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FACTORS AFFECTING TRAUMA OUTCOMES AND MORTALITY:

A COMPARISON OF AN ESTABLISHED LEVEL ONE TRAUMA UNIT AND A SECONDARY HOSPITAL IN SOUTH AFRICA

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CHAPTER 1

INTRODUCTION

Trauma is a disease process that is intimately related to man's interaction with other people and the environment. Trauma is the leading cause of non-natural death and a major cause of permanent disability and the economically active population group is most affected, thus increasing the real cost of injury to society (*Trunkey et al. 2008*).

There is no doubt that trauma is an end-product of multiple complex interactions between education levels, unemployment, poverty, alcohol and drug abuse, poor law enforcement, societal norms and multiple other factors.

This study was based on two similar studies conducted by American trauma surgeons. The American studies compared the mortality rates in rural regional hospitals in Mexico and Ghana to mortality rates in a Level 1 Trauma Unit in Seattle, USA (*Mock et al. 1993, Arreola-Risa et al. 1995*). They also looked specifically at what factors influenced the outcomes in all three of these facilities. Interestingly, there was no statistically significant difference in the mortality rates at the regional hospitals compared with the Level 1 Facility (*Mock et al. 1993, Arreola-Risa et al. 1995*). The study identified pre-hospital time and time in casualty as the major contributors to the probability of survival. These are factors that have been similarly identified in the South African trauma system as leading causes of increased mortality (*Murray et al. 1997*).

This author noted that the study took two very different socioeconomic environments (rural, developing countries vs urban first world) and compared their resources. This researcher wanted to see if the same outcomes would be reflected, if the two facilities compared, were in the same country, with patients from similar socioeconomic environments. The difference between the two facilities was that one had a Level 1 equivalent **Trauma Centre** and the other did not. As will be seen in the discussion, the demographic of the two populations and their severity of trauma was similar. The study was initiated as a result of the researcher's increased awareness of the difference in mortality between severely injured trauma patients treated in a particular regional facility (Facility B) as compared to a Level 1 equivalent Trauma Centre (Facility A) where the researcher had recently worked. There was a significant difference in trauma resuscitation protocols at the regional facility which in some cases deviated from the Advanced Trauma Life Support (ATLS) guidelines sanctioned by The American College of Surgeons. The study aims to prove that the mortality rates of trauma patients in a Level 1 equivalent Trauma Centre are significantly lower than those in a Regional Facility without a dedicated Trauma Centre. Secondly, it aimed to identify potentially reversible factors that could reduce trauma mortality.

A Level 1 Trauma Centre is a regional resource trauma centre, usually a tertiary care facility central to the trauma care system. Ultimately, it should be accessible to all patients who require the resources of a Level 1 centre. It must be capable of providing leadership and total care for every aspect of injury, from prevention through rehabilitation, and have 24-hour availability of all major specialities. In its central role, the Level 1 centre must have adequate depth of resources (*Celso et al. 2006*).

A tertiary trauma centre has a regional and supra-regional responsibility for service, teaching, outreach and research. The facilities equate with a South African (and USA) Level 1 trauma centre (*Hardcastle et al. 2011*).

A secondary level trauma centre also has a regional responsibility for patient care, teaching, outreach, but not for research. These facilities equate with a South African (and USA) Level 2 Trauma Centre (*Hardcastle et al. 2011*).

Both facilities are supported by specialist services (surgery, orthopaedics and anaesthetics), emergency departments, intensive care facilities and theatres, all operating on a full-time basis.

While tertiary units are supervised by Trauma Surgeons or Trauma Surgeons in training, secondary hospitals are supported by specialist surgeons. All South African surgeons undergo extensive training in Trauma Surgery and Intensive Care. For the two facilities studied, surgeons would have rotated through trauma units and/or intensive care units for at least two years of a total of six years post-graduate training. All entrants for post-graduate surgical training are required to have qualified in Advanced Trauma Life Support® prior to entering a training programme.

1.1 Professional Significance of the Problem

The knowledge gained from this study may pave the way for cost-effective interventions that will improve the standard of trauma care in South Africa. It will place an emphasis on the importance of proper training in trauma resuscitation, the value of trauma-data registries for future research and audit, and the need for the creation of effective trauma systems and management.

Trauma is a preventable disease. It consumes resources that could be better allocated. It targets the young and the economically productive. It leaves behind those populations that are unable to care for themselves, particularly children and the elderly. This adds to the economic burden in South Africa (*Celso et al. 2006, Gross et al. 1999*).

Great advances have been made in the treatment of trauma with the establishment, firstly in Birmingham in the UK and later in the USA, of so-called 'Trauma Centres'. South Africa followed this trend by establishing major trauma services at Johannesburg, Groote Schuur, Tygerberg, Pelonomi and Inkosi Albert Luthuli Central Hospitals (*Hardcastle et al. 2011*).

Initially the trauma system consisted only of "centres of excellence in a sea of indifference" (*Hardcastle et al. 2011*). However, it was soon apparent that including the entire spectrum of caregivers resulted in better outcomes and led to the surgeon-led trauma systems typical of those utilised in the United States *(Moore et al. 2010, O'Keefe et al. 1999*). This study investigated the need for skilled trauma care providers, not only in the large tertiary facilities, but also in the smaller, outlying, regional hospitals. Trauma systems, where the services and facilities outside the major trauma centres were included to provide optimal care and referral of the appropriate patient to the appropriate higher level of care facility, have improved outcomes (*Sampalis et al. 1999, Mann et al. 2001, Callese et al. 2015).*

Government investment in better health care provision can be facilitated by showing how cost-effective strategies can reduce the economic burden that trauma places on the country. A study such as this should empower professionals to take responsibility for their own conduct and growth and it enables patients to demand a better standard of trauma care. It challenges health care professionals to audit their service provision and, by so doing, improve on the level of care.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In their study ‘The Global Burden of Disease’ (1990) Lopez and Murray (*Murray et al. 1997*) gave projections for both mortality and burden of disease by cause for 2002, 2010 and 2020. The problem with their projection was that they underestimated the contribution that certain diseases would have on mortality and morbidity (e.g. the spread of Human Immunodeficiency Virus (HIV)). The subsequent study published by Mathers et al. in 2002 (*Mathers et al. 2002*), used three scenarios to project expected trends, this included baseline, optimistic and pessimistic projections, taking into account the role of economic and social development. According to the study by Mathers et al, the proportion of mortality related to non-communicable disease was set to rise from 59% in 2002 to 69% in 2030. In the baseline projection, road traffic accidents became the fourth leading cause of burden of disease worldwide. In the optimistic projection they become the third leading cause and in the baseline projection, HIV became the leading cause in low and middle income populations.

In South Africa, trauma, like HIV, has become an epidemic (*Bradshaw et al. 1996*). It is one of the biggest consumers of resources, particularly amongst young breadwinners (*Celso et al. 2006; Gross et al. 1999*), although very little of the health care budget, in any country, is actually spent on research in this field (*Gross et al. 1999; Rainier et al. 2003*). In Africa, in general, there are very few studies looking at how trauma affects mortality as a whole (*Murray et al. 1997)* or where it ranks. Trauma is the second leