frac{(N-1)(p_0 - p_1)^2}{p_1(1-p_1) \left[z_\beta - z_\alpha \sqrt{\frac{p_0(1-p_0)}{p_1(1-p_1)}} \right]^2}}$$

Here, z_β is the value of z that satisfies $\Pr(Z > z) = \beta$ where Z is a random variable following the standard normal distribution, and z_α is defined similarly. The figure below shows the relationship between power and required sample size in our case. With the power set to 0.8 (a typical value), the necessary sample size is $n=145$.

Figure 2.5 Sample Size Vs. Power



The actual sample size used in the study was $n=143$. As the statistical calculations above show, this sample size is sufficient to estimate a proportion actually equal to 0.5 within ± 0.08 , 19 times out of 20. (The margin of error would decrease as the true value of the proportion being estimated moves closer to 0 or 1.) It is also sufficient to achieve a power of nearly 80% in a one-sided test of the hypothesis $H_0 : p = p_0$ with an effect size of 0.1 and a significance level of 5%. The above calculations demonstrate that the sample size used in the study was statistically appropriate.

3.7 Data Collection, Management and Protection

Data was collected by pre-hospital emergency care providers using a pre-structured sheet (Pre-Hospital Penetrating injury and Fluid Management Survey Tool). The sheet contained numerous variable related to patient demographics and clinical information. The sheet contained no direct form of identification related to the patient or emergency care provider treating the patient. One sheet was completed per patient. After the sheet was completed by an emergency care provider, it was placed in a box at the ambulance base. Each ambulance base had one data collection box. The data collection box was opaque and had a locking mechanism, of which the primary investigator was the only individual with access. Every five days, data collection sheets were retrieved from the box the primary investigator. A high response rate was anticipated. Response rates are discussed in Chapter Four.

After all data collection sheets were collected, a data coding system using numbers and letters was used to associate variables collected into a computer program. A dual entry method, (i.e. two people entering the collected data into the computer program to avoid error) was used. All physical data sheets were locked in a wall safe, with the primary investigator being the only person having access. Backup copies of the data were retained on a mobile storage device. Electronic data was password protected.

Statistical analysis was performed by a statistician and the primary investigator using Microsoft Office® 2013 Excel® and IBM™ SPSS® Statistics for Windows®, Version 22.0 and The R Project for Statistical Computing (Software) respectively. Statistical consultation (statisticians) also took place with academic staff at the Faculty of Emergency Medical Sciences as well as the staff at the Cape Peninsula Library Bellville Campus.

3.8 Statistical Formulae Development

Frequency tables and basic graphical methods (bar graphs and pie graphs) were used to display frequencies and relative frequencies (proportions) for categorical variables. Histograms were used to display the distribution of continuous variables (e.g., intervals of time).

Confidence intervals for proportions will be calculated using the method of Sison & Glaz (1995) as implemented in the MultinomialCI library within R statistical software (Team 2018). Since proportion estimates from a multinomial distribution are mutually dependent, it was a

more reliable method used to calculate all the confidence intervals simultaneously, taking dependencies into consideration, rather than calculating them individually. Error bars based on these simultaneous 90% confidence intervals were added to the bar graphs. Confidence intervals for quantitative variables such as age were calculated using the t distribution method:

$$\bar{X} \pm t_{\alpha/2} \frac{S}{\sqrt{n}}$$

A significance level of 5% was used for all hypothesis tests, and the results of hypothesis tests were reported as p -values. Hypothesis testing for differences in means of quantitative variables between population subgroups was conducted using single-factor Analysis of Variance. The test statistic follows an F distribution with $a-1$ numerator degrees of freedom and $n-a$ denominator degrees of freedom, where n is the total sample size and a is the number of groups being compared. The F statistic is the ratio of mean squared error between groups to mean squared error within groups.

Pearson's Chi-Squared Test for Independence was used to test for an association between two categorical variables. The Pearson's Chi-Squared Test method entailed the construction of a two-way frequency table for these two variables. A comparison was completed using the test statistic T below to the χ^2 distribution with $(r-1)(c-1)$ degrees of freedom, where r is the number of rows in the table (number of categories of the first variable being compared) and c is the number of columns in the table (number of categories in the second variable being compared). The formula for the test statistic T is given below, where O_{ij} is the observed cell frequency in the i th row and j th column of the table, and E_{ij} is the expected frequency of that cell under the null hypothesis. If $r=2$ and $c=2$, a Yates continuity correction is applied to the statistic.

$$T = \sum_{i=1}^r \sum_{j=1}^c \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Several vital sign indicators and other key variables in the data (e.g., systolic BP, diastolic BP, heart rate) are interval-censored, denoting that we have a lower and upper bound for the value but do not know the exact value. For this reason, parametric survival regression

models were used, since they are designed to handle interval-censored dependent variables. Since our dependent variables are not survival times, we used the normal distribution as the underlying model distribution rather than the Weibull or exponential distribution as is typically used in survival analysis. A model with only an intercept (no independent variables) was used when the aim was to estimate the mean and obtain confidence intervals for interval-censored variables. A model with an independent variable was used to analyse the relationship between an interval-censored dependent variable and one or more independent variables. Details of the parametric survival regression model can be found in Kalbfleisch and Prentice (Kalbfleisch & Prentice 2002). The models were implemented using the *survival* library in R statistical software. The general model equation in the case of k independent variables is:

$$\log Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \varepsilon$$

Note that Y is not directly observed but is an interval-censored variable as discussed above. The X 's are the independent variables, the β 's are the parameters to be estimated and ε is a random error term.

3.9 Delineation of Research

This study did not cover documentation of fluid management for other traumatic injuries such as blunt trauma or any other non-penetrating injury. Patients (defined as patients less than twelve years) were not included in this study as per the World Health Organisations classification for paediatric medication administration (WHO 2013).

Evidence based guidelines of which pre-hospital emergency care providers' fluid management practices will be compared to, do not incorporate paediatric populations. Patients that have penetrating injuries that were more than twenty-four hours old were not included in this study as fluid management in the emergency setting may not be applicable. The administration of other pharmacological agents, irrespective of their composition or desired effect was not documented in this study, as it is not directly related to the concept of fluid management. Years of experience of emergency care providers was not measured.

Patients that are brought to the health facility care by other means (private transportation) other than pre-hospital emergency medical services (ambulance) were also not included in this study. This includes inter-hospital transfers, as data such as total volume of fluid, systolic blood pressure prior to fluid administration may not be directly available to pre-hospital emergency care providers completing the Pre-Hospital Penetrating injury and Fluid Management Survey Tool.

The study only looked at the areas serviced by the major four ambulance divisions in the Cape Metropole. The Cape Metropole was delineated to four major sectors serviced by four major provincial ambulance divisions in the Western Cape. The geographic map as seen in Annexure G. Using Cape Town as a central point of reference, the metropole extends from Cape Town CBD to Bloubergstrand, Durbanville and Kraaifontein in the Northern Suburbs, Macassar in the Eastern Suburbs, Fish Hoek to the South and Houtbay and Green Point to the West.

The documentation of other resuscitative efforts such as intubation, mechanical ventilation, or any other advanced life support procedures (pharmacological directed pain relief) was not documented or covered in this study as each of the parameters have other variables that was not be feasible to collect in this study. Lastly, causal relationships between variables was not analysed due to the characteristics of an observational descriptive methodology.

3.10 Assumptions

It was assumed that the Western Cape Department of Health: Director of Emergency Medical Services as well as the Health Research committee will readily accept this study (after ethical approval) and provide access to its health care facilities, as these governing bodies have direct interest in the proposed study.

It assumed that pre-hospital emergency care providers were willing to complete the Pre-Hospital Penetrating injury and Fluid Management Survey Tool after managing a patient that has sustained a penetrating traumatic injury and that the sheet will be completed honestly and accurately. It was also assumed that the sample was truly representative and the data collection tool was valid and reliable.

3.11 Expected Outcomes and Contributions of the Research

The expected outcomes of the study were to determine the fluid management practices for penetrating injury in the pre-hospital environment, and its relation to current evidence based practice as well as other significant aspects related to fluid management as seen in the objectives of the study. The secondary findings of the study were to identify the demographic profile of the penetrating injury patient as well as the chronological factors related to patient transportation.

The findings of this study will be made available nationally and internationally communities in pre-hospital emergency medicine (practice and education), epidemiology and the current discourse of fluid management in trauma through publication. Additionally, the findings obtained from this study will provide justification for further research (qualitative and quantitative) at undergraduate as well as post-graduate level.

Dissemination will take place on the form of publication in a relevant journal as well as possible poster presentation(s) at relevant conferences. A summary of the findings (results) will be sent to the Director of Emergency Medical Services and with the director's approval, summaries of the results will be placed on the notice board of the four ambulance divisions.

3.12 Limitations

The limitations of this study are inherent to the methodology which is linked to generalizability of results, seasonal trends in injury and response rate by emergency care providers. Clinical parameters are interlinked with one another and may directly or indirectly alter an individual's outcome. However, due to time and resource constraints clinical parameters such as blood lactate and arterial oxygenation to name a few not be measured. Additionally, in the acute traumatic setting some of these clinical measurements may be of lesser priority in the initial patient-stabilisation. The clinical data provided by pre-hospital health emergency care providers was self-reported. The number of pre-hospital emergency care providers participating in this study was limited.

3.13 Ethical Considerations

The potential for individual harm as well as group harm was minimised. As clinical data was collected from human subjects and clinical practice data from pre-hospital emergency care providers, special attention was made to respect for persons, beneficence, autonomy and

justice (Singh et al., 2007). These principles was applied in practice by not divulging the names of the patients, emergency care providers and health care facilities will be kept confidential during collection, storage, analysis or during dissemination. Incident numbers and patient report form numbers were used, thus providing the patients, emergency care providers as well as the organisation with anonymity. Pre-hospital emergency care providers were not forced or coerced in any way, nor were they compelled to participate for the entire three month data collection period. Informed consent was obtained from each practitioner prior to their participation in the study. The principles of capacity, disclosure, understanding and voluntary participation as described by Singh et al., (2007) were maintained during throughout the study.

The results of this study were discussed and disseminated in a manner that would directly or indirectly harm the patients, emergency care providers as well as the organisation as the protocols used are nationally approved by the HPCSA. Pre-hospital emergency care providers were instructed not to divulge other details of the patient other than what is asked for on the data collection sheet. Pre-hospital emergency care providers were not excluded based on age, gender, years of experience or institution where their qualification was obtained.

At the time of data collection, the primary investigator was an employee of the Western Cape Department of Health: Emergency Medical Services. This risk was managed by the supervisors during data collection and analysis.

3.14 Chapter Three Summary

A quantitative design was used to investigate the objectives of the study. The format of the study was an observational descriptive survey, describing the practitioner practices related to fluid management and the clinical and basic demographic parameters of patients with penetrating traumatic injuries in the pre-hospital environment. The approach used to obtain ethical clearance by the stakeholders was outlined at the start of the chapter. The data collection, management, protection and interpretation procedures were described. The chapter ends with the ethical considerations as well as the limitations of the study. The development of the data collection tool, its validity, limitations and practical application in this study was presented.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter represents the results of three months of the data collected in the investigation of intravenous fluid management practices for penetrating injury in the Cape Metropole. The results are aligned with the objectives of the study. Statistical calculations were computed by a statistician using computer software programs which included: Microsoft Office® 2013 Excel® and IBM™ SPSS® Statistics for Windows®, Version 22.0 and The R Project for Statistical Computing respectively. Sub-sections were created in alignment with the objectives of the study.

4.2 General Results and Patient Demographics

This section describes the general results obtained from the study as well as the findings related to patient demographics. The findings related to patient demographics includes: gender and age, while other general results included emergency care personnel qualifications and their relationship with sharp-object injury management.

An overview of the total reported trauma cases by each ambulance division managed by the Western Cape Government Emergency Services can be seen the table below (Table 4.1). The table is a summary of the total number of calls managed by the provincial ambulance service for the three month data collection period.

Table 4.1 Summary of Total Trauma Reported During the Three Month Data Collection Period

Ambulance District	Call Type ²⁵	Total Number of Calls (minus death on scene, death in ambulance and patients refusing care)			Total Number of Cases for each call type
		Feb	March	April	
Northern	Assault	149	163	133	445
	Shooting	20	48	16	84
	Other Trauma	101	103	99	303
	Haemorrhage	0	0	0	0
Western	Assault	145	164	212	521

²⁵ The category under each call type was provided by the Western Cape Government Emergency Services. These categories are used in their communication centre to document reported cases. No definition was provided for other trauma and haemorrhage.

	Shooting	1	8	10	19
	Other Trauma	87	111	78	276
	Haemorrhage	1	3	0	4
Southern	Assault	82	115	89	286
	Shooting	8	16	13	37
	Other Trauma	40	68	32	140
	Haemorrhage	0	1	0	1
Eastern	Assault	208	204	150	562
	Shooting	3	1	1	5
	Other Trauma	54	80	67	201
	Haemorrhage	0	0	0	0
Cases Documented		21	81	41	

4.2.1 Number of Cases per Month

Over the three-month period, 147 cases of penetrating injury with pre-hospital intravenous therapy were reported by pre-hospital emergency care providers who participated in this study. Cases are defined as patients that have met the study's inclusion criteria as defined in Chapter Three. Four cases were excluded due to incorrect completion of the data collection sheets. One-hundred-and forty-three cases represented an overview of penetrating traumatic injuries either caused by a knife, bullet or other sharp object as reported by pre-hospital emergency care providers. Table 4.2 displays the number of cases as well as the representative percentage over the three-month period. For this study, the most cases were reported by emergency care providers during the month of March 2014 (81 cases), followed by April 2014 (41 cases) while the least cases reported during the month of February 2014 (21 cases). As per the statistical calculations seen in Chapter 4, the sample size (143 cases) was statistically found to be appropriate for this study.

Table 4.2 Number of Penetrating Cases Over the Three Month Study Period

Month	Cases (n)	Percent
February	21	14.7
March	81	56.6
April	41	28.7
Total (N)	143	100.0

4.2.2 Gender and Age

From the 143 cases analysed over the three month period, 84.6% (121 cases n=143) cases were males and 15.4% (22 cases n=143) were females. Table 4.3 (below) depicts the overall summary statistics for gender. The statistics depicted in Table 4.3 are inclusive for all penetrating injury types. As seen in the table, majority of the cases were male.

Table 4.3 Overall Summary Statistics for Gender For All Cases

Gender	Sample Proportion	Lower 90% CI	Upper 90% CI
Male	84.6% (n=143)	80.4%	90.1%
Female	15.4% (n=143)	11.2%	20.9%

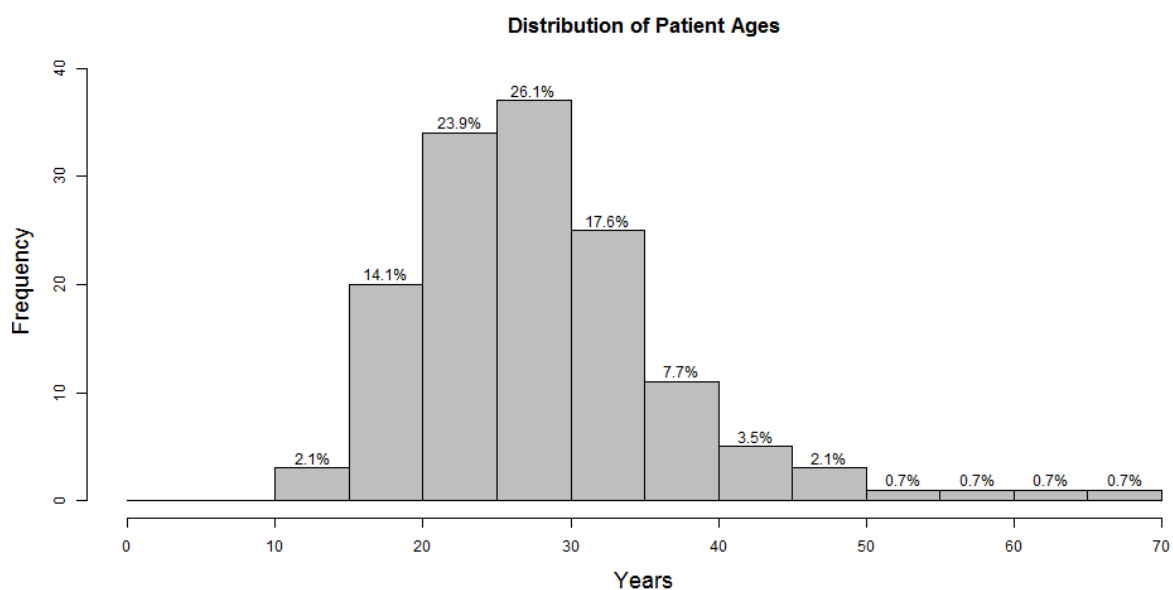
The mean age for patients with knife injuries was 28.8 while the mean age of patients with bullet injuries was 28.4. The mean age for patients with other penetrating injuries was 28.5. There was no statistically significant difference between the mean ages across these categories (ANOVA p-value = 0.97). Table 4.4 (below) depicts the overall summary statistics for patient age for all cases.

Table 4.4 Overall Summary Statistics For Patient Age For All Cases

Sample Mean	Sample Median	Lower 95% CI for mean (using t distribution)	Upper 95% CI for mean
28.6	27	27.1	30.1

From the Figure 4.1 (below), it can be seen that 60% of patients were in the 20-30 age range and over 90% were in the 15-35 age range (n=143).

Figure 4.1 Distribution of Patients Ages (N=143)



4.2.3 Penetrating Injury Type and Gender

The most common penetrating injury type was knife related (82 cases) followed by bullet related (50 cases) and other sharp object related (10 cases). Based on the data seen in Table 4.5 and the Pearson chi-squared test for independence, no statistically significant association between gender and type of injury was found (p-value = 0.64). Knife-and-bullet injury combinations and ‘other sharp object injury related’ categories were omitted from the test due to small sample sizes. Hence the proportions of knife, bullet and other injury types were not statistically significantly different for males and females. The sample proportion for all cases can be seen in Table 4.6.

Table 4.5 Gender and Penetrating Injury Type

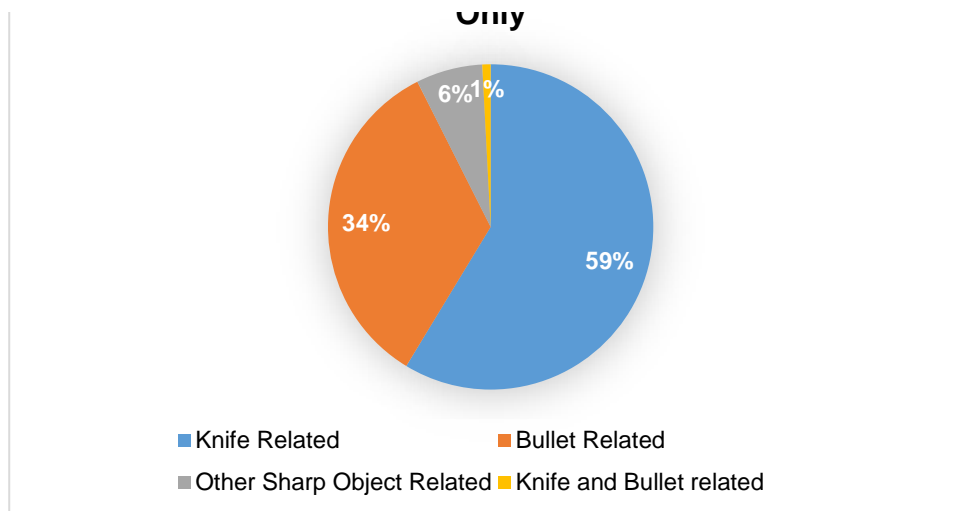
Gender	Knife	Bullet	Knife and Bullet	Other
Male	71	41	1	8
Female	11	9	0	2

Table 4.6 Injury Type and Sample Proportion for All Cases

Injury Type	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
Knife	57.3%	50.3%	64.4%
Bullet	35.0%	28.0%	42.1%
Knife and Bullet	0.7%	0%	7.8%
Other	7.0%	0%	14.1%

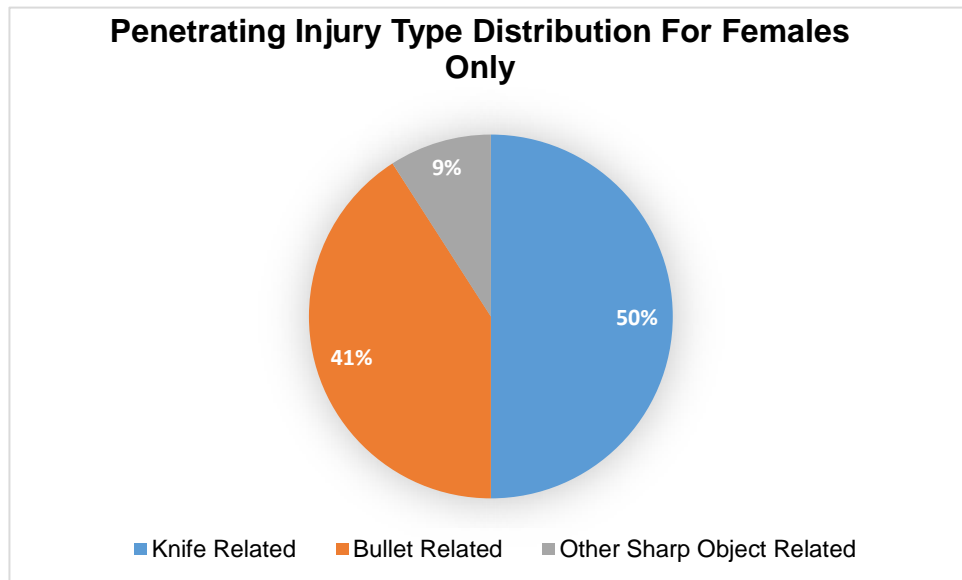
Over the three month data collection period, 71 males sustained penetrating injuries that were knife related, 41 males sustained penetrating injuries that were bullet related and 8 males had injuries caused by other sharp objects. One male had both knife and bullet injuries. Figure 4.2 (below) provides a graphic representation of for all male penetrating trauma cases.

Figure 4.2. Penetrating Injury Type Distribution for Males Only (n=121)



Over the three month data collection period, 11 females sustained penetrating injuries that were knife related, 9 females sustained penetrating injuries that were bullet related and 2 females had injuries caused by other sharp objects. Figure 4.3 (below) provides a graphic representation of for all female penetrating trauma cases

Figure 4.3 Penetrating Injury Type Distribution for Females Only (n=22)



4.2.4 Crew Qualification and Penetrating Injury Type Management

Overall, a greater number of penetrating traumatic injury cases were managed by advanced life support practitioners (79 cases) compared to intermediate life support practitioners (64 cases). Pearson’s chi-squared test for independence finds no association between the qualification of the emergency care provider and the type of injury sustained (p-value = 0.08) as seen in Table 4.7 below.

Table 4.7 Overall Summary Statistics for Crew Qualification

Qualification	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI	Cases
Intermediate Life Support	44.8%	38.5%	52.4%	64
Advanced Life Support	55.2%	49.0%	62.9%	79

Knife related wounds were predominantly managed by intermediate life support practitioners (42 cases n=143) compared to advanced life support practitioners (40 cases n=143). Advanced life support practitioners managed more cases with bullet related injuries (33 cases n=143) compared intermediate life support (17 cases n=143). For injuries classified as other sharp object related, there was no difference between intermediate and advanced life support practitioners. An advanced life support practitioner managed one case where a patient sustained knife and bullet related injuries.

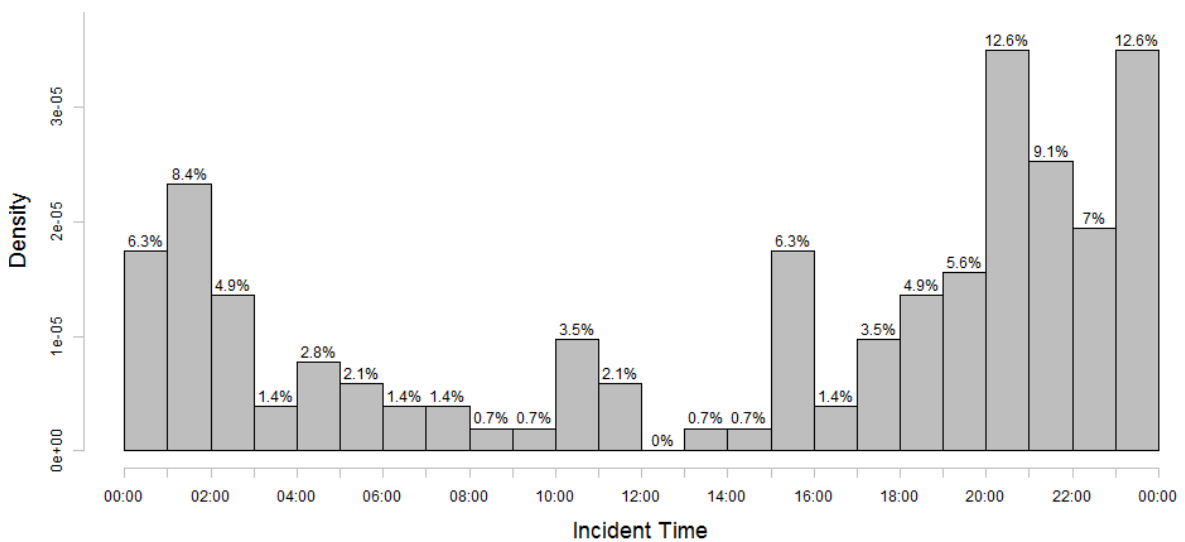
Table 4.8 Penetrating Injury Type Managed by Intermediate and Advanced Life Support

Qualification	Injury Type	Frequency	Percent (n=143)
Intermediate Life Support	Knife Related	42	65.6
	Bullet Related	17	26.6
	Other Sharp Object Related	5	7.8
Advanced Life Support	Knife Related	40	50.6
	Bullet Related	33	41.8
	Other Sharp Object Related	5	6.3
	Knife and Bullet related	1	1.3

4.2.5 Time Variables Associated With Time of Incident Dispatch, Scene Arrival Hospital Arrival

The histogram (Figure 4.4) displays the distribution of incident times over the three month data collection period. Incidents irrespective of their type are most frequently concentrated between the hours of 20h00 and 02h00, with 56% (n=143) of all incidents occurring during this six-hour interval. The dispatch times are similarly distributed since they lag only a few minutes behind the incident times.

Figure 4.4 Distribution of Incident Times (N=143)



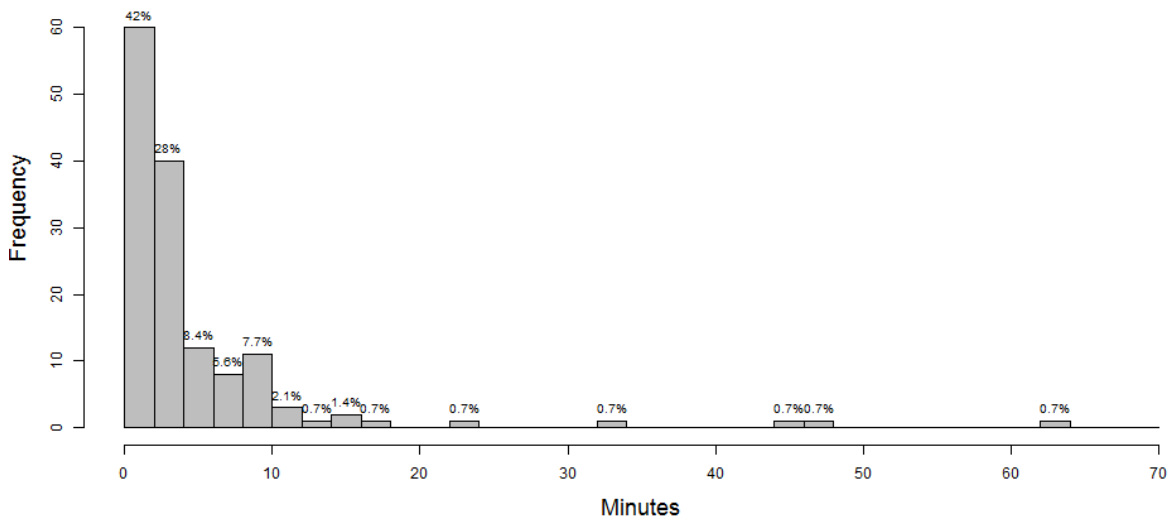
The time variables associated for all cases can be seen in Table 4.9 (below). Irrespective of the penetrating injury type or crew qualification, the mean time for each call took 5.41

minutes (SD 8.29) from incident occurrence to dispatch an ambulance, with the ambulance arriving on scene on 12.17 minutes (SD 5.67) after being dispatched and crews spent approximately 45.59 minutes (SD 15.80) for each call (mission). Histograms for each major time segment can be seen from Figure 4.5 to Figure 4.7.

Table 4.9 Time Variables And Their Associated Mean Times For all Penetrating traumatic Cases

Time Variable	Mean Time (minutes)	SD
Incident time to Dispatch Time	5.41	8.29
Dispatch Time to Scene Time	12.17	5.67
Scene Time to Hospital Time	29.50	12.11
Incident Time to Hospital Time (Mission Time)	45.59	15.80

Figure 4.5 Distribution of Incident Time to Dispatch Time (N=143)



It is evident from Figure 4.5 approximately 90% of cases (n=143), dispatch occur within 10 minutes of the incident. The time elapsed from dispatch to scene is more varied than time elapsed from incident to dispatch, as seen in Figure 4.6. The mean time taken from the time of incident to hospital time (mission time) was 45.59min (SD± 15.80).

Figure 4.6 Distribution from Dispatch Time to Scene Time (N=143)

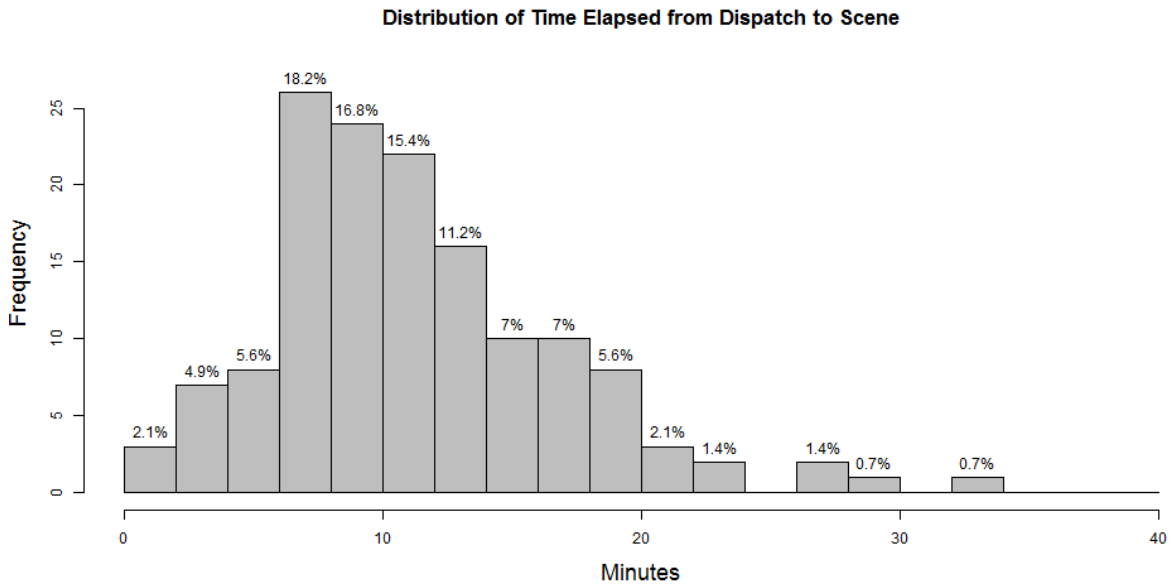


Figure 4.6 (above) illustrates the time distribution from dispatch time to scene arrival. For all penetrating trauma cases, the time from dispatch to scene arrival was more frequently located between the six to 12 minute intervals compared to the other time intervals.

Figure 4.7 Distribution from Incident Time to Hospital Time (N=143)



4.2.6 Healthcare Facilities Patients

Ten healthcare facilities were listed by emergency care providers to which patients with penetrating traumatic injuries were taken to for further medical care as seen in Table 4.10 Tygerberg Hospital (received approximately 40% of all cases n=143) and Groote Schuur Hospital (dedicated specialists trauma units) received the most percentage of penetrating cases, while the community healthcare facilities received the least percentage of penetrating cases.

Table 4.10 Healthcare Facilities

Healthcare facility	Level of Care	Number of Cases	Percent (n=143)
Delft Community Health Care Centre	Primary ²⁶	5	3.5
Elsies River Community Health Care Centre	Primary	14	9.8
GF Jooste Hospital	Secondary ²⁷	1	0.7
Groote Schuur Hospital	Tertiary ²⁸	21	14.7
Hottentots Holland Hospital (Helderberg Hospital)	Secondary	7	4.9
Karl Bremer District Hospital	Secondary	11	7.7
Kraaifontein Community Health Care Centre	Primary	5	3.5
Mitchell's Pain District Hospital	Secondary	11	7.7
New Somerset Hospital	Secondary	11	7.7
Tygerberg Hospital	Tertiary	57	39.9

²⁶ Facilities providing clinical care at a primary level are referred to as Community Health Centres (CHC). CHC's are facilities that, in addition to a range of other primary healthcare services, normally provides 24 hour maternity and accident and emergency services and up to 30 beds where patients can be observed for a maximum of 48 hours. These facilities have a procedure room but not an operating theatre, patients will not be given general anaesthetics, and they will not be admitted as inpatients in the community health centre (Cullinan 2006).

²⁷ Hospitals providing clinical care at a Secondary level are required to provide clinical care and be staffed permanently in at least five of the following eight basic specialties: surgery, medicine, orthopaedics, paediatrics, obstetrics and gynaecology, psychiatry, diagnostic radiology and anaesthetics (Cullinan 2006).

²⁸ Hospitals providing clinical care at a Tertiary level are required to provide clinical care at the specialist and sub-specialist level. Tertiary level facilities provide a range of specialities above the level of a secondary level facility and are not limited to: Anaesthetics, Cardiology, Cardiothoracic Surgery, Clinical Pharmacology, Critical Care & ICU, Craniofacial Surgery, Respiratory Medicine Trauma and Vascular Surgery(Cullinan 2006).

4.3 Clinical Presentation

4.3.1 Penetrating injury location

The percentages for penetrating injury locations can be seen in Figure 4.8. This variable (penetrating injury location) does not follow a multinomial distribution as various combination involving many anatomical locations were recorded for single cases and thus the confidence intervals could not be computed. The most common penetrating injury location was chest area followed by upper limbs and the lower limbs. The least number of wounds was sustained to the pelvis and neck. It is evident from the graph (Figure 4.8) that chest is the most common penetrating injury location, with 35.7% (n=143) of all such incidents involving a chest injury; followed by upper limbs with 31.5% (n=143).

Figure 4.8 Penetrating Injury Location and Anatomical Location (N=143)

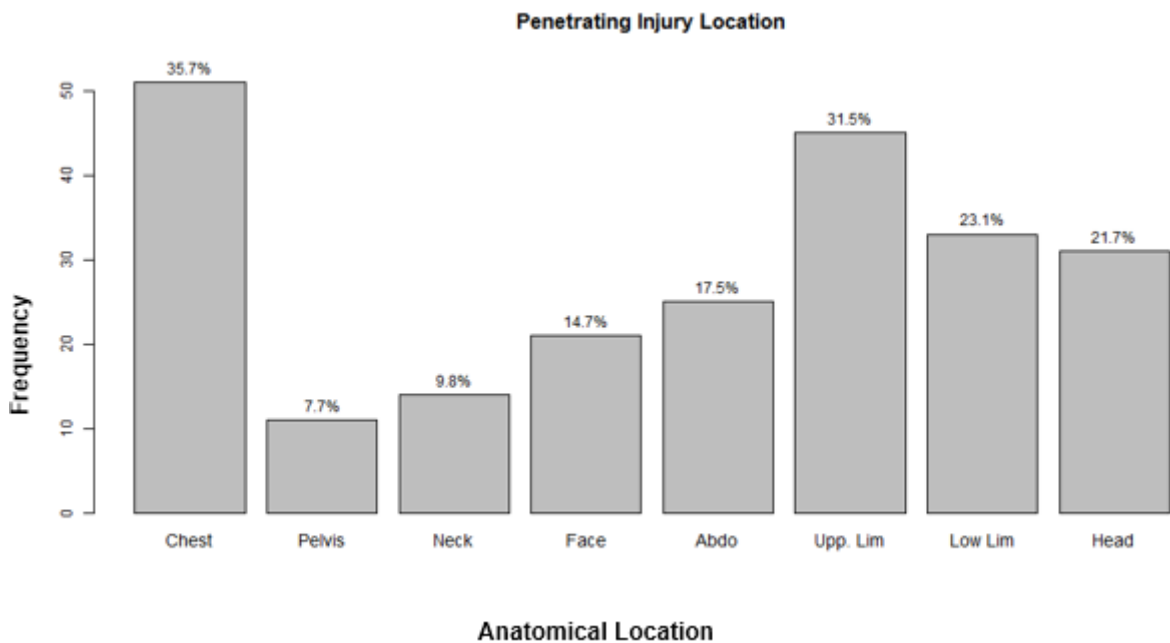


Table 4.11 shows results for Pearson chi-squared tests used to check for an association between penetrating injury location and gender. Pelvis and abdomen were combined due to the small sample sizes.

Table 4.11 Injury Location Pearson chi-squared p-value, Gender Significance and Nature of association

Injury Location	Pearson chi-squared p-value	Significant association with gender?	Nature of association
Chest	0.0097	Yes	Chest injuries relatively more common amongst males
Pelvis and Abdomen	1	No	No association
Neck, Face and Head	0.70	No	No association
Upper limbs	0.074	No	Slight evidence that upper limb injuries are relatively more common amongst females
Lower limbs	0.82	No	No association

4.3.2 Number Of Wounds Sustained

Caution was used when interpreting the average number of wounds, since the '7+' category left uncertainty regarding the actual number of wounds were recorded. For calculation purposes it was assumed to be 8. A Pearson chi-squared test found no association between gender and the number of wounds (p-value = 0.52). For purposes of this test the wounds variable was classified as 1, 2, or >2, since sample sizes in certain categories were too small to meet the assumptions of the Pearson chi-squared test for independence. Majority (43.4% or 62 cases n=143) of the documented cases sustained one wound. The number of wounds per patient decreased as the overall wound frequency increased, with the exception for cases that sustained more than 7 wounds.

4.3.3 Scene Arrival Vital Signs

Data associated with a patient's vital signs are interval-censored (blood pressure, heart rate, capillary refill time) or categorical (skin temperature, level of consciousness), and thus averages or confidence intervals were not calculated. However, Table 4.12 displays the appropriate statistical measured values. An approximation mean and confidence interval for the interval-censored variables was obtained using a parametric survival regression model with only an intercept.

Table 4.12 Estimated Means for Scene Vital Signs

Variable	Estimated mean	Approximate 95% CI for mean: lower bound	Approximate 95% CI for mean: upper bound
Scene Systolic BP	101.7	96.7	106.7
Scene Diastolic BP	55.3	51.5	59.1
Scene Heart Rate	106.0	102.8	109.1
Scene Capillary Refill Time	1.93	1.67	2.18

Figure 4.9 Scene Systolic Blood Pressure for All Cases (N=143)

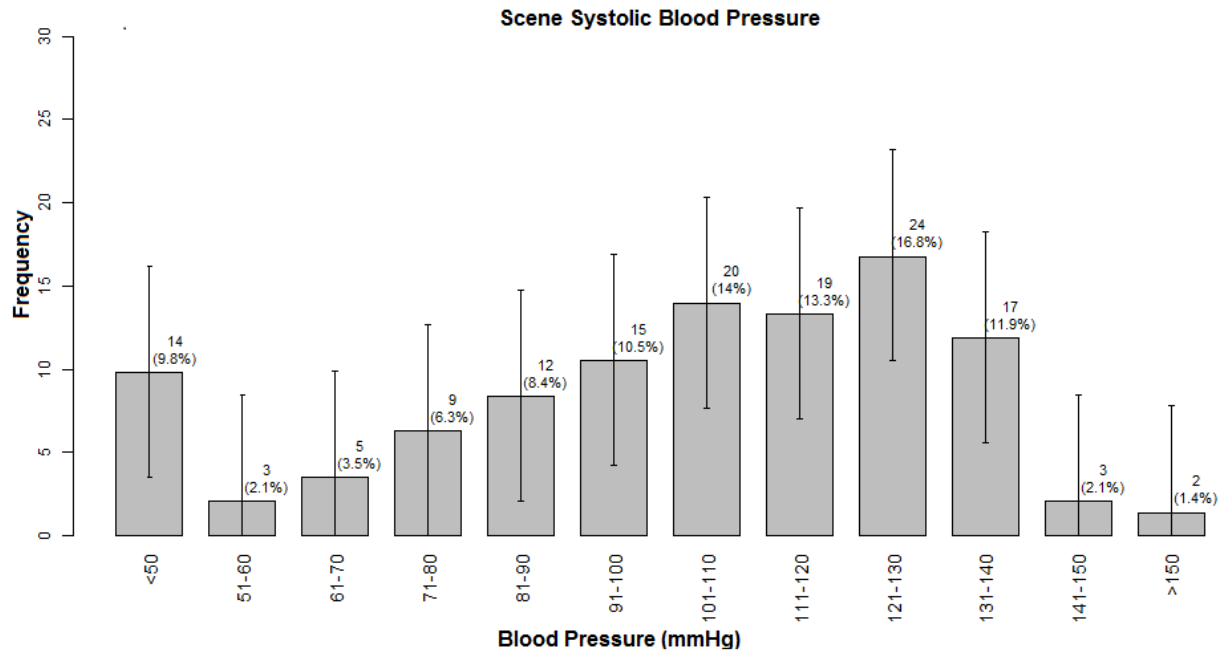


Figure 4.9(above) depicts the on-scene systolic blood pressure for all cases. From Figure 4.9, on-scene systolic blood pressure was more frequently found to be higher than 101mmHg; however, there are a greater number of cases with on-scene systolic blood pressures less than 50mmHg compared to cases with on-scene blood pressures between 51-60mmHg, 61-70mmHg, 71-80mmHg and 81-90mmHg.

Figure 4.10 depicts the on-scene heart rate for all cases. For all cases, the on-scene heart rate was more frequently located between 101-110, 111-120 and 121-130 beats-per-minute compared to the other on-scene heart rate intervals. Less than 2% (n=143) of all cases had an on-scene heart rate of less than 60 beats-per-minute.

Figure 4.10 Scene Heart Rate for all Cases (N=143)

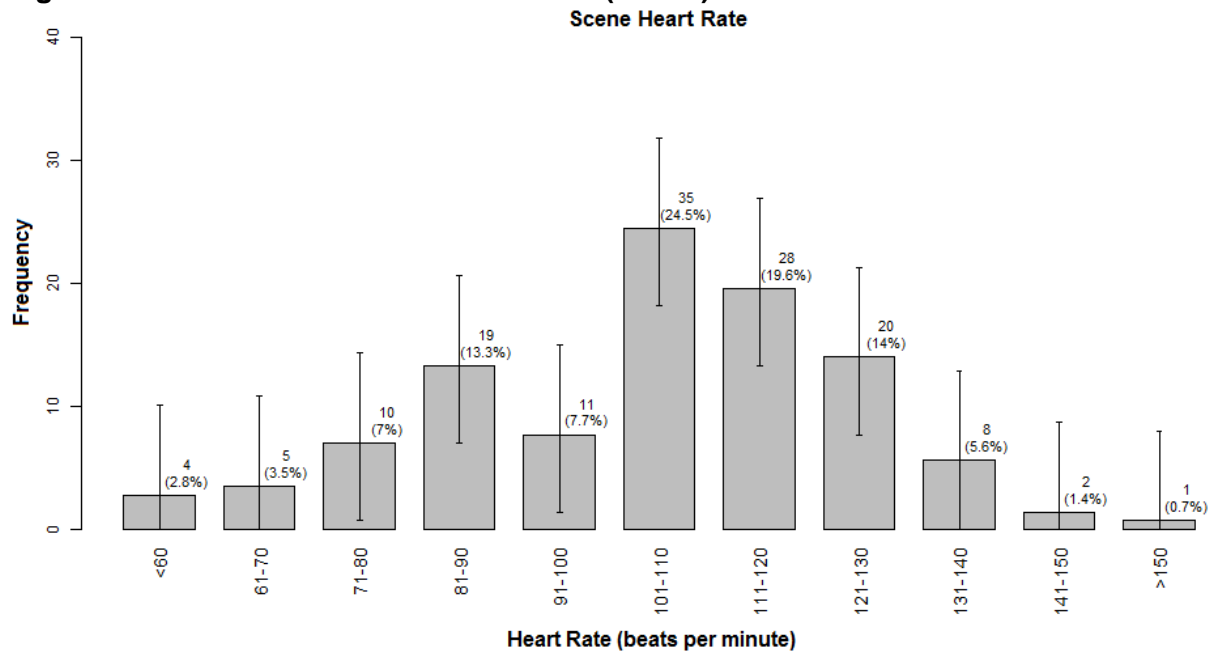
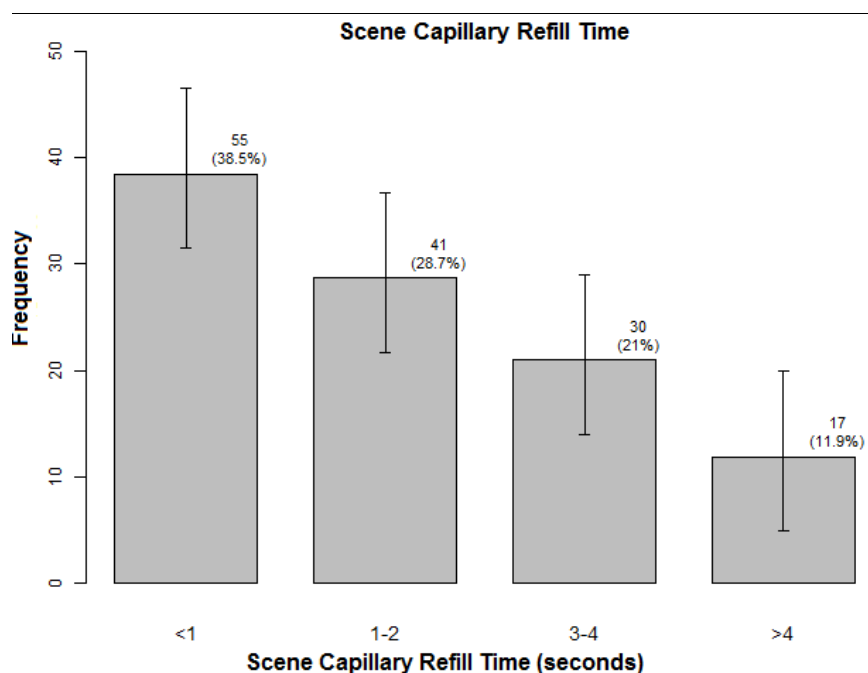


Figure 4.11 (below) illustrates the on-scene capillary refill time for all cases. The most frequent on-scene capillary refill time recorded was less than one second for all penetrating trauma cases. The least frequent number of all penetrating trauma cases had a capillary refill time greater than four seconds.

Figure 4.11 Scene Capillary Refill Time for all Cases (N=143)



The on-scene temperature was more frequently recorded as 'warm' (48.3% n=143), compared to 'cold' and 'cool' for all penetrating trauma cases as seen in Figure 4.12 below.

Figure 4.12 Scene Skin Temperature for all Cases (N=143)

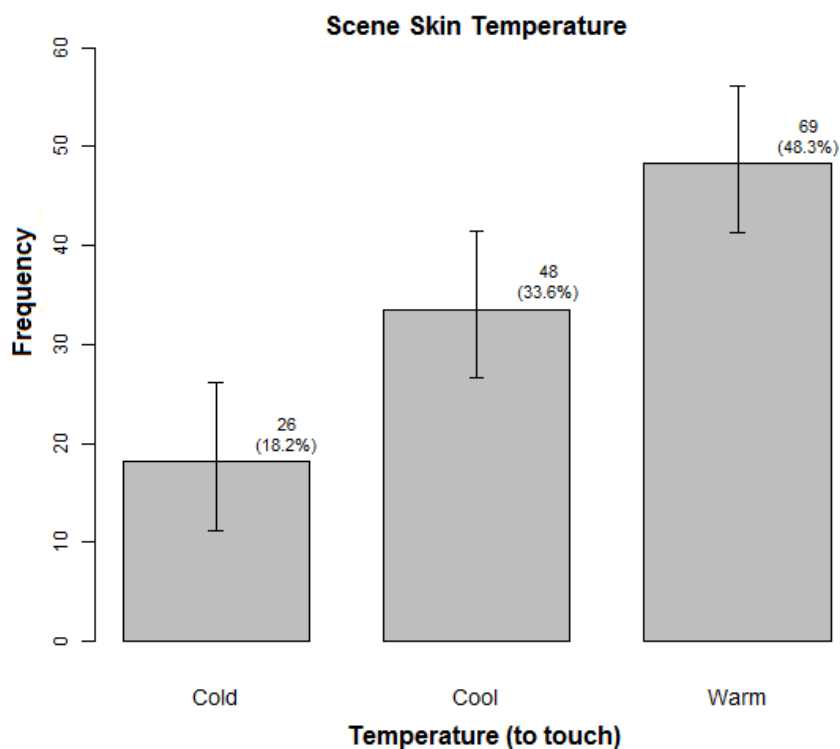
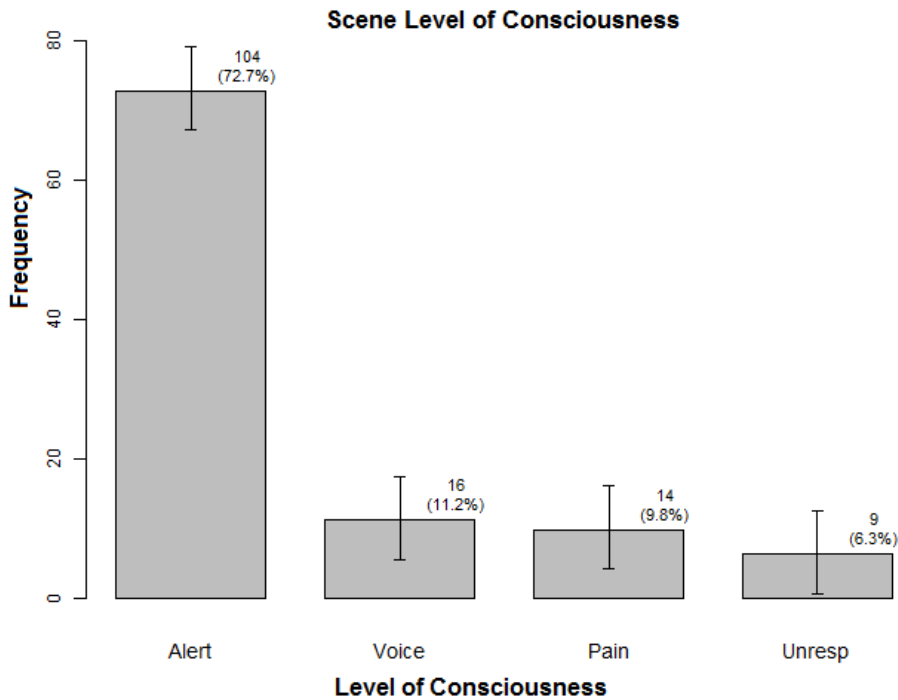


Figure 4.13 Scene Level of Consciousness for all Cases (N=143)



The on-scene level of consciousness was more frequently recorded as ‘alert’ on the Alert, Voice, Pain and Unresponsive scale (AVPU Scale) for all penetrating trauma cases compared to ‘voice’, ‘pain’ and ‘unresponsive’, as depicted in Figure 4.13 (above). For the interval-censored variables, analysis of an association with gender is conducted using a parametric survival regression model with gender as an independent variable.

Table 4.13 Statistical Relationships and Coefficients for Scene Vital Signs

Variable	Regression Coefficient on ‘Gender’	p-value for significance test on coefficient	Statistically significant?	Nature of relationship
Scene Systolic BP	-6.01	0.40	No	-
Scene Diastolic BP	-4.47	0.40	No	-
Scene Heart Rate	11.25	0.01	Yes	Scene heart rate is estimated to be 11.25 beats per minute higher for females than males
Scene Capillary Refill Time	0.027	0.94	No	-

Table 4.14 Sample Proportion for Scene Skin Temperature and Level of Consciousness at Scene

Scene Skin Temperature	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
Cold	18.2%	11.2%	26.1%
Cool	33.6%	26.6%	41.5%
Warm	48.3%	41.3%	56.2%
Scene Level of Consciousness	Sample Proportion	Lower 90% CI	Upper 90% CI
Alert	72.7%	67.1%	79.1%
Voice	11.2%	5.6%	17.6%
Pain	9.8%	4.2%	16.2%
Unresponsive	6.3%	0.7%	12.7%

No association exists between gender and skin temperature on scene (Pearson chi-squared p-value = 0.96; for purposes of this analysis, ‘cold’ and ‘cool’ were combined into one category due to small sample sizes). Similarly, no association exists between gender and level of consciousness on scene (Pearson chi-squared p-value = 0.44; for purposes of this analysis, ‘voice’, ‘pain’ and ‘unresponsive’ were combined into one category due to small sample sizes).

4.3.4 Hospital Arrival Vital Signs

As with the scene arrival vital signs, the data are interval-censored (blood pressure, heart rate, capillary refill time) or categorical (skin temperature, level of consciousness) it is not technically possible to calculate averages or confidence intervals. An approximation mean and confidence interval for the interval-censored variables was obtained using a parametric survival regression model with only an intercept.

Table 4.15 Estimated Means for Vital Signs Upon Hospital Arrival

Variable	Estimated mean (n=143)	Approximate 95% CI for mean: lower bound	Approximate 95% CI for mean: upper bound
Hospital Systolic BP	100.16	97.2	103.2
Hospital Diastolic BP	63.1	60.2	66.0
Hospital Heart Rate	103.0	100.6	105.5
Hospital Capillary Refill Time	1.71	1.48	1.94

For the interval-censored variables, analysis of an association with gender was conducted using a parametric survival regression model with gender as a (dummy) independent variable.

Table 4.16 Statistical Relationships and Coefficients Upon Hospital Arrival

Variable	Regression Coefficient on 'Gender'	p-value for significance test on coefficient	Statistically significant?	Nature of relationship
Hospital Systolic BP	-0.131	0.98	No	-
Hospital Diastolic BP	-2.84	0.48	No	-
Hospital Heart Rate	10.48	0.002	Yes	Hospital heart rate is estimated to be 10.48 BPM higher for females than males
Hospital Capillary Refill Time	-0.064	0.84	No	-

Table 4.17 Sample Proportion for Scene Skin Temperature and Level of Consciousness Upon Hospital Arrival

Hospital Skin Temperature	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
Cold	14.7%	7.7%	22.5%
Cool	35.7%	28.7%	43.4%
Warm	49.7%	42.7%	57.4%
Hospital Level of Consciousness	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
Alert	76.9%	72.2%	83.2%
Voice	10.5%	5.6%	16.8%
Pain	8.4%	3.5%	14.7%
Unresponsive	4.2%	0%	10.5%

No statistical association exists between gender and skin temperature upon hospital arrival (Pearson chi-squared p-value = 0.84). For purposes of temperature analysis, 'cold' and 'cool' were combined into one category due to small sample sizes. Similarly, no statistical association exists between gender and level of consciousness at hospital (Pearson chi-squared p-value = 0.44). For purposes of level of consciousness analysis, 'voice', 'pain' and 'unresponsive' were combined into one category due to small sample sizes.

4.4 Intravenous Fluid Management

4.4.1 Cases Receiving Intravenous Fluid and Intravenous Fluid Type

77.6% (N=143) received intravenous fluid therapy. In the category of crystalloids, the most common intravenous fluid administered was Ringers Lactate (105 cases n=143) followed by 0.9% Saline (1 case) and Plasmalyte-L (1 case). Only 1 case received intravenous colloid fluids. Table 4.18 displays the proportion of cases receiving and did not receive intravenous fluid. Some patients received a combination of intravenous fluids as seen in Table 4.17.

Table 4.18 Cases Received and Not Received Intravenous Fluid

IV Therapy	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
IV Fluid Received	77.6%	72.2%	83.4%
No IV Fluid Received	22.4%	16.8%	28.2%

Table 4.19 Intravenous Fluid Type and Sample Population

Fluid Type	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
Ringers Lactate	73.4%	67.8%	80.0%
0.9% Saline	0.7%	0%	7.3%
Colloid	0.7%	0%	7.3%
Plasmalyte-L	0.7%	0%	7.3%
0.9% Saline and a Colloid	0.7%	0%	7.3%
0.9% Saline, Ringers Lactate and a Colloid	1.4%	0%	8.0%
None	22.4%	16.8%	28.9%

4.4.2 Method of Fluid Administration and Average Volume Administered for All Cases

All cases receiving intravenous fluid was done via bolus administration and not via the use of an infusion device or via a specified infusion rate. The average volume administered was interval-censored and thus the average volume and confidence intervals were calculated using a parametric survival regression model with only an intercept as seen in table 4.20. The estimated mean intravenous fluid volume for all cases (n=143) receiving intravenous fluid was 901.0ml.

Table 4.20 Estimated Intravenous Fluid Mean All Cases

Variable	Estimated mean	Approximate 95% CI for mean: lower bound	Approximate 95% CI for mean: upper bound
Volume (mL)	901.0	789.7	1012.2

Similar intravenous fluid volumes (900-930mL range) were given to patients with penetrating chest injuries when compared to the estimated mean intravenous fluid volume received by all cases.

Table 4.21 Estimated Intravenous Fluid Mean for Penetrating Chest and Abdominal Injuries

Variable	Estimated mean	Approximate 95% CI for mean: lower bound	Approximate 95% CI for mean: upper bound
Volume administered to patients with penetrating chest injuries	925.3	745.8	1104.8
Volume administered to patients with penetrating abdominal injuries	1010.6	801.9	1219.3

4.4.3 Intravenous Cannulation Attempts And Cannulation Size

Cases marked as no intravenous fluid but were cannulised were counted as zeroes in the statistical analysis. The sample median for the number of intravenous cannulation attempts was 1, while the sample mean was 1.20. For the cases that received intravenous fluid (and thus were cannulised), the sample mean was 1.54, while the median was 1. The mean number of cannulas was 0.99 and the median was 1 as seen in table 4.22.

Table 4.22 Summary Statistics On The Number Of Cannulas Placed

No. of Cannulas Placed	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
0	22.4%	15.4%	29.6%
1	58.0%	51.0%	65.2%
2	18.2%	11.2%	25.4%
3	1.4%	0%	8.6%

The most frequent intravenous cannula size used was 18 Gauge. Intravenous cannulas of 22G and 24G were not recorded on any of the cases. The sample proportion for other intravenous cannula sizes can be seen in table 4.23.

Table 4.23 Summary Statistics On Cannula Sizes (Across All Cannulas, Irrespective Of Number Of Intravenous Cannulas)

Cannula Size	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
14G	5.7%	0%	13.5%
16G	23.4%	16.3%	31.2%
18G	48.9%	41.8%	56.7%
20G	22.0%	14.9%	30.0%

4.4.4 Intravenous Administration Set Type

The most common intravenous fluid administration set used to administer intravenous fluid was the 10-drops-per-ml administration set, followed by the 20-drops-per-ml administration set. Other administration set sizes were not used (60 and other size administration sets). The sample proportion and confidence intervals for administration set type can be seen in Table 4.24

Table 4.24 Summary Statistics on Intravenous Administration Set Type and Sample Proportion

Administration Set Type	Sample Proportion (n=143)	Lower 90% CI	Upper 90% CI
10-drops-per-ml	76.9%	71.3%	82.9%
20-drops-per-ml	0.7%	0%	6.7%
None	22.4%	16.8%	28.3%

4.4.5 Time Period for Intravenous Fluid Administered

The estimated mean time (minutes) over which intravenous fluid was administered was 18.33 minutes. Approximate 95% CI for mean: lower bound of 16.55 and an Approximate 95% CI for mean: upper bound of 19.31.

4.4.6 Intravenous Fluid and Vital Signs Comparison

A comparison of vital signs (on-scene and at hospital) for patients who received intravenous fluid to those who did not receive was done. On-scene systolic blood pressure is lower by an average of 28.61 units (mmHg) among those who received intravenous fluid compared to those who did not receive intravenous fluid. Similar findings were observed for systolic blood pressure upon hospital arrival as seen in Table 4.25. Table 4.25 also includes the regression coefficient on intravenous fluid as well as the p-value in determining the relationship between specific vital signs and intravenous fluid administration.

Table 4.25 Comparison of vitals (on-scene and at hospital) for patients who received intravenous fluid to those who did not receive intravenous fluid

Dependent Variable	Regression Coefficient on 'Fluid'	p-value for significance test on coefficient	Statistical Significance Observed	Nature of relationship
On-scene systolic BP	-28.61	3.52×10^{-7}	Yes	On-scene systolic BP is lower by an average of 28.61 units among those who received fluid compared to those who did not
On-scene diastolic BP	-17.96	3.80×10^{-5}	Yes	On-scene diastolic BP is lower by an average of 17.96 units among those who received fluid compared to those who did not
On-scene heart rate	9.11	0.015	Yes	On-scene heart rate is higher by an average of 9.11 BPM among those who received fluid compared to those who did not
On-scene capillary refill time	1.549	2.62×10^{-8}	Yes	On-scene capillary refill time is higher by an average of 1.549 seconds among those who received fluid compared to those who did not
Hospital systolic BP	-11.71	9.03×10^{-4}	Yes	Hospital systolic BP is lower by an average of 11.71 units among those who received fluid compared to those who did not
Hospital diastolic BP	-7.79	0.023	Yes	Hospital diastolic BP is lower by an average of 7.79 units among those who received fluid compared to those who did not
Hospital heart rate	4.87	0.10	No	-
Hospital capillary refill time	1.311	3.56×10^{-7}	Yes	Hospital capillary refill time is higher by an average of 1.311 seconds among those who received fluid compared to those who did not

In relation to categorical variables, there is a statistically significant association between on-scene skin temperature and whether fluid was administered (Pearson chi-squared p-value = 2.14×10^{-6}). Those who received fluid are more likely to have cold or cool skin temperatures. There is a statistically significant association between on-scene level of consciousness and whether fluid was administered (Pearson chi-squared p-value = 0.0002). Those who received fluid are more likely to have a level of consciousness other than alert (i.e. voice, pain, unresponsive).

Furthermore, there is a statistically significant association between hospital skin temperature and whether fluid was administered (Pearson chi-squared p-value = 8.39×10^{-7}). Those who received fluid are more likely to have cold or cool skin temperatures. A statistically significant association between hospital level of consciousness and whether fluid was administered (Pearson chi-squared p-value = 0.001) as those who received intravenous fluid are more likely to have a level of consciousness other than alert (i.e. voice, pain, unresponsive).

The following parameters were defined the following combined variables for further statistical analysis:

Parametric survival regression models were computed with each of these variables as the dependent variable and a categorical independent variable taking a value of 1 if intravenous fluids were administered and 0 if not. The results of these models are as in Table 4.26 below.

Table 4.26 Change in systolic blood pressure with statistical tests and nature of relationship with intravenous fluid administration

Dependent Variable	Regression Coefficient on 'Fluid'	p-value for significance test on coefficient	Statistically significant?	Nature of relationship
Change in systolic BP ^A	15.53	4.13×10^{-4}	Yes	If IV fluids were administered then change in systolic BP from scene to hospital is expected to be 15.53 units higher than if no fluids were administered, suggesting that administering IV fluids may cause systolic BP to rise, or mitigates its decrease
Change in diastolic BP ^B	11.47	5.97×10^{-4}	Yes	If IV fluids were administered then change in diastolic BP from scene to hospital is expected to be 11.47 units higher than if no fluids were administered, suggesting that administering IV fluids may cause diastolic BP to rise, or mitigates its decrease
Change in heart rate ^C	-2.042	0.556	No	Administering IV fluids appears to have no relationship to change in heart rate from scene to hospital
Change in capillary refill time ^D	-0.221	0.265	No	Administering IV fluids appears to have no relationship to change in capillary refill time from scene to hospital
^A Change in Systolic blood pressure (BP): an interval-censored variable with the lower bounds of the intervals calculated as the lower bound of Hospital Systolic BP intervals minus the upper bound of Scene Systolic BP intervals; the upper bound is calculated as the upper bound of Hospital Systolic BP intervals minus the lower bound of Scene Systolic BP intervals ^B Change in Diastolic BP: defined in a way analogous to Change in Systolic BP with the diastolic variables ^C Change in Heart Rate: defined in a way analogous to Change in Systolic BP but with the heart rate variables ^D Change in Capillary Refill Time: defined in a way analogous to Change in Systolic BP but with the capillary refill time variables				

It was not possible to test for a statistically significant relationship between change in skin temperature from scene to hospital and whether IV fluids were administered, due to the few cases where the skin temperature changed. Six cases were recorded where skin temperature decreased, 13 cases where it increased, and 124 cases where skin temperature remained the same from scene to hospital. Similarly, it was also not possible to test for a statistically significant relationship between change in level of consciousness from scene to hospital and whether intravenous fluids were administered because level of consciousness does not appear to be straightforwardly ordinal in the way it is defined. That is, it is not clear whether 'alert', 'voice', 'pain' and 'unresponsive' can be ranked in decreasing order of level of consciousness.

4.5 Chapter Four Summary

143 penetrating traumatic injury cases either caused by a knife, bullet or other sharp object were reported by pre-hospital emergency care providers over the three month period (February-April). The most common penetrating injury type was knife related (82 cases) followed by bullet related (50 cases) and other sharp object related (10 cases). One case involved a patient sustaining injuries that were knife as well as bullet related.

Irrespective of the nature of the penetrating injury (knife or bullet related), 84.6% (121 cases n=143) cases were males and 15.4% (22 cases n=143) were females. The mean age was 28.6 with no statistically significant association between gender and type of injury (p-value = 0.64).

More penetrating traumatic injury cases were managed by advanced life support practitioners (79 cases) compared to intermediate life support practitioners (64 cases), with no association between the qualification of the emergency care provider and the type of injury sustained (p-value = 0.08). Knife related wounds were predominantly managed by intermediate life support practitioners (42 cases) compared to advanced life support practitioners (40 cases). Advanced life support practitioners managed more cases with bullet related injuries (33 cases) compared intermediate life support (17 cases).

The most common penetrating injury location was chest area followed by upper limbs and the lower limbs. The least number of wounds was sustained to the pelvis and neck. The average number of penetrating wounds sustained by each patient was one wound.

77.6% (n=143) cases received intravenous fluid while 22.4% (n=143) received no intravenous fluid.

On-scene systolic blood pressure is lower by an average of 28.61 units (mmHg) among those who received intravenous fluid compared to those who did not receive intravenous fluid. Cases receiving fluid are more likely to have cold or cool skin temperatures. Cases receiving intravenous fluid are more likely to have a level of consciousness categorised as alert. Irrespective of penetrating injury type, incidents are most frequently concentrated between the hours of 20h00 and 02h00, with 56% (n=143) of all incidents occurring during this six-hour interval. Approximately 90% (n=143) of cases, dispatch occurs within 10 minutes of the incident.

CHAPETR FIVE

DISCUSSION

5.1 Introduction

This chapter contains the discussion revolving around the findings of this study as seen in Chapter 4. The discussion in this chapter will incorporate the findings of this study and contextualise them to the possible scenarios that have followed-on to the findings as well as linking to current and previous evidence within the context of trauma. The structure of this chapter will be written in accordance with the objectives for this study.

5.2 Response Rate

One-hundred-and-forty-seven responses were received over the three month data collection period, of which 143 were eligible for use in the data analysis. The four excluded cases were incorrectly completed and thus could not be used for data analysis.

Overall, more penetrating traumatic injuries were managed by Advanced Life Support (ALS) practitioners (n = 79 cases) when compared to intermediate life support practitioners (n = 64 cases). Pearson's chi-squared test for independence finds no association between the qualification of the emergency care provider and the type of injury sustained (p-value = 0.08). No statistical association between the qualification and type of injury could be found. ALS practitioners in the Western Cape work on ambulances and response cars and thus they are dispatched to the same patient caseload as other pre-hospital emergency care providers.

There are many factors that could have led to the low response rate some of which could be a low incidence of traumatic injuries due to seasonal trends for violent crime in South Africa (Breetzke & Cohn 2011) or a lack of interest by staff members participating in research. Watson et al., (2013) found that paramedics showed willingness and the capacity to engage in research; however they also exercise some restraint due to the perceived sacrifice of autonomy and challenge to their identity.

This study was not aimed at determining the factors for low response rates. The low response rate resulted in a small sample size which led to no statistical association (when comparing gender and temperature, and bullet and other penetrating injury types, pelvis and abdomen injury location and gender) even when variables were combined.

This study did not investigate the number of penetrating cases admitted to hospital who were transported by means other than the emergency medical services, nor did it investigate the number of penetrating traumatic injury cases taken to the mortuary (died on scene or in the ambulance). Knowing the total number of penetrating traumatic cases admitted to hospital by transportation means other than by ambulance as well as the number of cases taken to the mortuary would have provided a more accurate representation of the penetrating traumatic case/injury burden in the Cape Metropole and the dispersion of cases managed by the ambulance emergency services. Recording the cases not meeting the study's inclusion criteria would have been beneficial and is a limitation. Additionally, increasing the prospective data collection time period would have also provided an enhanced penetrating injury description as seen by pre-hospital emergency care providers working the Cape Metropole. However, these cases were not recorded due to resource constraints of this study.

5.3 Intravenous Fluid Management Practices for Penetrating injury

One of the core objectives of this study was to determine the intravenous fluid management practices for trauma with reference to: fluid type, volume of fluid administered, time period of fluid administration and number of intravenous attempts, number of intravenous cannula size (bore). Each sub-section below will discuss the results and comparisons drawn between various variables, ultimately completing the objectives of the study.

5.3.1 Intravenous Fluid Type

Intravenous fluid management is a vital component in the management of an injured patient. Much debate surrounds the topic regarding the choice of intravenous fluid type. However, current recommendations favour crystalloids over colloid based fluid for patients with trauma (Spahn, 2007;Feinman, et al., 2014).

The type of intravenous fluid administered to each patient was recorded in this study except for cases where pre-hospital emergency providers indicated that no intravenous therapy was initiated. The most common intravenous fluid administered by pre-hospital emergency care providers in this study was Ringers Lactate. The motive/rationale for intravenous fluid selection was not documented in this study as there are many factors which are complex to understand that could have contributed to how the pre-hospital emergency care providers selected the type of intravenous fluids to be administered. Understanding these factors in

great detail is beyond the scope of this study. Factors influencing the choice of Ringers Lactate by emergency care providers treating patients with penetrating traumatic injuries could be the HPCSA clinical protocols and the skills focused short course emergency care training for personnel working in the pre-hospital environment. Previous HPCSA clinical guidelines for intermediate level emergency care providers also stipulated the usage of 1000ml volume of Ringers Lactate for patients with traumatic injuries (HPCSA 2003). The latest protocols for Intermediate Life Support, Advanced Life Support (including Emergency Care Practitioners and Emergency Care Technicians) do not specify the types of intravenous fluid to be used for trauma (Health Professions Council of South Africa 2006). Local emergency medicine guidelines (South Africa) have also adopted the Advanced Trauma Life Support approach in the management of trauma, indicating the administration of a crystalloid fluid bolus of 20ml/kg alongside with haemorrhage control (Allorto et al., 2013).

Advanced Trauma Life Support® (ATLS®), an internationally acclaimed training course developed by the American College of Surgeons Committee on Trauma, currently recommends the administration of Ringers Lactate- a crystalloid fluid and the early use of blood and blood products for patients presenting with shock (ATLS & International ATLS Working Group 2013). Previous ATLS® recommendations also advocated the use of crystalloid intravenous fluids. Additionally, there is evidence from major international clinical guidelines at the time of data collection supporting the use of crystalloid fluids over other intravenous fluid types for trauma (Revell et al., 2002; Kortbeek et al., 2008; Perel & Roberts 2012).

Although Cotton et al., (2009), reported that penetrating injury cases can be complicated and certain clinical presentations may benefit in the administration of colloid-based intravenous fluids. In the study conducted by the researcher, crystalloid fluids are the predominant fluids used by all emergency care providers when managing patients with penetrating traumatic injuries in the Cape Metropole. This study did not aim to determine which practice guidelines practitioners subscribe to, nor was it set out to determine the preferred guidelines/ evidence based practices emergency care providers predominantly use to manage patients with penetrating traumatic injuries- as many guides/ protocols are listed in medical literature (Revell et al., 2003; Kortbeek et al., 2008). The preferred guidelines/ evidence based practices its own is requires further investigation. Emergency care providers routinely make critical decisions concerning the care given to a patient which is often done in a complex environment (O'Hara et al., 2015) and thus may not be linked to a single guideline.

The type of fluid carried on ambulances is determined by the ambulance service and not by the individual practitioner. Pre-hospital emergency care services commonly stock Ringers Lactate and 0.9% Saline as the intravenous crystalloids fluids of choice. Furthermore, 0.9% Saline is predominantly procured for the emergency medical services in 200ml volume bags, while Ringers Lactate is predominantly procured in 1000ml volume bags. Most emergency medical services do not routinely stock colloid fluids possibly due to their cost and the clinical recommendations supporting crystalloid over colloids. This may account for there being only one case in which a colloid base intravenous fluid was administered. The limited selection for crystalloids as well as large volume intravenous fluid bags being restricted to Ringers Lactate may have led to Ringers Lactate being the intravenous fluid of choice by pre-hospital emergency care providers.

Despite the overwhelming recommendation favouring crystalloids over colloids, clinical judgement pertaining to the choice of fluid is still required by the health care provider. Quantifiable variance even within the crystalloid intravenous fluid category in base-deficit and lactate was noted during fluid resuscitation. Fluid resuscitation with Ringers Lactate elevated lactate levels, while resuscitation with normal saline negatively affected the base deficit in Class I Haemorrhage (<750mL blood loss) (Ross et al., 2015). Fluid resuscitation with crystalloids (normal saline) can cause a metabolic acidosis due to its high concentration of chloride (Credland 2016). Although there are these physiological implications when administering the recommended intravenous fluid type, these factors do not appear to be considered by the respondents in this study.

The findings of this study suggest that pre-hospital emergency care providers are using the appropriate intravenous fluid type (crystalloids) for trauma, aligned to current evidence based practices and recommended clinical guidelines.

5.3.2 Intravenous Fluid Volume and Administration Time

Hypotensive resuscitation involves targeting a lower blood pressure until definitive haemostasis is achieved. It has been described as a trade-off between adequacy of tissue perfusion, versus normalizing coagulopathy and gaining haemostasis (West & Dawes 2015). Along with correct intravenous fluid selection, appropriate intravenous fluid volumes should also be administered.

In this study, 77.6 % of all cases (n=143) received intravenous fluid. The mean fluid volume administered to all cases was 901.0 ml (Approximate 95% CI for mean: lower bound 789.7mL and Approximate 95% CI for mean: upper bound 1012.2ml). The mean volume of fluid administered to patients with penetrating abdominal injuries was 1010.6ml (Approximate 95% CI for mean: lower bound 801.9mL and Approximate 95% CI for mean: upper bound 1219.3mL), while mean volume of fluid administered to patients with penetrating chest injuries was 925.3mL (Approximate 95% CI for mean: lower bound 745.8mL and Approximate 95% CI for mean: upper bound 1104.8mL). The greater mean volume administered to patients with abdominal wounds could be related to an increased injury severity as the abdominal compartment hosts large blood vessels as well as highly vascularised organs. Injury severity being a major cause for greater fluid volume administration cannot be proven with the type of data collected in this study.

When intravenous fluids were administered, a change in systolic blood pressure from scene to hospital was 15.53 mmHg higher (11.47 mmHg for diastolic blood pressure) compared when no intravenous fluids were administered. The above finding indicates that administering intravenous fluids resulted in an increase in systolic and diastolic blood pressure.

Previous recommendations (8th Edition) by the Advanced Trauma Life Support® (ATLS®) group advocated the replacement strategy of 3 ml of crystalloid for every 1 ml of blood loss with, up to 2 litres (adult), and despite increasing evidence of harm, this practice is still advocated (West & Dawes 2015). The most recent ATLS® recommendations (9th edition) continues to support the administration of intravenous crystalloids although ATLS® now recommends 1 litre and not 2 litres during resuscitation (ATLS & International ATLS Working Group 2013). The change in recommendation is important as a crystalloid infusion of 1.5 litres or more in trauma patients was an independent risk factor for mortality (Ley et al., 2011). Santibanez-Gallerani et al., (2001) found that intravenous fluid volume greater than 100ml/kg lead to an increased inflammatory cytokine level and mortality. The administration of large intravenous volumes may also result in isovolemic anaemia- characterised by blood volume but a decreased total haemoglobin concentration resulting in lower oxygen carrying capacity (Gutierrez et al., 2004).

The volume of intravenous fluid administered to patients with penetrating chest trauma in this study raises concerns around patient safety. The mean intravenous fluid volume administered to patients with chest trauma is 1.5 litres (independent risk factor for mortality).

There are individual cases where more than 1.5 litres of fluid was administered. Immediate versus delayed fluid resuscitation for patients with penetrating torso trauma (with blood pressure ≤ 90 mmHg) in an urban setting was investigated by Bickell et al., (1994). Their findings and the findings by Hussmann et al., (2012) supported delayed aggressive fluid resuscitation for hypotensive patients until operative intervention. Although crystalloids were administered to these patients, the type of crystalloid fluid was Ringers Acetate which has a dissimilar chemical composition to Ringers Lactate and elicits a different physiological response once administered. Multivariable retrospective analysis was performed on 776,734 trauma patients by Haut, et al., (2011) between 2001 to 2005 for all patients with penetrating or blunt injuries admitted to healthcare facilities (more than 600 United States healthcare facilities). The authors found that patients receiving intravenous fluids were significantly more likely to die (odds ratio [OR] 1.11, 95% confidence interval [CI] 1.05–1.17). These associations were especially marked in patients with penetrating mechanism (OR 1.25, 95% CI 1.08–1.45), hypotension (OR 1.44, 95% CI 1.29–1.59), severe head injury (OR 1.34, 95% CI 1.17–1.54), and patients undergoing immediate surgery (OR 1.35, 95% CI 1.22–1.50).

The accuracy and self-reported intravenous fluid volumes administered to medical patients in the pre-hospital environment (non-trauma, non-cardiac arrest patients) was investigated by Coppler et al., (2015). They found the median absolute error comparing self-reported to mass-derived fluid volume was 109 mL [IQR: 41-205 mL], and less than 250 mL in more than 80% of patients to be within the 250mL of mass-derived fluid volume while the median absolute error comparing documented fluid to mass-derived fluid volume was 142 mL [IQR: 64-265 mL], and was less than 250 mL in 71% of subjects. They also found no difference in absolute error for either self-reported or document fluid volumes were modified by transport time or pre-hospital systolic blood pressure. Evidence investigating the accuracy and self-reported intravenous fluid volumes administered to trauma patients is limited. This study did not measure the accuracy of administered volume- only self-reported volumes as reported in the collection sheet.

In this study, pre-hospital emergency care providers administered intravenous fluid over a mean time period of 18.33 minutes (Approximate 95% CI for mean: lower bound 16.55min and Approximate 95% CI for mean: upper bound 19.31min). The time mean time described above is within the context for which the total volume of fluid was administered and not increments of the total volume administered to each case. The mean time taken from arriving on scene to hospital arrival was 29.50 minutes (SD 12.11). An animal study by Li, et al.,

(2011) showed that survival and organ function after uncontrolled haemorrhagic shock were best when a resuscitative target mean arterial pressure of 50–60 mmHg was applied at a maximum time period of 90 minutes. Due to the nature of the rat-model study, these parameters can be completely suitable to human patients, especially the elderly and patients with other comorbidities needs further confirmation and investigation (Li, et al., 2011).

Pre-hospital emergency providers may see intravenous fluid administration as a standard intervention during patient care for trauma. However, this intervention is questionable as a standard point of care for all patients, with one recommendation of withholding intravenous fluid administration in the pre-hospital setting, as improved patient outcomes were seen for both penetrating and blunt trauma (Cotton et al., 2009).

All patients with a penetrating traumatic injury may not require intravenous resuscitation. The injury or injuries may have been non-life-threatening and may have not pose a threat to the patient's haemodynamic status and circulation. The vital signs of the patients not receiving intravenous fluids indicates that (Table 4.6.6.1 chapter 4) on-scene systolic blood pressure is lower by an average of 28.61 mmHg among patients who received fluid compared to those who did not receive fluid with a similar finding for on scene hospital blood pressure. An increase in capillary refill time and heart rate was also observed among patients who received fluid compared to those who did not receive fluid.

Intravenous fluid was administered via bolus administration technique using a 10-drops-per-ml administration-set. In acute setting, this administration-set selection allows for rapid administration of intravenous fluid. The alternative intravenous fluid administration technique involves the use of a mechanical device (infusion pump) which infuses the intravenous fluid volume at a rate determined by the emergency care provider. Infusion pumps are primarily used for fluid maintenance and medication infusion and not for large intravenous fluid volumes over short time periods. This study only included acute cases. Cases requiring inter-facility transportation were not included and in these cases infusion pumps are primarily used. Furthermore, infusion devices add a greater cost as they require specialised administration sets and healthcare institutions are under tremendous pressure to minimise costs. There are no studies that have calculated the cost of pre-hospital trauma care. Studies conducted in the hospital environment estimated that serious abdominal gunshot injuries cost at least 13- times more than the annual per capita South African government expenditure on health in 2003 (Allard & Burch 2005).

The end point of fluid resuscitation has been described by (Al-Khafaji & Webb 2004) as a process to increase intra-vascular volume, augmenting cardiac output and organ perfusion. Failure to resuscitate patients adequately may lead to multi-organ dysfunction syndrome and, eventually death (Al-Khafaji & Webb 2004).

5.3.3 Indicators for Intravenous Fluid Administration

This study investigated the vital signs obtained on upon scene arrival as well as the vital signs obtained upon hospital arrival. The interval-censored vital signs (clinical indicators) included blood pressure, heart rate, skin temperature, level of consciousness and capillary-refill-time. The estimated means for all the vital signs are presented in Chapter 4. The mean values recorded on scene are greater than the normal physiological values for healthy individuals. A deviation from the normal physiological values is expected as these individuals experienced a penetrating traumatic injury.

The mean systolic blood pressure on scene was 101.7mmHg (Approximate 95% CI for mean: lower bound 96.7mmHg and Approximate 95% CI for mean: upper bound 106.7mmHg). On-scene systolic blood pressure is lower by an average of 28.61 mmHg among those who received intravenous fluid compared to those who did not receive intravenous fluid. When comparing the mean vital signs for those that received fluid and those that did not receive fluid, systolic and diastolic blood pressure and capillary refill time were used as indicators for fluid administration. Clinically, the mean values for blood pressure, heart rate and level of consciousness would indicate that the patients who received intravenous fluid mean values were in Class II for shock (750-1000ml or 15-30% blood loss) using the ATLS® classification for shock. However, there were individual cases with clinical parameters supporting Class IV shock (>200ml or >40% blood loss) with shock as per the ATLS® classification (Manuel et al., 2013). The ATLS® network recommends the administration of a crystalloid during fluid resuscitation for patients in Class II shock.

Revell et al., (2002) described the dilemma faced by medical personnel during fluid resuscitation. The dilemma involves finding the balance when administering intravenous fluids as fluid administration may delay transportation to definitive care and may expose the patient to other adverse physiological changes or withhold intravenous fluids which may exacerbate organ ischemia.

Haemorrhage in an animal model was induced to a pulse pressure of 5mmHg and where fluid resuscitated to 40, 60 and 80 mmHg. The 80mmHg group had the highest mortality and the greatest bleeding (Stern et al., 1995). When considering the mean values for the vital signs obtained on scene and upon hospital arrival, it is evident that using the Injury Severity Score (ISS) that majority of the cases in this study were severely injured (Lefering 2009).

A conceptual model for intravenous fluid therapy involving four phases (Rescue, Optimization, Stabilization, and De-escalation (ROS-D)) was described by (Hoste et al., 2014). The model suggests that once the need for fluid is identified, the stage of fluid resuscitation should then have been selected by the health care provider. The workgroup recommends that patients in the rescue phase (context of pre-hospital emergency care and the setting for this study) are given rapid fluid boluses of 500ml over a maximum of 15 minutes, thereafter followed by 'fluid challenges' 100–200 ml over 5–10 min with re-assessment to optimize tissue perfusion.

The clinical parameters associated with the end-point to fluid resuscitation were defined as the last vital signs taken upon hospital arrival. Pre-hospital emergency care providers may have recorded the last vital signs upon entering the emergency centre and others may have recorded the last vital signs upon entering the hospital premises. Delays in the public health system often results in pre-hospital emergency care providers continuing emergency care in the health care facility awaiting a hospital bed or a medical practitioner to accept the patient into the facility and continue patient care. During this time, the practitioner may continue with fluid resuscitation and other therapies within their scope. Thus, the interpretation of the true end-point of fluid resuscitation by pre-hospital emergency care providers should be interpreted with caution due to the above-mentioned limitation.

5.4 Gender and Age

Globally, the number of unintentional injuries for males are greater when compared to females and it has been estimated by the World Health Organization that over 2.5 million deaths and over 87 million disability-adjusted life-years occur in males, while 1.4 million deaths and over 51 million disability-adjusted life-years occurs in females for 2004 (Chandran et al., 2010).

Gender contributes to trauma survival with a dimorphic representation for survival advantage for males versus females not attributable to mechanism of injury, severity of injury, or pattern of injury (Females under 50 years of age mortality rate 5% vs Males of equal age mortality rate 7% odds ratio 1.27, $P < 0.002$) (Wohlmann et al., 2001). Majority of the patients (84.6%) in this study, irrespective of the type of penetrating injury, were male, while the remainder of the patients (15.4%) were female.

Gender associated with violence, resulting in physical injury has been studied in the South African context (Smith & Marais 2011) with males at a greater risk of being a victim of violence and victims of traumatic injuries caused by violence (five male violent deaths for every female violent death)(South African Medical Research Council & University of South Africa Institute for Social & Health Sciences 2010). Furthermore, in the framework of domestic violence, Abrahams et al., (2010) describes males as the predominating victims of gun violence, while women are most vulnerable behind closed doors, where guns are used to intimidate, control, hurt and kill intimate partners.

This study was not aimed at determining the predisposing or contributing factors for traumatic injuries nor was it aimed at determining the contextual factors at the time of the physical injury- as there are many contributing factors for violence resulting in physical injury, as seen in Table 5.1.

The mean age for patients with knife injuries in this study was 28.8 years while the mean age of patients with bullet injuries was 28.4 years. The Pearson chi-squared test for independence showed no statistically significant association between gender and type of injury (p -value = 0.64; the single case of knife-and-bullet injury and other categories were omitted from the test due to small sample sizes).

Degiannis et al., (2006) investigated penetrating cardiac injuries in South Africa of which the mean age for male patients was 29 years. A mean age of 28.1 years was noted for patients sustaining penetrating traumatic injuries to the chest in Los Angeles, United States of America(Mandal & Oparah 1989). Mnguni et al., (2012) calculated a mean age of 29.2 (\pm 10.7) years when prospectively investigating penetrating abdominal traumatic injuries in Durban, South Africa. Laing et al., (2014) found a mean age of 28 years when investigating the burden and outcome of trauma after the implementation of an electronic surgical registry in the metropolitan area of Pietermaritzburg, South Africa. Similarly, while average cost per

bullet to the South African healthcare system, (Norberg et al., 2009) noted an average age of 28 years (203 cases). In Ghana, the peak age for patients with penetrating abdominal injuries managed at a teaching hospital was 20-29 years, with a male to female penetrating injury abdominal injury ratio of 8:1 in a 411 patient group (Ohene-Yeboah et al., 2010). Similarly 449 cases (92%) were male (male to female ratio, 12:1) for penetrating injury to abdomen, in Durban, South Africa (Mnguni et al., 2012).

Although more male patients were injured when comparing males and females, no statistically significant association between gender and type of injury was found (p -value= 0.64) using Pearson chi-squared test for independence. Similar studies investigating traumatic injuries and gender have also found greater traumatic injuries sustained by males when compared to females (Ohene-Yeboah et al. 2010; Bukur et al. 2011; Onat et al. 2011; Smith & Marais 2011; Tariq et al. 2011; Yazici et al. 2012; Lockyer et al. 2013; Nicol et al. 2014).

The 2007 National Profile of Injuries in South Africa reported leading causes of external death was by sharp force (44, 8%) was experienced by individuals in the age group between 15-24 years (Prinsloo, 2007). Individuals between the ages of 15-29 years are seen as ages prone to crime (Pampel & Gartner, 1995). No single/ individual attributable factor predisposing men to traumatic injury when compared to females. A multitude of factors exist often socio-demographic, often with an interrelation between each other as seen in Table 5.1. inclusive of the factors mentioned in Table 5.1, Dhaffala et al., (2013) attributed socio-demographic variables such as male gender, age less than 40 years, single status, poverty, and black as those with the highest absolute risk of injury in Mthatha located in the Eastern Cape of South Africa.

This study was not aimed determining whether patients were victims or perpetrators, however, Ormstad et al., (1986) found that 88% (125 cases) of perpetrators were males when investigating homicidal fatalities caused by sharp force injury.

Table 5.1 Contributing Factors to Physical Injury

Factor	Source	Outcome
Age, sex, personality traits, low education levels, poor insight, low income and individual activities like alcohol consumption	(Kurt 2009)	Individual factors which may affect health outcomes.
Individual biological factors such as low heart rate	(Farrington 1998)	All individual level risk factors for interpersonal violence
Male hormones and testosterone	(Rosenberg & Mercy 1991)	
Psychological factors like psychopathology	(Flannery et al., 2001)	
Combination of heavy drinking with impulsive personality	(Caetano et al., 2001)	
Lack of remorse toward others	(Gray et al., 2003)	
Poor self-control	(Hern et al., 2005)	
Outdoors	(Yazici et al., 2012)	Propensity to violence
Males are more mobile with active participation in high risk taking activities	(Lema et al., 2011)	

Ethnicity was not documented in this study. Documenting ethnicity may have provided a better dispersion of traumatic injury amongst the diverse South African population. Moore et al., (2013), found that black patients were three times more likely to present to an emergency room with a gunshot wound compared to non-black patients at the Level I Trauma Centre in Nashville, Tennessee in the United States of America.

The demographic information found in this study and other studies measuring epidemiological data in the traumatic injury realm is of great significance and importance to stakeholders responsible for general injury prevention (health policy, clinical guidelines) and those responsible for safety/ violence prevention (youth violence prevention) of South African citizens. Victims of unintentional violence may also suffer from post-traumatic-stress-disorder (Kaminer et al., 2008) and increases the risk for substance misuse (Mathews et al., 2009).

Emergency Services can also utilize epidemiological data (gender, age and geographical location, receiving health care facilities) to develop clinical-quality management systems to measure injury incidence, anticipate trends traumatic injuries trends and medical stock

procurement needs alongside the measurement of pre-hospital clinical care. Effective and efficient injury response is as important as injury prevention.

5.5 Penetrating Injury Type

Knife related injuries were the most common penetrating injury type in this study (82 cases n=143). 50 cases (n=143) experienced penetrating injury as a result of a bullet while ten cases experienced penetrating injuries caused by sharp objects (other than knives or bullets). In terms of injury management, knife related wounds were predominantly managed by intermediate life support practitioners (42 cases) compared to advanced life support practitioners (40 cases). Advanced life support practitioners managed more cases with bullet related injuries (33 cases) compared intermediate life support (17 cases). Although penetrating injury type was categorically measured in this study (bullets, knife and other), 'other means' other sharp object casing penetrating injuries could include screw drivers, spears and glass fragments (Kong et al., 2015). The penetrating cases in this study incidents irrespective of their type were most frequently concentrated between the hours of 20h00 and 02h00, with 56% of all incidents occurring during this six-hour interval.

A trauma surveillance in Cape Town, South Africa analysing 9236 consecutive trauma centre admissions found the most common mechanism of injury was assault with a sharp object (1933 cases [20.9%]) or blunt object (1571 cases [17.0%]) (Nicol et al., 2014). In Pietermaritzburg, South Africa an analysis of the mechanism of injury revealed that 1,081 (40.7 %) penetrating injury, of which stab wounds (858 cases) were the most frequent cause of penetrating traumatic injury followed by gunshot (202 cases) wounds impalements (14 cases) and animal injuries (4 cases) and other (3 cases). In Turkey, a four-year retrospective review of penetrating thoracic injury revealed that stab wounds were the most frequent mode of injury comprising 89 cases (89.9%) (Yazici et al., 2012). In London over an 18 month period at a trauma centre, 32 % of penetrating neck injuries was attributed to stab wounds, while the rest of the mechanisms of injury was attributed to (48 %), gunshot wounds (4 %), shotgun wounds (4 %) and other accidental causes (12 %) (Siau et al., 2013). Thus, it can be seen that penetrating injury is not limited to the African context.

This study was not aimed at determining the risk factor(s) and determinants for the individual(s) inflicting the injury nor and the individual sustaining the injury nor did investigate wound morphology, precise location and angle of the penetrating wound.

The motive behind injury affliction are numerous and there is no single risk factor for violent interactions, but rather a broad range of complex interacting factors that can be understood by way of the ecological model (Rosenberg et al., 2008). The ecological model lists domestic violence as a type of violence, notwithstanding the usage of firearms in non-fatal cases of domestic violence (Abrahams et al., 2010).

South Africa's past played an important role in the country's current standing. Up until South Africa's democratic freedom in 1994, South Africa was subject to apartheid state repression, national liberation struggle, arbitrary detentions, political unrest and violence (Kramer & Ratele 2012). Post-Apartheid, (Kramer & Ratele 2012) attributed rapid urbanisation, glaring racial and gender socioeconomic inequalities, widespread poverty, high unemployment, high levels of alcohol and drug abuse, patriarchal views of manhood, and a weak uneven police enforcement of laws are part of an ensemble of factors that characterise post-apartheid South Africa. Additionally, using a four level ecological model Kurt (2009) describes some risk factors for violence and further describes the important variables associated with each level. Irrespective of the level, certain variables are directly applicable to the South African context which includes: economic disparities, social care systems, political and judicial systems and social instability (Kramer & Ratele 2012).

Mock et al., (1994) studied gunshot and stab wounds in Seattle USA from 1986 to 1992. A major finding was the variance in the cost associated with the hospital charges for gunshot (\$ 17,367) wounds versus stab (\$ 7,699) wounds. The authors indicated that even if guns were eliminated and the same level of violence occurred with stab wounds instead of gunshot wounds, \$1.5 million in hospital costs alone would be saved.

Gun violence can be as a result of vigilante policing (Harris 2001) and criminal activity (Cock 2000). Nina (2000) describes vigilantism as an adoption of either a crime or social order approach, directly using physical force and intimidation at levels not normally used by the state. Gun ownership is mainly a male phenomenon, a means to demonstrate manhood, particularly among young men (Burnett et al., 2002). In South Africa, unlicensed firearms are more likely to be used in violent crimes compared to legally owned firearms which is one of the main risk factors for murder of intimate partners (Abrahams et al., 2010).

5.6 Wound Location and Number of Wounds

The results from this study indicated (in order of most frequent anatomical site) the chest (35.7% n=143), upper-limbs (31.5% n=143) and the lower limbs (23.1% n=143) were the most common anatomical areas for penetrating traumatic injuries. There was a significant association between gender and penetrating injuries to the chest, with chest injuries being more common in male patients (chi-squared p value 0.0097). Majority of the cases (43.4% n=143) only sustained one penetrating traumatic injury. These results are similar to that found by (Brink et al., 1998) who investigated victims of physical assault of blunt and penetrating origin and (Norberg et al., 2009) who investigated patients the cost of treating gunshot victims in Cape Town, South Africa of which 59% had injuries to the chest (203 cases). In this study, there was no statistically significant association with gender and other penetrating injury locations other than trauma to the chest.

As seen in Chapter 4, the majority of the vital signs (blood pressure, heart rate, skin temperature, capillary refill time) on scene were either within normal range or mildly elevated. The elevation above normal threshold could be due to the fight or flight physiological response to stress. The scene heart rate was statistically significant finding with a scene heart rate of 11.25 beats per minute higher for females (p value 0.01) compared to males irrespective of penetrating injury type or intravenous fluid therapy. Similarly, hospital heart rate was 10.48 beats per minute higher (p value 0.002) for females than males. There was no statistical significance for any of the vital signs when compared to gender. However, a statistically significant association between vital signs on scene and hospital were found for cases receiving intravenous fluids.

Penetrating injury to the chest is associated with a higher mortality when compared with blunt force trauma (Cury et al., 2009). In Tanzania, traumatic chest injuries is one of the leading causes of morbidity among the young and old (Lema et al., 2011). Chest injuries require early recognition and frequently special clinical interventions (resuscitative measures, preoperative care and surgical and non-surgical procedures) may contribute to the outcome of the patient (Tariq, 2011; Lema, 2011). This study did not document patient mortality at any level of intervention (by first responder, ambulance crew, hospital arrival or after definitive care), however it is noted that gunshot wounds to the heart carry the greatest mortality (Mandal & Oparah 1989). Further research is needed to determine patient mortality post clinical management and the level of clinical care by emergency care providers in the South African context.

The majority of patients (43% n=143) in this study group sustained one wound as a result of the penetrating traumatic injuries, with no association between the number of wounds and gender (p-value = 0.52). An observational study by (Tingne et al., 2014) found the neck and head to be the preferred anatomical site for perpetrators of interpersonal violence inflicting penetrating or blunt injuries to their victims. This study was not aimed at determining whether the patient was the victim or the perpetrator, nor was it aimed at providing detailed wound morphological patterns of the penetrating traumatic injuries which may include wound depth, length, and type of damage to the skin. Additionally, the clinical practices and the understanding thereof by emergency care for wound cleaning and irrigation immediately post injury was not ascertained. The expectation of emergency care providers to document wound cavitation (objectively using an approved measurement device) may have been problematic due to the large emergency provider workforce presenting logistical constraints, the possibility in delay of patient treatment, infection risk as well as general resource constraints.

The data collection tool was not designed for emergency care providers to ascertain entrance and exit wounds. Documenting wounds deemed to be entrance and exit for bullet related injuries would have been beneficial as pre-hospital emergency care providers who are often first on scene and have the opportunity of examining injuries prior to any clinical or surgical intervention. It has been suggested that healthcare providers have accurate knowledge of the types of injuries and should also be familiar with the appropriate terminology, as failure to recognize and describe injuries may pose challenges in the legal system (Sharma 2003). Further research is needed in the South African context ascertaining the forensic knowledge and documentation processes used by emergency care for bullet related penetrating traumatic injuries.

Nonetheless, knowing the number of wounds as well as their anatomical locations provided insight into the penetrating injury cases managed by emergency care providers and provided vital information that may be used to direct further clinical and non-clinical research. Evaluations between single and multiple wounds were able to provide clues as to the relationship between the victim and perpetrator in homicide incidents (Ormstad et al., 1986), as well as multiple wounds suggested the intent to kill (Ambade & Godbole 2006). Additionally knowing the clinical presentations of penetrating injuries impacts current clinical guidelines which includes aiding the differential diagnosis and providing appropriate diagnostic investigations and definitive treatment (Spahn, 2007; Mc Swain, 2011).

This study did not document whether the object causing the penetrating injury was retained or not. In the South African context, retained sharp objects, if present are often located in the abdomen and upper limbs and patients may be haemodynamically stable (Kong et al., 2015). Kong et al., (2015) further mentions that few centres often have the experience to appropriately develop clinical guidelines to manage retained penetrating objects. This has major implications on clinical guidelines for the initial management of patients with retained sharp objects- especially in the pre-hospital context.

5.7 Crew Qualification and Penetrating Injury Type Management

Pre-hospital emergency care providers provide important medical care on scene and rapid transportation (Shere-Wolfe et al., 2012) to hospital with the aim of increasing the chance of survival of injured patients. Many debates exists between the level of care provided and the efficacy of clinical interventions (Lieberman et al., 2000) and the overall benefit of Advanced Life Support (ALS) (Isenberg & Bissell 2005) in the pre-hospital environment to injured patients (Ryynänen et al., 2010).

Ryynänen et al., (2010) conducted a systematic review comparing ALS vs Basic Life Support (BLS) investigating patients outcomes related to mortality or health-related quality of life or capacity to perform daily activities. Their selection criteria were rigorous and included subsections investigating penetrating injury. For this reason, their journal article was extensively used in this section.

The crew qualification in this study directly contributes to the level of clinical care (ALS or ILS) received by the patient. The Health Professions Council of South Africa: Professional Board for Emergency Care is the statutory body regulating the capabilities and protocols of pre-hospital emergency care providers in South Africa. Currently in South Africa, only Intermediate Life Support (ILS) and Advanced Life Support (ALS) providers are able to provide intravenous fluid therapy to patients. There is heterogeneity for ALS in South Africa. ALS providers include individuals with a Critical Care Assistants qualification, National Diploma Emergency Care qualification, National Higher Certificate Emergency Care qualification as well as practitioners with Bachelor Technology or Bachelor's degree in Emergency Medical Care qualification. Each of these qualifications has different education levels as well as independent registration at the HPCSA. The practitioner qualification base as described above was used when determining the intravenous fluid management practices for penetrating injury.

There was a difficulty in comparing the ILS South African level of care to the international counterparts, as many pre-hospital emergency systems provide clinical care based on political, geographical, cultural and economic factors to name a few (Ryynänen et al., 2010). There may also be different educational training and clinical capabilities in pre-hospital emergency systems outside of South Africa. In some instances ALS care was described from a physician perspective (Ummenhofer & Scheidegger 2002).

Thus, capabilities and protocols for BLS and ALS providers in previous studies had to be thoroughly scrutinised when drawing comparisons between the South African ILS/ALS versus the BLS/ALS levels of care in other pre-hospital systems often with very close similarities for ALS and overlapping in the use of basic emergency techniques (Ryynänen et al., 2010).

In their systematic review comparing BLS versus ALS in the provision of pre-hospital care, Ryynänen et al., (2010), found overall no evidence making ALS superior over BLS. Individual studies in the systematic review were identified demonstrating BLS superior to ALS. The systematic review (Ryynänen et al., 2010) has multiple points for discussion and their results cannot be directly compared to ALS and ILS in this study. Some of these points include the measurement of variables between the systematic review and this study, as seen below:

- This study did not look at patient mortality, whereas Ryynänen et al., (2010) included mortality for certain injury types.
- This study did not look at transport means other than road ambulance transportation, whereas the systematic review Ryynänen et al., (2010) looked at ground ambulance and air ambulance transportation methods. No specification for rural versus urban response was notated.
- Certain studies in the systematic review Ryynänen et al., (2010) identified ALS-paramedic and ALS-physician or ALS-paramedic and physician whereas this study only looked at ALS-paramedic.
- Multiple clinical interventions were investigated in the systematic review by Ryynänen et al., (2010), whereas this study only looked at intravenous fluid management practices.
- This study was dedicated to penetrating injury whereas the systematic review looked at ALS care for medical and traumatic cases, with only a small subsection for penetrating injury.

A noteworthy point when comparing ALS and BLS with patient outcomes is that ALS interventions are often carried out on patients that are critically ill and with severe pathology (Isenberg & Bissell 2005). Thus, the length of stay at hospital, clinical outcome or mortality may not necessarily be due to ALS interventions but rather due to the severity of illness and clinical cause after the traumatic injury.

Isenberg & Bissell (2005) conducted a literature review to determine the benefit of ALS in cases involving trauma, cardiac arrest, myocardial infarction, and altered mental status. Their findings indicated no benefit in ALS when compared with BLS for urban trauma, with some articles indicating a higher mortality rates when managed by ALS providers. Specifically for penetrating injury, Isenberg, (2005) found poor evidence that ALS care improves survival in patients with short transport times to Level-I trauma centres. This study had major limitations as it did not account key ALS clinical interventions and comparing them to BLS interventions, nor did it look at specific traumatic injuries such as penetrating injury. For their study, ALS was classified according to the American National Highway Traffic Safety Administration's National Standard Curriculum for Emergency Care Technicians which is different to the South African ALS with reference to scope and capabilities of care. Additionally, the variance for patient outcomes also differed when looking at individual paper used in the literature review. Some outcomes where mortality orientated, injury severity aligned, while others investigated changes in clinical parameters after ALS or BLS intervention(s). A systematic review and meta-analysis found benefit in pre-hospital emergency services, with the findings indicating a reduction in patient mortality (Henry & Reingold 2012).

There is a shortage of ALS practitioners in South Africa, when compared to other levels of qualification and the country's population size (Govender et al., 2012). This may be attributable to the number of cases managed by ILS versus ALS in this study. In most cases ALS interventions often are additions to BLS interventions, nonetheless upon multivariate analysis, ALS interventions on scene for penetrating injury significantly correlated with increased mortality (Funder et al., 2011).

Due to the multitude of factors contributing to patient outcomes as well as the contributing factors related to clinical care, the clinical decision making process and including the contextual circumstances; concluding that one level of care is superior to the other, by means of causality cannot be made for this study. This study was not also aimed at providing a definitive conclusion on the level of care delivered to patients and their clinical outcome.

5.8 Time Variables Associated with Patient Management (Time of Incident Dispatch, Scene Arrival and Hospital Arrival)

Time is an important variable in the provision of medical care and more so in the event of life-threatening conditions. The first twenty four hours has been said to be the most deadliest for trauma patients with thoracic, vascular and central nervous system injuries the most common causes of death within hour after admission to hospital (Acosta et al., 1998). Furthermore, the first hour after an injury has been referred to as the 'golden hour', which advocates for definitive care within the first hour after injury to reduce patient morbidity and mortality (Lerner & Moscati 2001). However, many have questioned the golden hour concept (Lerner, 2001; Ali Ali, et al., 2015; Newgard, et al., 2015).

In the pre-hospital environment two major schools of thought directing clinical care. The first being the 'scoop and run' approach, while the other being the 'stay and play approach'. The former approach involves the hasty removal of the patient from the scene to hospital, while providing limited but essential care, and the latter incorporating primary treatment and patient stabilisation on scene prior to hospital transport (Smith & Conn 2009). This approach applied in the concept of the golden hour has seen a reduction in casualty fatality rate (before golden hour implementation 13.7 [469 of 3429] vs after golden hour implementation 7.6 [1344 of 17 660]; $P < .001$) in the military environment, however the percentage of casualties that died of their wounds (before golden hour implementation 4.1% [83 of 2025] vs after golden hour implementation 4.3% [380 of 8791]; $P = .71$) remained unchanged.

For all cases in this study, a scene to hospital time of 29.50 minutes (SD 12.11) and a mission time (incident time to hospital time) of 45.59 minutes (SD15.80) was recorded. This study did not investigate clinical interventions other than intravenous fluid therapy, nor did the study investigate the time taken to perform clinical skills (including intravenous cannulation). 30-day patient survival was also not investigated. Recording the time to perform procedures related to haemorrhage control and intravenous therapy would have provided a greater understating in relation to the time spent on scene. Further investigation is required into the haemorrhage control practices, 30-day survival as well as the time associated with these clinical procedures.

Scene times are often increased when simple and complex clinical skills are performed in the field managing life threatening injuries that may accompany a traumatic injury (Smith & Conn 2009). Funder et al., (2011) reported that a higher mortality was found among patients

treated on-scene for more than 20 minutes ($p = 0.0001$), however on-scene time was not a significant predictor for 30-day mortality in the multivariate analysis (OR 3.71, 95% CI 0.66 to 20.70 $p=0.14$). The results by Funder et al., (2011) cannot be directly used as a comparative to this study for various reasons including, geographical variables from the scene to hospital, health care system (patients taken directly to a dedicated trauma centre), level of qualification, extent of injury and nature of clinical interventions performed in the field. The concept of the golden hour has been practiced for more than three decades (Newgard et al., 2010), however there is little evidence to support this practice (Lerner & Moscati 2001).

This study did not look at clinical interventions performed in the field by pre-hospital emergency care providers that may accompany a penetrating traumatic injury. These clinical interventions includes needle decompression for a tension pneumothorax, wound care control and preventing further external haemorrhage or even endotracheal intubation to provide adequate oxygenation and ventilation to name few. Thus, it is challenging to definitively indicate that scene to hospital times is too long for this study. These additional procedures may have also contributed to changes in the clinical status of patients in this study.

Additionally, a district health care system is adopted in the Cape Metropole, implying the all health care facilities to do not accept cases involving physical trauma. Patients with severe injuries may require transportation to healthcare facilities with specialist care, thus the scene to hospital time may be increased due to the distance from the scene to the hospital.

Although intravenous fluid management practices (number of attempts, type and volume of fluid etc.) were documented, the exact initiation time was not recorded. As a result, pre-hospital emergency care providers may have initiated intravenous therapy en-route to hospital, while others may have initiated intravenous therapy on scene. Further research is needed in determining the time associated with the above mentioned clinical procedures. Gonzalez et al., (2008) found the mean time spent on scene with single intravenous cannulation attempt 14.5 minutes ($P < 0.0001$) and a mean time of 15.7 minutes in the urban setting ($P < 0.005$). The result by Gonzalez et al., (2008) cannot be directly inferred to this study as Gonzalez et al., investigated trauma associated with motor vehicle accidents and not penetrating injury as result of sharp object injury. This study only included urban emergency responses. The four ambulance bases selected for this study were located in the

Cape Metropole. There has been a debate regarding urban versus rural patients and their received clinical care(Isenberg & Bissell 2005).

Swaroop et al., (2013) found that patients with penetrating thoracic injuries are transported more quickly to urban trauma centres with shorter pre-hospital times associated with increase in patient survival. It has been said that trauma is one of the leading pre-hospital disease profiles in South Africa (Hardcastle et al., 2012) with majority of trauma deaths in the developing world occurring in the out-of-hospital environment (Henry & Reingold 2012). Pre-hospital emergency care providers may rapidly transport patients to the required healthcare/ specialist centres, however upon arrival they may need to wait to be triaged, bed a patient or a doctor to accept the patient. A recent assessment of the trauma workload in a rural district healthcare facility in South Africa indicated a great trauma burden with an inadequate capacity in the management of the burden. The concept of scoop and run, nearest appropriate facility and the golden hour may not be applicable in the South African context.

5.9 Chapter Five Summary

Chapter five discussed the findings of this study. Although this study only considered penetrating injuries over a three month period, notable results were obtain within the current paucity of intravenous fluid therapy in the South African pre-hospital, environment. For this study population, statistically significant results were observed when certain variables were analysed and compared to one another. Additionally, demographic results obtained in this patient sample group within this study were similar to previous mortality statistics for external trauma deaths in South Africa.

A major limitation of this study was the inherent methodology imbedded within the quantitative paradigm. This study only observed the intravenous fluid practices for penetrating injury as well as the recording of patient demographics. This study was not equipped (nor aimed) at identifying the causal direct and indirect variables influencing the results of this study. Thus, the casual factors contributing to the results in this study can only be explained, within reason, using other contextual studies investigating the variable in question. Further sections of this chapter will elaborate on the recommendations based on the results of this study.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This final chapter consists of summaries, conclusions and recommendations. The limitations of intravenous fluid practices are discussed within the context of this study as well as suggested future research endeavours. The recommendations are directed at health-stakeholders, policy makers and researchers.

The first chapter introduced the topic of intravenous fluid and trauma management, for trauma within the pre-hospital environment. This chapter also provided an overview and significance of as well as defining certain concepts within the context of emergency care.

The demographic profiles of patients with penetrating traumatic injuries as well as variables related to intravenous fluid therapy were reviewed followed by the methodological processes pertaining to the patient-inclusion as well as the pre-hospital emergency care provider criteria are detailed. The development of the data collection tool, its limitations and practical application was presented in Chapter 3.

The three month data collection period compared treatment processes in accordance with the research objectives. The findings were discussed alongside similar studies and evidence based medicine approaches by identifying probable origins according to with the study's objectives.

Chapter six is the final chapter within the thesis and encompasses a summary of each chapter, final conclusions and recommendations. The recommendations are centred on the major findings alongside the research objectives. A final conclusion to the research question- what are the intravenous fluid management practices for penetrating injury in the Western Cape Metropole?

6.2 Data Collection Tool (Annexure F)

The variables outlined in the data collection tool were taken from current injury surveillance tools. The data collection tool demonstrated an alternative data collection method, documenting important variables related to patient demographics, clinical presentation and clinical management (intravenous fluid therapy). The number of incorrectly completed sheets in comparison to the correctly completed sheets indirectly demonstrated the ease of completion, however this requires further investigation. The data collection tool presents further opportunities in interest of more accurate and reputable data collection for specific injury types.

6.3 Objective 1

To describe the pre-hospital fluid management practices for penetrating injury in the Cape Metropole, with reference to: fluid type, volume of fluid administered, time period of fluid administration and number of intravenous catheters size (bore)?

6.3.1 Objective 1 Research outcome and Conclusion

The results of this study demonstrated that amongst the sampled pre-hospital emergency care providers and patients. The majority of patients received a crystalloid intravenous fluid of which Ringer's Lactate was the most frequently administered fluid (71% n=143). The estimated total mean volume of administered fluid was 901.0ml across all patients with penetrating traumatic injuries and all fluid types. The mean time period for which intravenous fluid was administered was 18.33 minutes, with the most frequent intravenous cannula bore size of 18G (48.9% n=143). One intravenous cannula was the most frequent (58% n=143) inserted for patients.

6.3.2 Objective 1 Recommendations

Expanding the geographic boundaries will provide an improved perspective regarding the intravenous fluid practices in rural settings and the intravenous fluid practices in other urban environments. Further research identifying other clinical therapies initiated by pre-hospital emergency care providers for penetrating injuries in conjunction with intravenous fluid therapy is needed. Assessing other therapies would be beneficial in identifying the prioritisation

of clinical therapies as determined by the pre-hospital emergency care provider as well as associated therapies practiced alongside intravenous fluid administration.

Research focussing on the intravenous fluid practices by pre-hospital emergency care providers for patients with penetrating injury during an inter-healthcare-facility transfer where intravenous fluid therapy was initiated by in-hospital health care providers and only continued by pre-hospital emergency care providers. Healthcare providers working in the in-hospital environment have different scopes of practice as well as different/alternative diagnostic and monitoring tools compared to pre-hospital emergency care providers.

This study only investigated penetrating traumatic injuries over three consecutive months. An investigation period longer than three months may provide a better understanding into the intravenous fluid management practices over larger samples. Results based seasonal trends may aid in understanding intravenous fluid practices as well as the demographic profiles.

Future research expanding the scope of the study from the pre-hospital setting to the in-hospital setting and investigating the intravenous fluid practices as well as the clinical status of patients once they are admitted into the emergency centre would be beneficial. A study investigating patient outcome post-penetrating injury will provide valuable results specific to the South African population and health care system. Similarly, further research is needed investigating the intravenous fluid practices and other therapies for patients that have died in the pre-hospital setting, while under the care of a pre-hospital emergency care provider.

Further research to identify the clinical and contextual decision barriers and enablers for the use non-use of colloid intravenous fluid administration by pre-hospital emergency care providers in the pre-hospital environment for penetrating traumatic injuries is needed.

A cost-analysis specifically on the cost of intravenous fluid therapy in the pre-hospital context will provide an economic perspective as trauma is one of top three causes of external mortality within the Western Cape. Further research guiding the development of a reporting tool aimed at unifying the reporting and documentation of patient and practitioner data similar to design by Laing, et al., (2014b).

6.4 Objective 2

Identify the clinical indications/ indicators used in pre-hospital emergency care for fluid resuscitation?

6.4.1 Objective 2 Research Outcome and Conclusion

The key clinical indicators used by pre-hospital emergency care providers when administering intravenous fluid for penetrating traumatic injuries included blood pressure, heart rate and capillary refill time. Lower on-scene systolic and diastolic blood pressure readings were observed among those who received intravenous fluid compared to those who did not receive intravenous fluid. Higher heart rates were observed amongst those who received intravenous fluid compared to those who did not receive intravenous fluid. Longer on-scene capillary refill times were observed amongst those who received intravenous fluid compared to those who did not receive intravenous fluid. Lower blood pressures, higher heart rates and longer capillary refill times are suggestive of hypovolemic shock.

6.4.2 Objective 2 Recommendations

Further investigations identifying pre-hospital emergency care providers knowledge and understanding of the physiological theories supporting low and high intravenous fluid administration strategies. Future research is also needed into the protocol of fluid administration strategies frequently used by pre-hospital emergency care providers for penetrating injuries.

Future research is needed to determine the clinical indicators used by pre-hospital emergency care providers during intravenous fluid therapy for patients with blunt traumatic injuries as well as patient outcomes in the South African context. A review the current and previous intravenous fluid therapy strategies taught at higher education institutions offering qualifications in the field of health sciences would provide much needed insight.

6.5 Objective 3

Describe the clinical end-points used by pre-hospital emergency care providers for fluid resuscitation?

6.4.1 Objective 3 Research Outcome and Conclusion

End point was defined as the patient's vital signs at hospital. After intravenous fluid administration a positive increase in systolic and diastolic blood pressure was observed with a change in systolic blood pressure compared to when no intravenous fluids were administered. This finding suggests that intravenous fluid administration has a positive increase in systolic and diastolic blood pressure or mitigates its decrease. No statistical difference was observed in change in heart rate from scene to hospital for patients that were given intravenous fluid compared to those that were not given intravenous fluid. The same findings were observed for capillary refill time.

6.4.2 Objective 3 Recommendations

The recommendations made for Objective in 6.6.2.2 can also be adopted for this outcome. Additionally, further research is needed to obtain an objective clinical endpoint used by pre-hospital emergency care providers for intravenous fluid administration. The research should include end-points that are clearly referenced in terms of cessation of therapies and the reporting and documentation of clinical parameters.

6.5 Objective 4

To determine the clinical presentation of the penetrating traumatic injury/ injuries with reference to anatomical location(s) of penetrating injury/injuries, number of penetrating injuries/wounds, the systolic blood pressure, heart rate and capillary-refill-time upon scene arrival as well as the systolic blood pressure, heart rate and capillary refill-time upon hospital arrival?

6.5.1 Objective 4 Research Outcome and Conclusions

The chest (35.7% n=143), upper-limbs (31.5% n=143), lower limbs (23.1% n=143) and the head (21.7% n=143) were the most common anatomical areas for penetrating traumatic injuries. A single penetrating wound (43.4% n=143) was the most frequently observed wound count. The number of wounds per patient decreased as the overall wound frequency increased. The mean scene systolic and diastolic blood pressure was 101.7mmHg and 55.3mmHg respectively. While the scene heart rate was 106.0 beats per minute and mean scene capillary refill time 1.93 seconds. Upon hospital arrival, the mean systolic blood pressure was 100.16mmHg, while the diastolic blood pressure increased by 7.8mmHg to

63.1mmHg. The mean heart rate upon hospital arrival was 103.0 beats per minute. The mean capillary refill time upon hospital arrival was 1.71 seconds.

Penetrating traumatic injuries are most common in the upper limbs and lower limbs and the head. A single wound was the most frequent number of wound sustained. Mean arterial blood pressure on scene is lower than the expected clinical norm for an adult patient. Systolic blood pressure is on average lower upon hospital arrival compared to systolic blood pressure noted on scene. Heart rates are lower upon hospital arrival compared to on-scene.

6.5.2 Objective 4 Recommendations

Further research identifying specific anatomical locations of penetrating traumatic injuries within the thoracic cavity as well as the associated clinical outcome and survival and mortality rates are needed.

Future investigations into the clinical and haemodynamic status of penetrating injury patients where specified intravenous fluid protocols were used as well as the investigation of the clinical outcome and where appropriate, the survival and mortality rates will be useful. Investigations detailing other clinical investigations practiced on penetrating injury patients other than intravenous fluid therapy are also needed.

6.6 Objective 5

To describe the basic demographic profile of the patient including age and gender.

6.6.1 Objective 5 Research Outcome and Conclusions

The basic demographic profile of the patient that sustained a penetrating traumatic injury during the collection period was male, between the age group of 15- 35 years, injured between the hours of 20h00 and 02h00. A statistically significant relationship between male patients and penetrating chest injuries was observed. Penetrating injury victims were treated more often by advanced life support compared to intermediate life support providers. However, a greater number of stab wounds (42 cases n=143) were treated intermediate life support and compared to advanced life support (40 cases) n=143. The opposite was observed for advanced life support. A greater number of penetrating injuries originating from bullet(s) (33 cases n=143) were treated by advanced life support compared 17 cases (n=143) managed by intermediate life support. Individuals with penetrating injuries are more

likely to be taken a tertiary level health care facility with a dedicated 24-hour specialist trauma unit.

6.6.2 Objective 5 Recommendations

Further epidemiological research investigating specific demographic traits predisposing males between the ages of 15-35 years in experiencing a penetrating traumatic injury is needed. Investigating the nature of the association between seasonal changes, behavioural traits and other factors are necessary. Future research detailing wound morphology and thoracic organ system changes for patients that have survived to discharge and those that have died in the pre-hospital or in-hospital environment.

Further investigations are required into the enablers and challenges faced by in-hospital emergency centre staff upon the admission of a patient with a penetrating injury from the pre-hospital emergency setting. Research is also needed to identify the efficacy and appropriateness of current and previous violence prevention programs in the Cape Metropole. In addition to the previous recommendations, the development of a reliable, systematic and reputable trauma registry documenting epidemiological and clinical descriptors of victims across South Africa or the limitations in unifying local databases is needed. There is a limited and varied approach in the recording process for new and repeated penetrating injury cases across South Africa. South Africa currently relies on mortality data as one of the only longitudinal databases providing epidemiological and geographic information for trauma victims. Data from the trauma registry could compare similarities and/or differences between deceased victims of penetrating injury versus penetrating injury victim survivors, as well as any other time related epidemiological and geographic trends or variances. The trauma registry could incorporate the some of the principles and processes utilised by Laing, et al., (2014b) reporting process as indicated earlier.

Research is also needed into the challenges of the penetrating trauma case-load on hospital resource allocation, especially at tertiary level/ specialist trauma centres. Resource allocation could be researched alongside the health economic impact, quality of care and achievement of clinical goals to name a few.

BIBLIOGRAPHY

- Abrahams, N., Jewkes, R. & Mathews, A., 2010. Guns and gender-based violence in South Africa. *South African Medical Journal*, 100(9), pp.586–588.
- Acosta, J.A. et al., 1998. Lethal injuries and time to death in a level I trauma center. *Journal of the American College of Surgeons*, 186(5), pp.528–33.
- Al-Khafaji, A. and & Webb, A.R., 2004. Fluid Resuscitation. *Contin Educ Anaesth Crit Care Pain*, 4(4), pp.127–131.
- Alam, H.B. & and Velmahos, G.C., 2007. New Developments in Fluid Resuscitation. *The Surgical clinics of North America*, 87(1), p.55–72, vi.
- Alam, H.B. & and Velmahos, G.C., 2011. New Trends in Resuscitation. *Current Problems in Surgery*, 48(8), pp.531–564.
- Ali, B.A. et al., 2015. Influence of prehospital response times in the survival of trauma patients in Navarre. *Anales del sistema sanitario de Navarra*, 38(2), pp.269–278.
- Allard, D. and & Burch, V.C., 2005. The cost of treating serious abdominal firearm-related injuries in South Africa. *South African Medical Journal*, 95(8), pp.591–4.
- Allorto, N. et al., 2013. Advanced Trauma Life Support and Principles of Trauma Management. In T. Hardcastle & G. O'Reilly, eds. *AFEM Handbook of Acute and Emergency Care*. Oxford University Press, p. 728.
- Ambade, V.N. and & Godbole, H.V., 2006. Comparison of wound patterns in homicide by sharp and blunt force. *Forensic science international*, 156(2–3), pp.166–70.
- Annane, D. et al., 2013. Effects of fluid resuscitation with colloids vs crystalloids on mortality in critically ill patients presenting with hypovolemic shock: the CRISTAL randomized trial. *JAMA : the journal of the American Medical Association*, 310(17), pp.1809–17.
- ATLS & International ATLS Working Group, 2013. Advanced Trauma Life Support (ATLS®): the ninth edition. *The Journal of Trauma and Acute Care Surgery*, 74(5), p.1363.
- Australian Consortium for Classification Development, 2017. *The International Statistical Classification of Diseases and Related Health Problems, Australian modification (ICD-10-AM/ACHI/ACS)*, New South Wales.

- Balogh, Z. et al., 2003. Supranormal trauma resuscitation causes more cases of abdominal compartment syndrome. *Archives of Surgery*, 138(6), pp.637–643.
- Band, R.A. et al., 2014. Severity-adjusted mortality in trauma patients transported by police. *Annals of emergency medicine*, 63(5), p.608–614.e3.
- Barsoum, N. & Kleeman, C., 2002. Now and Then , the History of Parenteral Fluid Administration. *American Journal of Nephrology*, 90073(22), pp.284–289.
- Beuran, M. et al., 2012. Prehospital trauma care: a clinical review. *Chirurgia (Bucharest, Romania : 1990)*, 107(5), pp.564–70.
- Bickell, W. et al., 1994. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *New England Journal of ...*, 331(17), pp.1105–1109.
- Birkhahn, R., Gaeta, T. & Terry, D., 2005. Shock index in diagnosing early acute hypovolemia. *The American journal of ...*, 23(3), pp.323–6.
- Bowman, B. et al., 2010. Costing injuries in South Africa : preliminary results and challenges from a pilot study. *African Journal of Health Sciences*, 17(3), pp.57–63.
- Brattstrom, O. et al., 2010. Early predictors of morbidity and mortality in trauma patients treated in the intensive care unit. *Acta Anaesthesiologica Scandinavica*, 54(8), pp.1007–1017.
- Breetzke, G.D. & Cohn, E.G., 2011. Seasonal Assault and Neighborhood Deprivation in South Africa: Some Preliminary Findings. *Environment and Behavior*, 44(5), pp.641–667.
- Brink, O., Vesterby, A. & Jensen, J., 1998. Pattern of injuries due to interpersonal violence. *Injury*, 29(9), pp.705–9.
- Brohi, K. et al., 2008. Acute coagulopathy of trauma: hypoperfusion induces systemic anticoagulation and hyperfibrinolysis. *J Trauma*, 64(5), p.1211–7; discussion 1217.
- Brohi, K. et al., 2003. Acute traumatic coagulopathy. *Journal of Trauma-Injury Infection & Critical Care*, 54(6), pp.1127–1130.
- Bruns, B. et al., 2008. Prehospital hypotension redefined. *The Journal of trauma*, 65(6), pp.1217–21.

Bukur, M. et al., 2011. Self-inflicted penetrating injuries at a Level I Trauma Center. *Injury*, 42(5), pp.474–7.

Bulger, E. et al., 2011. Out-of-hospital hypertonic resuscitation after traumatic hypovolemic shock: a randomized, placebo controlled trial. *Annals of Surgery*, 253(3), pp.431–441.

Bull, J.P., 1978. Measures of severity of injury. *Injury*, 9(3), pp.184–187.

Burnett, N. et al., 2002. Children , Youth , and Gun Violence The Future of Children. *The Future of Children*, 12(2), pp.1–176.

Burša, F. & Pleva, L., 2014. Anaerobic metabolism associated with traumatic hemorrhagic shock monitored by microdialysis of muscle tissue is dependent on the levels of hemoglobin and central venous oxygen saturation: a prospective, observational study. *Scandinavian journal of trauma, resuscitation and emergency medicine*, 22(1), p.11.

Butchart, A. & Engstro, K., 2002. Sex- and age-specific relations between economic development , economic inequality and homicide rates in people aged 0 – 24 years : a cross-sectional analysis. , 80(1), pp.797–805.

Byers, R., 2010. An upshot of war - damage control resuscitation. *International emergency nursing*, 18(4), pp.221–5.

Cabrales, P. & Intaglietta, M., 2013. Blood Substitutes: Evolution From Non-Carrying To Oxygen and Gas Carrying Fluids. *Asaio*, 59(4), pp.337–354.

Caetano, R., Nelson, S. & Cunradi, C., 2001. Intimate partner violence, dependence symptoms and social consequences from drinking among white, black and Hispanic couples in the United States. *American Journal on Addictions*, 10, pp.60–69.

Campion, E.M. et al., 2013. Implementation of a military-derived damage-control resuscitation strategy in a civilian trauma center decreases acute hypoxia in massively transfused patients. *The journal of trauma and acute care surgery*, 75(2 Suppl 2), pp.S221-7.

Carley, S., 2013. JC PROMMT Pre-hospital fluids for trauma – do they improve survival. *St. Emlyn's*. Available at: <http://stemlynsblog.org/pre-hospital-fluids-for-trauma-do-they-improve-survival/>.

Carr, B.G. et al., 2006. A meta-analysis of prehospital care times for trauma. *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, 10(2), pp.198–206.

Carr, B.G. et al., 2008. The time cost of prehospital intubation and intravenous access in trauma patients. *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, 12(3), pp.327–32.

Centers for Disease Control, 2011. *Injuries and Violence Worldwide*,

Centre for the Study of Violence and Reconciliation (CSV), 2009. *Why does South Africa have such high rates of violent crime ?*,

Chandran, A., Hyder, A. a & Peek-Asa, C., 2010. The Global Burden of Unintentional Injuries And An Agenda For Progress. *Epidemiologic reviews*, 32(1), pp.110–20.

Chesters, a., Roberts, I. & Harris, T., 2013. Minimising Blood Loss in early Trauma Resuscitation. *Trauma*, 16(1), pp.27–36.

Chudnofsky, C.R. et al., 1989. Intravenous fluid therapy in the prehospital management of hemorrhagic shock: improved outcome with hypertonic saline/6% Dextran 70 in a swine model. *The American journal of emergency medicine*, 7(4), pp.357–63.

Clarke, D.L., Aldous, C. & Thomson, S.R., 2014. Assessing the gap between the acute trauma workload and the capacity of a single rural health district in South Africa. What are the implications for systems planning? *European Journal of Trauma and Emergency Surgery*, 40, pp.303–308.

Clowes, L. & Lazarus, S., 2010. RRisk And Protective Factors To Male Interpersonal Violence : Views Of Some Male University Students. *African Safety Promotion Journal*, 8(1), pp.1–18.

Cock, J., 2000. Section Three : Firearms and a Culture of Violence in South Africa. In V. Gamba & C. Hansmann, eds. *Society Under Siege Vol III: Managing Arms in South Africa*. pp. 75–95.

Coppler, P. et al., 2015. Accuracy of Prehospital Intravenous Fluid Volume Measurement by Emergency Medical Services. *Prehospital Emergency Care*, Ahead of P(Ahead of Print), p.Ahead of Print.

- Cotton et al., 2009. Guidelines for prehospital fluid resuscitation in the injured patient. *The Journal of Trauma*, 67(2), pp.389–402.
- Cotton, B. et al., 2006. The cellular, metabolic, and systemic consequences of aggressive fluid resuscitation strategies. *Shock*, 26(2), pp.115–21.
- Credland, N., 2016. Managing the trauma patient presenting with the lethal triad. *International journal of orthopaedic and trauma nursing*, 20, pp.45–53.
- Crewdson, K. et al., 2009. Is the prevalence of deliberate penetrating trauma increasing in London? Experiences of an urban pre-hospital trauma service. *Injury*, 40(5), pp.560–563.
- Cullinan, K., 2006. Health services in South Africa: a basic introduction. *The South African Health News Service*, (January), p.38.
- Curry, N. & Davis, P.W., 2012. What's new in resuscitation strategies for the patient with multiple trauma? *Injury*, 43(7), pp.1021–8.
- Cury, F. et al., 2009. Rates of thoracic trauma and mortality due to accidents in Brazil. *Annals of thoracic medicine*, 4(1), pp.25–6.
- Davis, J., Alsafran, S. & Richie, C., 2014. Time to Resuscitate a Sacred Cow... with Normal Saline. *The American Surgeon*, 80(3), pp.301–306.
- Deb, S. et al., 1999. Resuscitation with lactated Ringer's solution in rats with hemorrhagic shock induces immediate apoptosis. *Journal of Trauma*, 46(4), pp.582–589.
- Degiannis, E. et al., 2006. Penetrating Cardiac Injuries: Recent Experience in South Africa. *World journal of surgery*, 30(7), pp.1258–64.
- Delano, M.J. et al., 2015. Prehospital Resuscitation of Traumatic Hemorrhagic Shock with Hypertonic Solutions Worsens Hypocoagulation and Hyperfibrinolysis. *Shock*, 44(1), pp.25–31.
- Dhaffala, A. et al., 2013. Demographic profile and epidemiology of injury in Mthatha, South Africa. *African Health Sciences*, 13(4), pp.1144–1148.
- Donson, H., 2009. *A profile of fatal injuries in South Africa 2008*,

- Dretzke, J. et al., 2004. Clinical effectiveness and cost-effectiveness of prehospital intravenous fluids in trauma patients. *Health Technology Assessment*, 8(23), pp.1–103.
- Dutton, R.P., 2007. Current concepts in hemorrhagic shock. *Anesthesiology clinics*, 25(1), p.23–34, viii.
- Dutton, R.P., Mackenzie, C.F. & Scalea, T.M., 2002. Hypotensive Resuscitation during Active Hemorrhage: Impact on In-Hospital Mortality. *The Journal of TRAUMA Injury, Infection and Critical Care*, 52(6), pp.1141–1146.
- Eckstein, M. et al., 2000. Effect of prehospital advanced life support on outcomes of major trauma patients. *The Journal of trauma*, 48(4), pp.643–8.
- Engels, P.T. et al., 2014. IV access in bleeding trauma patients: a performance review. *Injury*, 45(1), pp.77–82.
- Farrington, D.P., 1998. Predictors, Causes, and Correlates of Male Youth Violence. *Crime and Justice*, 24(May), pp.421–475.
- Feinman, M., Cotton, B. a & Haut, E.R., 2014. Optimal fluid resuscitation in trauma: type, timing, and total. *Current opinion in critical care*, 20(4), pp.366–72.
- Ferrara, A. et al., 1990. Hypothermia and acidosis worsen coagulopathy in the patient requiring massive transfusion. *American journal of surgery*, 160(5), pp.515–8.
- Finfer, S.R., Vincent, J.-L. & De Backer, D., 2013. Circulatory Shock. *New England Journal of Medicine*, 369(18), pp.1726–1734.
- Flannery, D.J., Singer, M.I. & Wester, K., 2001. Violence Exposure, Psychological Trauma, and Suicide Risk in a Community Sample of Dangerously Violent Adolescents. *Journal of the American Academy of Child & Adolescent Psychiatry*, 40(4), pp.435–442.
- Fouche, C. & Bartley, A., 2011. Sampling in the quantitative paradigm. In A. Devos et al., eds. *Research at Grass Roots*. Pretoria: Van Schaik, p. 255.
- Frank, M. et al., 2010. Proper estimation of blood loss on scene of trauma: tool or tale? *The Journal of trauma*, 69(5), pp.1191–5.

- Funder, K.S., Petersen, J.A. & Steinmetz, J., 2011. On-scene time and outcome after penetrating trauma: an observational study. *Emergency medicine journal: EMJ*, 28(9), pp.797–801.
- Gan, T.J., 2011. Colloid or Crystalloid: Any Differences in Outcomes? *International Anesthesia Research Society*, pp.27–32.
- Ganter, M.T. & Pittet, J., 2010. New insights into acute coagulopathy in trauma patients. *Best Practice & Research Clinical Anaesthesiology*, 24(1), pp.15–25.
- Gonzalez, R.P. et al., 2008. On-scene intravenous line insertion adversely impacts prehospital time in rural vehicular trauma. *The American surgeon*, 74(11), pp.1083–7.
- Google Maps, 2017. AfriGIS Map Data PTY Ltd. *Western Cape Map Scale 1:2000000*. Available at: <https://www.google.co.za/maps/@?dg=dbrw&newdg=1>.
- Gordon, J.E., 1949. The Epidemiology of Accidents. *American Journal of Public Health*, 39(4), pp.504–515.
- Govender, K. et al., 2012. The pending loss of advanced life support paramedics in South Africa. *African Journal of Emergency Medicine*, 2(2), pp.59–66.
- Gray, N.S. et al., 2003. Violence viewed by psychopathic murderers. *Nature*, 423(6939), pp.497–498.
- Griffel, M.I. & Kaufman, B.S., 1992. Pharmacology of colloids and crystalloids. *Critical care clinics*, 8(2), pp.235–53.
- Grimshaw, J. et al., 1995. Effectiveness Bulletin Developing and implementing clinical practice guidelines. *Quality in Healthcare*, 4, pp.55–64.
- Groenewald, P. et al., 2010. Local-level mortality surveillance in resource-limited settings: a case study of Cape Town highlights disparities in health. *Bulletin of the World Health Organization*, 88(6), pp.444–51.
- Guidet, B. et al., 2010. A balanced view of balanced solutions. *Crit Care*, 14(5), pp.1–12.
- Gutierrez, G., Reines, H.D. & Wulf-Gutierrez, M.E., 2004. Clinical review: hemorrhagic shock. *Critical care (London, England)*, 8(5), pp.373–81.

Hampton, D. a et al., 2013. Prehospital intravenous fluid is associated with increased survival in trauma patients. *The journal of trauma and acute care surgery*, 75(1 Suppl 1), pp.S9-15.

Hardcastle, T. et al., 2012. The Prehospital Burden of Disease due to Trauma in KwaZulu-Natal: The Need for Afrocentric Trauma Systems. *World Journal of Surgery*.

Harris, B., 2001. "As for Violent Crime that's our Daily Bread": Vigilante violence during South Africa's period of transition. *Violence and Transition Series*, 1. Available at: <http://www.csvr.org.za/wits/papers/papvtp1.htm#executive> [Accessed May 1, 2016].

Hasler, R., Nüesch, E. & Jüni, P., 2012. Systolic blood pressure below 110mmHg is associated with increased mortality in penetrating major trauma patients: Multicentre cohort study. *Resuscitation*, 83(4), pp.476–481.

Hatoum, O.A.; et al., 2002. Continuous fluid resuscitation and splenectomy for treatment of uncontrolled hemorrhagic shock after massive splenic injury. *The Journal of Trauma and Acute Care Surgery*, 52(2), pp.253–258.

Hauschild, V. et al., 2017. *A Taxonomy of Injuries for Public Health Monitoring and Reporting*, United States of America.

Haut, E.R. et al., 2011. Prehospital intravenous fluid administration is associated with higher mortality in trauma patients: a National Trauma Data Bank analysis. *Annals of Surgery*, 253(2), pp.371–7.

Health Professions Council of South Africa, 2006. *Advanced Life Support Practitioner Protocols 2006*, South Africa.

Health Professions Council of South Africa, 2015. *Quality and Equitable Healthcare for all*, Pretoria.

Henry, J. & Reingold, A., 2012. Prehospital trauma systems reduce mortality in developing countries: a systematic review and meta-analysis. *Journal of Trauma-Injury, Infection, and ...*, 73(1), pp.261–268.

Hern, E., Glazebrook, W. & Beckett, M., 2005. Reducing knife crime. *British Medical Journal*, 330(7502), pp.1221–1222.

- Hess, J.R. et al., 2008. The coagulopathy of trauma: a review of mechanisms. *The Journal of trauma*, 65(4), pp.748–54.
- Hillman, K., 2004. Colloid versus crystalloids in shock. *Indian Journal of Critical Care Medicine*, 8(1), p.16.
- Holcomb, J.B. et al., 2007. Damage control resuscitation: directly addressing the early coagulopathy of trauma. *The Journal of trauma*, 62(2), pp.307–10.
- Holder, Y. et al., 2001. *Injury Surveillance Guidelines*, Atlanta, USA.
- Hoste, E. a. et al., 2014. Four phases of intravenous fluid therapy: A conceptual model. *British Journal of Anaesthesia*, 113(5), pp.740–747.
- HPCSA, 2011. Health Professions Council of South Africa Professional Board for Emergency Care Capabilities of Emergency Care Providers. , (June), pp.2–4.
- HPCSA, 2003. *Intermediate Life Support Practitioner Protocols*, South Africa.
- Hussmann, B. et al., 2012. increased prehospital replacement volume lead to a poor clinical course and an increased mortality? A matched-pair analysis of 1896 patients of the Trauma Registry. *Injury*, 44(5), pp.611–617.
- Hußmann, B. et al., 2011. Influence of prehospital fluid resuscitation on patients with multiple injuries in hemorrhagic shock in patients from the DGU trauma registry. *Journal of emergencies, trauma, and shock*, 4(4), pp.465–71.
- ICECI Coordination and Maintenance Group, 2004. International Classification of External Causes of Injuries (ICECI) version 1.2. A Related Classification in the World Health Organization Family of International Classifications. , (July), pp.1–393.
- Inaba, K. et al., 2009. Mortality impact of hypothermia after cavitory explorations in trauma. *World journal of surgery*, 33(4), pp.864–869.
- Inan, M., 2012. Damage Control Surgery in the Light of a New Paradigm: Damage Control Resuscitation. *Balkan Medical Journal*, 29(2), pp.117–117.

Iqbal, M., Banerjee, S. & Spaight, A., 2009. Prehospital intravenous cannulation: reducing the risks and rate from inappropriate venous access by paramedics. *Emergency Medicine ...*, 26(6), pp.198–206.

Isenberg, D.L. & Bissell, R., 2005. Does advanced life support provide benefits to patients?: A literature review. *Prehospital and disaster medicine*, 20(4), pp.265–70.

James, M.F.M. et al., 2011. Resuscitation with hydroxyethyl starch improves renal function and lactate clearance in penetrating trauma in a randomized controlled study: the FIRST trial (Fluids in Resuscitation of Severe Trauma). *British journal of anaesthesia*, 107(5), pp.693–702.

Jayaraman, S., Sethi, D. & Wong, R., 2014. Advanced trauma life support training for ambulance crews. *Cochrane database of systematic reviews (Online)*, (8), pp.1–20.

John, J., 2015. Algorithms for managing the common trauma patient. *South African Medical Journal* 105.6, 105(6), pp.502–507.

Jørgensen, K., Larsen, O.B. & Berg, L., 2007. *NOMESCO Classification of External Causes of Injuries* 4th ed. B. Frimodt-Møller, ed., Copenhagen: Nordic Medico-Statistical Committee (NOMESCO).

Junger, W.G. et al., 2012. Resuscitation of traumatic hemorrhagic shock patients with hypertonic saline-without dextran-inhibits neutrophil and endothelial cell activation. *Shock (Augusta, Ga.)*, 38(4), pp.341–50.

Kacker, S. et al., 2016. Socioeconomic correlates of trauma: An analysis of emergency ward patients in Yaoundé, Cameroon. *Injury*, 47(3), pp.658–664.

Kalbfleish, J.D. & Prentice, R.L., 2002. *The Statistical Analysis of Failure Time Data*, John Wiley & Sons.

Kaminer, D. et al., 2008. Risk for post-traumatic stress disorder associated with different forms of interpersonal violence in South Africa. *Social Science and Medicine*, 67(10), pp.1589–1595.

Katzenellenbogen, J.M. & Hoffman, M., 2007. Key Concepts in Epidemiology. In G. E. R. K. J. M. A. K. S. S. Joubert & R. Ehrlich, eds. *Epidemiology: A Research manual for south africa*. Cape Town: Oxford University Press Southern Africa, p. 19.

Kelly, A. & Horsley, C., 2000. The limitations of evidence based practice for emergency medicine. *Hong Kong Journal of Emergency Medicine*, 7, pp.116–120.

Kirkpatrick, A.W. et al., 2008. Acute resuscitation of the unstable adult trauma patient: bedside diagnosis and therapy. *Trauma and Critical Care*, 51(1), pp.57–69.

Kong, V. et al., 2015. Retained weapon injuries: experience from a civilian metropolitan trauma service in South Africa. *European Journal of Trauma and Emergency Surgery*, 41(2), pp.161–166.

Kortbeek, J.B. et al., 2008. Advanced trauma life support, 8th edition, the evidence for change. *The Journal of trauma*, 64(6), pp.1638–50.

Kramer, S. & Ratele, K., 2012. Young Black Men's Risk to Firearm Homicide in Night Time Johannesburg, South Africa: a Retrospective Analysis based on the National Injury Mortality Surveillance System. *African Safety Promotion Journal*, 10(1), pp.16–28.

Krug, E. et al., 2002. *The world report on violence and health*,

Krug, E., Sharma, G. & Lozano, R., 2000. The Global Burden of Injuries. *American journal of public health*, 90(4), pp.523–526.

Kuhajda, I. et al., 2014. Penetrating trauma. *Journal of thoracic disease*, 6(Suppl 4), pp.S461-5.

Kurt, D., 2009. *Sharp Object Fatalities in East London: A Descriptive Study*.

Kutcher, M.E. et al., 2013. A paradigm shift in trauma resuscitation: evaluation of evolving massive transfusion practices. *JAMA surgery*, 148(9), pp.834–40.

Kuzma, K. et al., 2009. When are prehospital intravenous catheters used for treatment? *The Journal of emergency medicine*, 36(4), pp.357–62.

Kwan, I., Bunn, F. & Roberts, I., 2009. Timing and volume of fluid administration for patients with bleeding. *The Cochrane Library*, 1(3), pp.1–3.

Laing, G. et al., 2014. The design, construction and implementation of a computerised trauma registry in a developing South African metropolitan trauma service. *Injury*, 45(1), pp.3–8.

- Laing, G.L. et al., 2014. Understanding the Burden and Outcome of Trauma Care Drives a New Trauma Systems Model. *World journal of surgery*, 38(7), pp.1699–1706.
- Lakhal, K. et al., 2012. Noninvasive monitoring of blood pressure in the critically ill: Reliability according to the cuff site (arm, thigh, or ankle)*. *Critical Care Medicine*, 40(4), pp.1207–1213.
- Lefering, R., 2009. Development and validation of the Revised injury severity classification score for severely injured patients. *European Journal of Trauma and Emergency Surgery*, 35(5), pp.437–447.
- Lema, M.K. et al., 2011. Pattern and outcome of chest injuries at Bugando Medical Centre in Northwestern Tanzania. *Journal of Cardiothoracic Surgery*, 6(1), pp.2–7.
- Lerner, E.B. & Moscati, R.M., 2001. The golden hour: scientific fact or medical “urban legend”? *Academic emergency medicine: official journal of the Society for Academic Emergency Medicine*, 8(7), pp.758–760.
- Lewis, C. & Wood, D., 2015. Interpersonal violence as a major contributor towards the skewed burden of trauma in KwaZulu-Natal, South Africa. *South African Medical Journal*, 105(10), pp.827–830.
- Ley, E., Clond, M. & Srour, M., 2011. Emergency department crystalloid resuscitation of 1.5 L or more is associated with increased mortality in elderly and nonelderly trauma patients. *Journal of Trauma*, 70(2), pp.398–400.
- Li, T. et al., 2011. Ideal Permissive Hypotension to Resuscitate Uncontrolled Hemorrhagic Shock and the Tolerance Time in Rats. *Anesthesiology*, 114(1), pp.111–119.
- Liamis, G., Filippatos, T.D. & Elisaf, M.S., 2015. Correction of hypovolemia with crystalloid fluids: Individualizing infusion therapy. *Postgraduate Medicine*, 127(4), pp.405–412.
- Liberman, M., Mulder, D. & Sampalis, J., 2000. Advanced or basic life support for trauma: meta-analysis and critical review of the literature. *The Journal of trauma*, 49(October), pp.584–599.
- Lier, H. et al., 2008. Preconditions of hemostasis in trauma: a review. The influence of acidosis, hypocalcemia, anemia, and hypothermia on functional hemostasis in trauma. *The Journal of trauma*, 65(4), pp.951–960.

- Lobo, S.M. et al., 2006. Prospective, randomized trial comparing fluids and dobutamine optimization of oxygen delivery in high-risk surgical patients. *Critical care (London, England)*, 10(3), p.R72.
- Lockyer, A. et al., 2013. Patterns of injury in penetrating sharp trauma in a Provincial KwaZulu-Natal Hospital. *African Journal of Emergency Medicine*, 3(2), pp.67–70.
- Mabry, R. & McManus, J.G., 2008. Prehospital advances in the management of severe penetrating trauma. *Critical care medicine*, 36(7 Suppl), pp.S258-66.
- MacFarlane, C., Loggerenberg, C. & Kloeck, W., 2005. International EMS systems in South Africa: past, present, and future. *Resuscitation*, 64(2), pp.145–158.
- MacLeod, J. & Lynn, M., 2003. Early coagulopathy predicts mortality in trauma. *Journal of Trauma- ...*, 55(1), pp.39–44.
- Madan, A.K. et al., 2007. Unemployment rates and trauma admissions. *World journal of surgery*, 31(10), pp.1930–3.
- Maegele, M. et al., 2007. Early coagulopathy in multiple injury: an analysis from the German Trauma Registry on 8724 patients. *Injury*, 38(3), pp.298–304.
- Maki, D., Kluger, D. & Crnich, C., 2006. The risk of bloodstream infection in adults with different intravascular devices: a systematic review of 200 published prospective studies. *Mayo Clinic Proceedings*, 81(9), pp.1159–1171.
- Mandal, a K. & Oparah, S.S., 1989. Unusually low mortality of penetrating wounds of the chest. Twelve years' experience. *The Journal of thoracic and cardiovascular surgery*, 97(1), pp.119–25.
- Manring, M.M. et al., 2009. Treatment of war wounds: a historical review. *Clinical orthopaedics and related research*, 467(8), pp.2168–91.
- Manuel, M. et al., 2013. Renaissance of base deficit for the initial assessment of trauma patients: a base deficit-based classification for hypovolemic shock developed on data from 16,305 patients derived from the TraumaRegister DGU®. *Critical care (London, England)*, 17(2), p.R42.

- Martini, W.Z. et al., 2005. Independent contributions of hypothermia and acidosis to coagulopathy in swine. *The Journal of trauma*, 58(5), pp.1002–1009.
- Martini, W.Z., Cortez, D.S. & Dubick, M. a, 2013. Comparisons of normal saline and lactated Ringer's resuscitation on hemodynamics, metabolic responses, and coagulation in pigs after severe hemorrhagic shock. *Scandinavian journal of trauma, resuscitation and emergency medicine*, 21, p.86.
- Martini, W.Z. & Holcomb, J.B., 2007. Acidosis and coagulopathy: the differential effects on fibrinogen synthesis and breakdown in pigs. *Annals of surgery*, 246(5), pp.831–5.
- Mathews, S. et al., 2009. Alcohol use and its role in female homicides in the Western Cape, South Africa. *Journal of Studies on Alcohol and Drugs*, 70(3), pp.321–327.
- Mattes, R., 2006. How Does SA Compare? Experiences of crime and policing in an African context. *SA Crime Quarterly*, 18, pp.17–24.
- Matzopoulos, R. et al., 2006. Estimating the South African trauma caseload. *International Journal of Injury Control and Safety Promotion*, 13(1), pp.49–51.
- Matzopoulos, R. et al., 2015. Injury-related mortality in south africa: A retrospective descriptive study of postmortem investigations. *Bulletin of the World Health Organization*, 93(5), pp.303–313.
- Matzopoulos, R. et al., 2010. The Provincial Injury Mortality Surveillance System (PIMSS): a surveillance tool for the Western Cape. *Injury Prevention*, 16(Suppl 1), pp.47–49.
- Matzopoulos, R. & Niekerk, A. Van, 2007. *A Profile of Fatal Injuries in South Africa*,
- Mc Swain, N.E. et al., 2011. State of the art of fluid resuscitation 2010: prehospital and immediate transition to the hospital. *The Journal of trauma*, 70(5 Suppl), pp.S2–S10.
- McCoy, C. & Menchine, M., 2013. 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. *Annals of emergency medicine*, 31(2), pp.167–174.
- McDermid, R.C., 2014. Controversies in fluid therapy: Type, dose and toxicity. *World Journal of Critical Care Medicine*, 3(1), p.24.

- McKenzie, K. et al., 2012. Classifying external causes of injury: History, current approaches, and future directions. *Epidemiologic Reviews*, 34(1), pp.4–16.
- Medby, C., 2014. Is There a Place for Crystalloids and Colloids in Remote Damage Control Resuscitation? *Shock (Augusta, Ga.)*, 41(1), pp.47–50.
- Meel, B., 2003. Mortality of children in the Transkei region of South Africa. *The American Journal of Forensic Medicine and Pathology*, 24(2), pp.141–7.
- Meier, J., Henes, J. & Rosenberger, P., 2014. Bleeding and coagulopathies in critical care. *The New England journal of medicine*, 370(22), pp.2152–3.
- Mnguni, M.N., Muckart, D.J.J. & Madiba, T.E., 2012. Abdominal trauma in Durban, South Africa: Factors influencing outcome. *International Surgery*, 97(2), pp.161–168.
- Mock, C. & Cherian, M.N., 2008. The global burden of musculoskeletal injuries: challenges and solutions. *Clinical orthopaedics and related research*, 466(10), pp.2306–16.
- Mock, C., Pilcher, S. & Maier, R., 1994. Comparison of the costs of acute treatment for gunshot and stab wounds: further evidence of the need for firearms control. *Journal of Trauma*, 36(4), pp.516–522.
- Moeller, C. et al., 2016. How safe is gelatin? A systematic review and meta-analysis of gelatin containing plasma expanders versus crystalloids and albumin. *Journal of Critical Care*.
- Moore, D.C. et al., 2013. Gunshot victims at a major level I trauma center: A study of 343,866 emergency department visits. *Journal of Emergency Medicine*, 44(3), pp.585–591.
- Moore, K.E. & Murtaugh, R.J., 2001. Pathophysiologic characteristics of hypovolemic shock. *The Veterinary clinics of North America. Small animal practice*, 31(6), pp.1115–28.
- Morgan, T.J. & Venkatesh, B., 2003. Designing “balanced” crystalloids. *Critical care and resuscitation: journal of the Australasian Academy of Critical Care Medicine*, 5(4), pp.284–91.
- Morrison, C.A. et al., 2011. Hypotensive resuscitation strategy reduces transfusion requirements and severe postoperative coagulopathy in trauma patients with hemorrhagic

shock: preliminary results of a randomized controlled trial. *The Journal of trauma*, 70(3), pp.652–63.

MRC-UNISA, 2013. *Firearm related homicides in Gauteng*,

Muckart, D.J., 1991. Trauma-The Malignant Epidemic. *South African Medical Journal*, 79(2), pp.93–95.

Murray, C.J.L. & Lopez, a D., 1997. Alternative projections of mortality and disability by cause 1990- 2020: Global Burden of Disease Study. *Lancet*, 349(9064), pp.1498–1504.

Murugan, R. & Kellum, J.A., 2012. Fluid balance and outcome in acute kidney injury. *Critical Care Medicine*, 40(6), pp.1970–1972.

Mutschler, M. et al., 2014. Assessment of hypovolaemic shock at scene: is the PHTLS classification of hypovolaemic shock really valid? *Emergency medicine journal: EMJ*, 31(1), pp.35–40.

Mutschler, M. et al., 2013. The Shock Index revisited - a fast guide to transfusion requirement? A retrospective analysis on 21,853 patients derived from the TraumaRegister DGU®. *Critical care (London, England)*, 17(4), p.R172.

Mutschler, M., Nienaber, U. & Brockamp, T., 2013. A critical reappraisal of the ATLS classification of hypovolaemic shock: does it really reflect clinical reality? *Resuscitation*, 84(3), pp.309–313.

Myburgh, J. a & Mythen, M.G., 2013. Resuscitation fluids. *The New England journal of medicine*, 369(13), pp.1243–51.

Naidoo, N., Zalgoanker, M. & Christopher, L.D., 2014. Pre-hospital phlebotomy and point of care testing: Relevance and implications for professional emergency care practice. *Medical Technology SA*, 27(2), pp.40–45.

Napolitano, L.M., 2005. Resuscitation Endpoints in Trauma. *Transfusion Alternatives in Transfusion Medicine*, 6(4), pp.10–21.

National Center for Injury Prevention and Control & Control, P.C. for D., 2014. *Surveillance of Non-Fatal Injuries Treated In Emergency Departments : Instructions for Completing the Data Collection Form*,

- Newgard, C.D. et al., 2010. Emergency medical services intervals and survival in trauma: assessment of the “golden hour” in a North American prospective cohort. *Annals of emergency medicine*, 55(3), pp.235–246.
- Newgard, C.D. et al., 2015. Revisiting the “Golden Hour”: An Evaluation of Out-of-Hospital Time in Shock and Traumatic Brain Injury. *Annals of emergency medicine*, 66(1), p.30–41.e3.
- Nicol, A. et al., 2014. Trauma Surveillance in Cape Town, South Africa: An Analysis of 9236 Consecutive Trauma Center Admissions. *JAMA surgery*, 149(6), pp.549–556.
- Nina, D., 2000. Dirty Harry is Back: Vigilantism in South Africa - The (Re)Emergence of the “Good” and “Bad” Community. *African Security Review*, 9(1), pp.18–28.
- Nolan, J., 2001. Fluid resuscitation for the trauma patient. *Resuscitation*, 48(1), pp.57–69.
- Norberg, J. et al., 2009. The costs of a bullet – inpatient costs of firearm injuries in South Africa. *South African Medical Journal*, 99(6), pp.6–8.
- Norman, R. et al., 2006. *Revised Burden of Disease Estimates for the Comparative Risk Factor Assessment , South Africa 2000*,
- Norman, R., 2007. The high burden of injuries in South Africa. *Bulletin of the World Health Organization*, 85(9), pp.695–702.
- Norman, R. et al., 2007. The high burden of injuries in South Africa. *Bulletin of the World Health Organization*, 85(9), pp.695–702.
- O’Grady, N.P. et al., 2011. Guidelines for the prevention of intravascular catheter-related infections. *Clinical infectious diseases: an official publication of the Infectious Diseases Society of America*, 52(9), pp.e162-93.
- O’Hara, R. et al., 2015. A qualitative study of systemic influences on paramedic decision making: care transitions and patient safety. *Journal of health services research & policy*, 20(1), pp.45–53.
- Ohene-Yeboah, M. et al., 2010. Penetrating Abdominal Injuries in Adults Seen at Two Teaching Hospitals in Ghana. *Ghana medical journal*, 44(3), pp.103–8.

- Onat, S. et al., 2011. Urgent thoracotomy for penetrating chest trauma: Analysis of 158 patients of a single center. *Injury*, 42(9), pp.900–904.
- Orbegozo Cortes, D. et al., 2014. Colloids for fluid resuscitation: what is their role in patients with shock? *Minerva anestesiologica*, 80(8), pp.963–9.
- Ormstad, K. et al., 1986. Patterns in sharp force fatalities--a comprehensive forensic medical study. *Journal of forensic sciences*, 31(2), pp.529–542.
- Ottochian, M. et al., 2009. Does age matter? The relationship between age and mortality in penetrating trauma. *Injury*, 40(4), pp.354–7.
- Patterson, G., 2003. *Pearson's thoracic and esophageal surgery* 3rd ed., Philadelphia: Churchill Livingstone Elsevier.
- Peden, M. & Butchart, A., 1999. Trauma and injury. In N. Crisp & A. Ntuli, eds. *South African Health Review 1999*. Durban: Health Systems Trust, pp. 331–344.
- Peden, M., McGee, K. & Krug, E., 2002. *Injury: a leading cause of the global burden of disease* E. Krug, ed., Geneva: Geneva : World Health Organization.
- Perel, P. & Roberts, I., 2012. *Colloids versus crystalloids for fluid resuscitation in critically ill patients (Review)*,
- Perel, P., Roberts, I. and Ker, K., 2013. Colloids versus crystalloids for fluid resuscitation in critically ill patients (Review). *Cochrane Database Syst Review*, 2(2), pp.1–71.
- Perkins, J.G. & Beekley, A.C., 2012. Damage control resuscitation. In E. Savitsky et al., eds. *Combat Casualty Care: Lessons Learned from OEF and OIF*. Office of the Surgeon General, Department of the Army: Fort Detrick. Virginia: The Office of the Surgeon General Department of the Army, United States of America, p. 121–164.
- Phillips, D. et al., 2013. Crystalloids vs. colloids: KO at the twelfth round? *Critical care (London, England)*, 17(3), p.319.
- Poloujadoff, M.P. et al., 2006. Survival of severely shocked patients who present with absent radial pulse and unrecordable blood pressure in the pre-hospital phase. *Resuscitation*, 69(2), pp.185–189.

- Prottengeier, J. et al., 2015. The prehospital intravenous access assessment: a prospective study on intravenous access failure and access delay in prehospital emergency medicine. *European journal of emergency medicine: official journal of the European Society for Emergency Medicine*, nd(nd), p.nd.
- Red Cross Air Mercy Services, 2014. About Us - The SA Red Cross Air Mercy Service. Available at: <https://www.ams.org.za/about-us> [Accessed August 3, 2017].
- Reed, J. a et al., 2003. Rates of unemployment and penetrating trauma are correlated. *Southern medical journal*, 96(8), pp.772–4.
- Revell, M., Greaves, I. & Porter, K., 2003. Endpoints for fluid resuscitation in hemorrhagic shock. *The Journal of Trauma and Acute Care Surgery*, 54(5), p.63.
- Revell, M., Porter, K. & Greaves, I., 2002. Fluid resuscitation in prehospital trauma care: a consensus view. *Emergency Medicine Journal: EMJ*, 19(6), pp.494–8.
- Roche, A.M. & James, M.F.M., 2009. Colloids and crystalloids: does it matter to the kidney? *Current opinion in critical care*, 15(6), pp.520–4.
- Rogmans, W. et al., 1998. *Classification of External Causes of Injuries (ICECI) an international task force under the auspices of the WHO*,
- Rosenberg, M.L. et al., 2008. Interpersonal Violence. In and P. M. Dean T Jamison, Joel G Breman, Anthony R Measham, George Alleyne, Mariam Claeson, David B Evans, Prabhat Jha, Anne Mills, ed. *Disease Control Priorities in Developing Countries, 2nd edition*. New York: Oxford University Press, pp. 755–770.
- Rosenberg, M.L. & Mercy, J.A., 1991. Assaultive Violence. In M. L. Rosenberg & M. A. Fenley, eds. *Violence in America: A Public Health Approach*. Oxford University Press, pp. 14–50.
- Ross, S.W. et al., 2015. Impact of common crystalloid solutions on resuscitation markers following Class I hemorrhage A randomized control trial. *Journal of Trauma and Acute Care Surgery*, 79(5), pp.732–740.
- Ryynänen, O.-P. et al., 2010. Is advanced life support better than basic life support in prehospital care? A systematic review. *Scandinavian journal of trauma, resuscitation and emergency medicine*, 18(62), pp.2–14.

- Santibanez-Gallerani, A. et al., 2001. Improved survival with early fluid resuscitation following hemorrhagic shock. *World journal of surgery*, 25(5), pp.592–7.
- Santry, H.P. & Alam, H.B., 2010. Fluid resuscitation: past, present, and the future. *Shock (Augusta, Ga.)*, 33(3), pp.229–41.
- Sasser, S. et al., 2005a. *Prehospital trauma care systems*, Geneva, Switzerland.
- Sasser, S. et al., 2005b. *Prehospital Trauma Care Systems*, Geneva, Switzerland.
- Schreiber, M.A. et al., 2015. A controlled resuscitation strategy is feasible and safe in hypotensive trauma patients. *Journal of Trauma and Acute Care Surgery*, 78(4), pp.687–697.
- Schreiber, M. a, 2005. Coagulopathy in the trauma patient. *Current opinion in critical care*, 11(6), pp.590–7.
- Schreiber, M. a., 2004. Damage control surgery. *Critical Care Clinics*, 20(1), pp.101–118.
- Schuurman, N. et al., 2015. Intentional injury and violence in Cape Town, South Africa: An epidemiological analysis of trauma admissions data. *Global Health Action*, 8(1), pp.1–9.
- Seamon, M., Doane, S. & Gaughan, J., 2013. Prehospital interventions for penetrating trauma victims: A prospective comparison between Advanced Life Support and Basic Life Support. *Injury*, 44(5), pp.634–638.
- Seamon, M.J.M. et al., 2007. Prehospital procedures before emergency department thoracotomy: “scoop and run” saves lives. *The Journal of trauma*, 63(1), pp.113–20.
- Seedat, M. et al., 2009. Violence and injuries in South Africa: prioritising an agenda for prevention. *Lancet*, 374(9694), pp.1011–22.
- Segui-Gomez, M. & MacKenzie, E.J., 2003. Measuring the public health impact of injuries. *Epidemiologic Reviews*, 25(October), pp.3–19.
- Shafi, S., Elliott, A.C. & Gentilello, L., 2005. Is hypothermia simply a marker of shock and injury severity or an independent risk factor for mortality in trauma patients? Analysis of a large national trauma registry. *The Journal of trauma*, 59(5), pp.1081–1085.
- Sharma, B.R., 2003. Clinical forensic medicine - Management of crime victims from trauma to trial. *Journal of Clinical Forensic Medicine*, 10(4), pp.267–273.

Shere-Wolfe, R.F., Galvagno, S.M. & Grissom, T.E., 2012. Critical care considerations in the management of the trauma patient following initial resuscitation. *Scandinavian journal of trauma, resuscitation and emergency medicine*, 20, p.68.

Shoemaker, W., Appel, P. & Kram, H. et al, 1988. Prospective trial of supranormal values of survivors as therapeutic goals in high-risk surgical patients. *Chest*, 94, pp.1176–1186.

Siau, R.T.K. et al., 2013. Management of penetrating neck injuries at a London trauma centre. *European archives of oto-rhino-laryngology: official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS): affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery*, 270(7), pp.2123–8.

Simpson, P. et al., 2012. Beliefs and expectations of paramedics towards evidence-based practice and research. *International Journal Evidence Based Healthcare*, 10(3), pp.197–203.

Singh, J., Kagee, A. & Swartz, L., 2007. Research Ethics, Human Rights and Community Participation. In G. E. R. K. J. M. A. K. S. S. Joubert & R. Ehrlich, eds. *Epidemiology: A Research manual for south africa*. Cape Town: Oxford University Press Southern Africa, pp. 31–36.

Sison, C.P. & Glaz, J., 1995. Proportions Simultaneous Confidence Intervals and Sample Size Determination for Multinomial Proportions. *Journal of the American Statistical Association*, 90(429), pp.366–369.

Smith, M. & Marais, S., 2011. A Profile of fatal injury risk for older adults in urban South Africa. *Injury Prevention*, 16(Supplement 1), pp.A208–A209.

Smith, R.M. & Conn, A.K.T., 2009. Prehospital Care – Scoop and run or stay and play? *Injury*, 40(4), pp.S23-6.

Smorenberg, A., Ince, C. & Groeneveld, A.J., 2013. Dose and type of crystalloid fluid therapy in adult hospitalized patients. *Perioperative medicine (London, England)*, 2(1), p.17.

South African Medical Research Council, 2012. The National Injury Mortality Surveillance System (NIMSS). *Safety and Peace Promotion Research Unit*. Available at: <http://www.mrc.ac.za/crime/nimms.htm>.

- South African Medical Research Council & University of South Africa Institute for Social & Health Sciences, 2010. *A Profile of Fatal injuries in Mpumalanga in 2009: The 3rd Annual Report of the National Injury Mortality Surveillance System*,
- Spahn, D. et al., 2007. Management of bleeding following major trauma: a European guideline. *Critical care (London, England)*, 11(1), pp.9–22.
- Stern, S.A., Dronen, S.C. & Wang, X., 1995. Multiple Resuscitation Regimens in a Near-fatal Porcine Aortic Injury Hemorrhage Model. *Academic Emergency Medicine*, 2(2), pp.89–97.
- Swaroop, M. et al., 2013. Pre-hospital transport times and survival for Hypotensive patients with penetrating thoracic trauma. *Journal of Emergencies, Trauma, and Shock*, 6(1), pp.16–20.
- Swaroop, M. et al., 2013a. Pre-hospital transport times and survival for Hypotensive patients with penetrating thoracic trauma. *Journal of emergencies, trauma, and shock*, 6(1), pp.16–20.
- Swaroop, M. et al., 2013b. Pre-hospital transport times and survival for Hypotensive patients with penetrating thoracic trauma. *Journal of emergencies, trauma, and shock*, 6(1), pp.16–20.
- Swart, L., Seedat, M. & Vellema, J., 2008. *Adolescent homicide victimisation in Johannesburg, South Africa*,
- Tariq, U.M. et al., 2011. Changes in the patterns, presentation and management of penetrating chest trauma patients at a level II trauma centre in southern Pakistan over the last two decades. *Interactive cardiovascular and thoracic surgery*, 12(1), pp.24–7.
- Team, R., 2018. R: A language and environment for statistical computing. Available at: <https://www.r-project.org>. [Accessed May 20, 2018].
- Thorsen, K. & Ringdal, K., 2011. Clinical and cellular effects of hypothermia, acidosis and coagulopathy in major injury. *British Journal of ...*, 98(7), pp.894–907.
- Tingne, C.V. et al., 2014. Quantitative analysis of injury characteristics in victims of interpersonal violence: An emergency department perspective. *Journal of Forensic and Legal Medicine*, 26, pp.19–23.

- Turner, J. et al., 2000. A randomised controlled trial of prehospital intravenous fluid. *Health technology assessment (Winchester, England)*, 4(31), pp.1–57.
- Ummenhofer, W. & Scheidegger, D., 2002. Role of the physician in prehospital management of trauma: European perspective. *Current opinion in critical care*, 8(6), pp.559–565.
- Vandromme, M. & Griffin, R., 2010. Lactate is a better predictor than systolic blood pressure for determining blood requirement and mortality: could prehospital measures improve trauma triage? *Journal of the American ...*, 210(5), pp.861–867.
- Vandromme, M.J. et al., 2010. Lactate is a better predictor than systolic blood pressure for determining blood requirement and mortality: could prehospital measures improve trauma triage? *Journal of the American College of Surgeons*, 210(5), pp.861–7, 867–9.
- Velasco, I.T. et al., 1989. Hypertonic and hyperoncotic resuscitation from severe hemorrhagic shock in dogs: a comparative study. *Critical care medicine*, 17(3), pp.261–4.
- Wang, C.-H. et al., 2014. Liberal versus restricted fluid resuscitation strategies in trauma patients: a systematic review and meta-analysis of randomized controlled trials and observational studies. *Critical care medicine*, 42(4), pp.954–61.
- Watson, D.L.B. et al., 2013. Evidence from the scene: paramedic perspective on involvement in out-of-hospital research. *Annals of emergency medicine*, 60(5), pp.641–650.
- Watts, D.D. et al., 1998. Hypothermic Coagulopathy in Trauma : Effect of Varying Levels of Hypothermia on Enzyme Speed , Platelet Function , and Fibrinolytic Activity. *Journal of Trauma-Injury Infection & Critical Care*, 44(5), pp.846–854.
- West, N. & Dawes, R., 2015. Trauma resuscitation and the damage control approach. *Surgery*, 33(9), pp.430–436.
- WHO, 2013. WHO Model List of Essential Medicines for Children. , p.3.
- Wohltmann, C.D. et al., 2001. A multicenter evaluation of whether gender dimorphism affects survival after trauma. *American journal of surgery*, 181(4), pp.297–300.
- Woolf, S.H. et al., 1999. Clinical guidelines: potential benefits, limitations, and harms of clinical guidelines. *British Medical Journal*, 318(7182), pp.527–30.

World Bank, 2013. *World Bank List of Economies*,

World Health Organization (WHO), 2014. *Injuries and Violence: the facts*,

World Health Organization (WHO), 2010. *Injuries and Violence: The Facts*, Geneva.

World Health Organization (WHO), 2015. *Preventing youth violence: an overview of the evidence*,

World Health Organization (WHO), 1996. "Violence: a public health priority". *WHO global consultation on violence and health*. Geneva,

Yaghoubian, A. et al., 2007. Reanalysis of prehospital intravenous fluid administration in patients with penetrating truncal injury and field hypotension. *The American surgeon*, 73(10), pp.1027–30.

Yazici, Ü. et al., 2012. Penetrating chest injuries: analysis of 99 cases. *Turkish Journal of Medical Sciences*, 42(6), pp.1082–1085.

Young, J.B. et al., 2014. Saline versus Plasma-Lyte A in initial resuscitation of trauma patients: a randomized trial. *Annals of Surgery*, 259(2), pp.255–62.

Zarychanski, R. et al., 2013. Association of hydroxyethyl starch administration with mortality and acute kidney injury in critically ill patients requiring volume resuscitation: a systematic review and meta-analysis. *JAMA: the journal of the American Medical Association*, 309(7), pp.678–88.

ANNEXURES

Annexure A: Ethics Clearance Certificate by Faculty of Health and Wellness Sciences Research Ethics Committee- Cape Peninsula University of Technology



HEALTH AND WELLNESS SCIENCES RESEARCH ETHICS COMMITTEE (HW-REC)

Registration Number NHREC: REC- 230408-014

P.O. Box 1906 • Bellville 7535 South Africa
Symphony Road Bellville 7535
•Tel: +27 21 959 6352 • Fax +27 21 953 8490
Email: danielso@cput.ac.za

27 June 2013
CPUT/HW-REC 2013/H28

Faculty of Health and Wellness Sciences
Emergency Medical Sciences Department

Dear Mr Mustafa Zalgaonker

APPLICATION TO THE HW-REC FOR ETHICAL CLEARANCE

Approval was granted on 13 June 2013 by the Health and Wellness Sciences-REC to Mustafa Zalgaonker for your application. This approval is for research activities related to a Master of Emergency Medical Care at this institution.

Title: Intravenous fluid management practices for penetrating trauma in the pre-hospital environment of the Western Cape Metropole.

Internal Supervisor: Dr YG Aboua
Internal Co-supervisor: Mr L Christopher

Comment:

Approval will not extend beyond 27 June 2014. An extension should be applied for 6 weeks before this expiry date should data collection and use/analysis of data, information and/or samples for this study continue beyond this date.

Note:

The investigator(s) should understand the conditions under which they are authorized to carry out this study and they should be compliant to these conditions. **It is required that the investigator(s) complete an annual progress report that should be submitted to the HW-REC in December of that particular year, for the HW-REC to be kept informed of the progress and of any problems you may encounter.**

Kind Regards



Zuleika Nortjé
CHAIRPERSON – ETHICS RESEARCH COMMITTEE
FACULTY OF HEALTH AND WELLNESS SCIENCES

Annexure B: Research Approval Letter by Western Cape Health Research Committee



STRATEGY & HEALTH SUPPORT

Health.Research@westerncape.gov.za
tel: +27 21 483 6857; fax: +27 21 483 9895
5th Floor, Norton Rose House, 8 Riebeeck Street, Cape Town, 8001
www.capegateway.gov.za

REFERENCE: RP 145 /2013
ENQUIRIES: Ms Charlene Roderick

70 First Avenue
Grassy Park
7941

For attention: **Mustafa Zalgaonker**

Re: Intravenous Fluid Management Practices for Penetrating Trauma in the Pre-Hospital Environment of the Western Cape Metropole

Thank you for submitting your proposal to undertake the above-mentioned study. We are pleased to inform you that the department has granted you approval for your research.

Please contact the following people to assist you with any further enquiries in accessing the following sites:

Western Cape Ambulance Service Shaheem de Vries Contact No. 021 948 9903

Kindly ensure that the following are adhered to:

1. Arrangements can be made with managers, providing that normal activities at requested facilities are not interrupted.
2. Researchers, in accessing provincial health facilities, are expressing consent to provide the department with an electronic copy of the final report within six months of completion of research. This can be submitted to the provincial Research Co-ordinator (Health.Research@westerncape.gov.za).
3. The reference number above should be quoted in all future correspondence.

We look forward to hearing from you.

Yours sincerely

A handwritten signature in black ink, appearing to read "DR NT Naledi".

DR NT Naledi
DIRECTOR: HEALTH IMPACT ASSESSMENT
DATE: 04/12/13
CC S KARIEM

CHIEF DIRECTOR: GENERAL SPECIALIST & EMS

**Annexure C: Research Approval Letter by Director Western Cape Health Department
Health- Emergency Medical Services**



DIRECTORATE: EMERGENCY MEDICAL SERVICES

ENQUIRIES: Dr Shaheem de Vries

shaheem.devries@pgwc.gov.za

+27 21 932 1367

ATTENTION: MR MUSTAFA ZALGAONKER

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

Dear Mr Zalgaonker,

Your letter on the above matter refers.

Thank you for the request to conduct research within the Western Cape Government Emergency Medical Services. Your proposal has been evaluated by the Emergency Medicine Divisional Research Committee and has been recommended for approval by this office.

I am therefore pleased to inform you that such approval is hereby granted.

I wish you well in your endeavor and trust that you will keep this office and its department informed of your findings when these become available.

Yours sincerely

A handwritten signature in purple ink, appearing to read "Shaheem de Vries".

Dr Shaheem de Vries
Head: Emergency Medical Services
Western Cape Government Health

Date: 8th January 2014



WCG Health: EMS - Emergency Communications Centre

Private Bag X24; Bellville (+27) 21 932 1367 (+27) 21 931 8490

www.capegateway.gov.za

Annexure D: Emergency Care Provider Information Sheet

Intravenous Fluid Management Practices for Penetrating Trauma in the Pre-Hospital Environment of the Western Cape Metropole

January 2014

Dear Colleagues,

My name is Mustafa Zalgaonker. I am completing my Master's Degree in Emergency Medical Care at Cape Peninsula University of Technology. One of the academic requirements for this course is to conduct a research project. My research project is looking at the fluid management practices for penetrating trauma in the pre-hospital environment. The research question is: *What the fluid management practices are, for penetrating trauma in the pre-hospital environment of the Western Cape Metropole?*

Ethical clearance has been obtained by the Cape Peninsula University of Technology and the Western Cape Provincial Health Research Committee has also approved this study.

What is the purpose of this study?

The aim of the study is to determine fluid management practices for penetrating trauma in the pre-hospital environment of the Metropole Western Cape, as evidence has shown that inappropriate fluid resuscitation may worsen injury and can be detrimental to a patient's survival.

What do we expect from you if you agree to participate?

If you agree to participate in this study, you would be required to complete a questionnaire related to fluid management after treating a patient that has sustained a penetrating injury. One sheet should be completed for every patient. The sheet has similar information as the patient report form.

Will my confidentiality be guaranteed?

Confidentiality and anonymity will be maintained as your name will not be written on the data collection sheet. The outcome of this study will not influence your work performance.

How would you know if we are eligible to participate in this study?

In order to participate you have to meet the following criteria:

1. Be a registered **Paramedic** (Advance Life Support- Critical Care Assistant, National Diploma, Emergency Care Technician or **ETech/** Bachelors Emergency Care) OR **Intermediate Life Support** (AEA) with any amount of experience
2. Give informed consent to participate (agreeing to participate) in the study.

What is the study duration?

The duration of the study will be three (3) months. The preliminary dates are mid-January 2014 to 30 April 2014.

What are the benefits and risks in my participation?

There are no physical risks that you may experience. If you agree to participate you are only required to complete a data collection sheet and place the sheet in box at your base once completed.

The benefits of participating in this study are not aimed at benefiting the individual. Rather, it is aimed at collectively benefiting the profession of emergency pre-hospital emergency care. Thus, the results of this study may enhance other discussions and alterations to the current practice.

Your participation will be **highly appreciated**, however, it is completely voluntary and you may withdraw from the study at any time. We humbly request your participation in our study.

For any inquiries or further information before, after or during the study, you are welcome to contact me or the Department of Emergency Medical Sciences (EMS) at Cape Peninsula University of Technology as seen below:

Mustafa Zalgaonker (Primary Investigator):

0765078366 (muszal01@hotmail.com)

Dr. YG Aboua (Department of Biomedical Sciences Cape Peninsula University of Technology and Supervisor for this study): 021 959 6983 (AbouaY@cput.ac.za)

Mr L. Christopher (HOD of Department Emergency Medical Sciences and Co-Supervisor): 021 953 8408 (lloyd@cput.ac.za)

Yours Sincerely



M. Zalgaonker

Annexure E: Emergency Care Provider Consent Form

CONSENT FORM

I.....(your full name).....(SA ID number), hereby agree to participate in the above Fluid Management and Penetrating injury study by M. Zalgaonker during February 2014- April 2014.

1. I understand that my **personal information on this sheet** as well as **the data collection sheets that I complete** will not be divulged to anyone, including the managers or other staff members of this or any other organisation.
2. I understand that my **individual data collection sheets** will also be **anonymously** used in the analysis of data.
3. I understand that I can withdraw the study at any point (by providing written notification to researchers) without disclosing a reason to anyone.
4. I agree that I am physically and emotionally capable of completing the data collection sheet after managing patients that have sustained penetrating traumatic injuries.
5. I understand that I will not use this study as a means of interference towards my ethical duties as well as operational duties as a pre-hospital emergency care provider.

<i>Please Mark with an X where appropriate</i>		<i>Participant number (for office use ONLY)</i>		
Name and Surname				
Ambulance Base	Northern Division	Southern Division	Western Division	Eastern Division
Signature				
Date	DD: MM: 2013			

Annexure F: Participant Data Collection Tool

Intravenous Fluid Management Practices for Penetrating Trauma in the Pre-Hospital Environment of the Western Cape Metropole

Sheet no:....

Instructions: 1. Please see reverse of this sheet to see if patient meets criteria for this study (inclusion criteria).

2. Please complete and mark with an X where appropriate and once complete place in the box at the base. Many Thanks

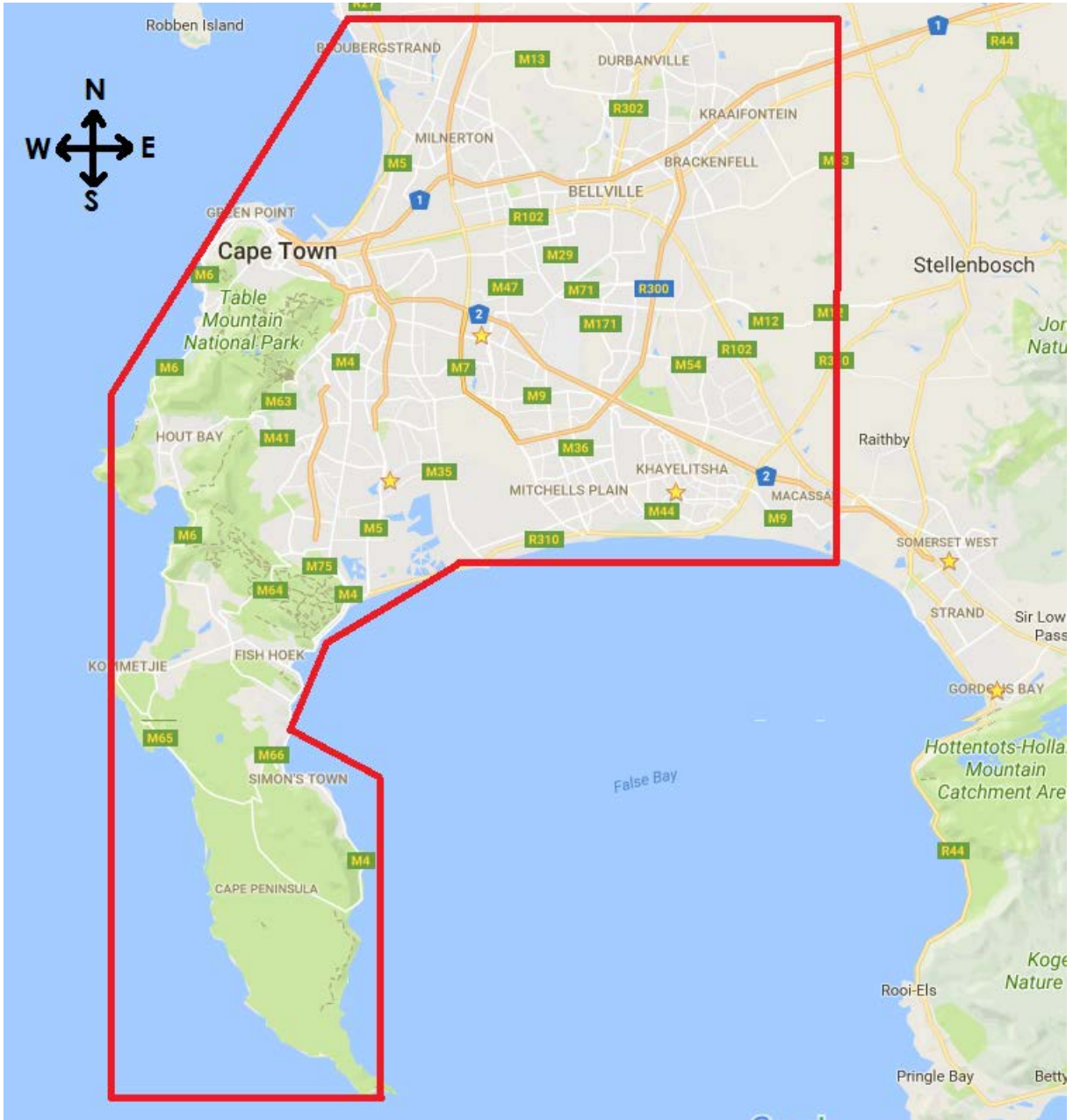
1. Patient Demographics				
Patient Age	Years			
Gender	Male	Female		
Weapon	Knife	Bullet		
	Other (specify):			
Senior Crew Qualification	ILS	ALS		
Incident Time	HH:MM			
Dispat Time	HH:MM			
Scene Time	HH:MM			
Hosp. Time	HH:MM			
Health Facility Patient transported				
2. Clinical Management				
Penetrating Injury Location (Can be anterior or posterior)	Chest	Abdomen		
	Pelvis	Upp. limbs		
	Neck	Low. Limbs		
	Face	Head		
Total No. Wounds	1 5	2 6	3 7	4 7+
2.1 Upon Scene Arrival Vitals				
Systolic BP mmHg	<50	51-60	61-70	71-80
	81-90	91-100	101-110	111-120
	121-130	131-140	141-150	>150
Clinical Management Cont.				
Diastolic BP mmHg	<20	21-30	31-40	41-50
	51-60	61-70	71-80	> 80
Heart rate BPM	<60	61-70	71-80	81-90
	91-100	101-110	111-120	121-130
	131-140	141-150	>150	
Cap. Refill Time(sec)	<1	1-2	3-4	> 5
Skin Temp.	Cold	Cool		Warm
Level of <u>Consc.</u>	Alert	Voice	Pain	Unresponsive
2.2 Upon Hosp. Arrival Vitals				
Systolic BP mmHg	<50	51-60	61-70	71-80
	81-90	91-100	101-110	111-120
	121-130	131-140	141-150	>150
Diastolic BP mmHg	<20	21-30	31-40	41-50
	51-60	61-70	71-80	> 80
Heart rate BPM	<60	61-70	71-80	81-90
	91-100	101-110	111-120	121-130
	131-140	141-150	>150	
Cap. Refill Time (sec)	<1	1-2	3-4	> 5
Skin Temp.	Cold	Cool		Warm
Level of <u>Consc.</u>	Alert	Voice	Pain	Unresponsive
3. Fluid Management				
Fluid Type(s)	Saline (0.9%)	Ringers Lac.		
	Other (Specify name):			
Total Volume Administered	<250ml	250- 500ml		
	500ml -1000ml	1000-1500ml		
Method of Fluid Administration	1500ml +			
	Bolus(es)			
No. IV attempts	Infusion (Specify rate):			
	1	2	3	4
IV No. Catheters and Size	5	6	7	7+
	IV 1	14G 20G	16G 22G	18G 24G
Admin Set type	IV 2	14G 20G	16G 22G	18G 24G
	IV 3	14G 20G	16G 22G	18G 24G
Time Period Fluid Administered	60dropper		20 Dropper	
	10Dropper		Other:	
Time Period Fluid Administered	10min		10-20min	
	20-30min		30min+	

1

Primary Researcher M. [Zalgaonker 0765078366 muszal01@hotmail.com](mailto:zalgaonker.0765078366@muszal01@hotmail.com)

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Annexure G: Cape Metropole Delineation



Annexure H: Cape Geographical Location of Healthcare Facilities and Ambulance Bases (Google Maps 2017)

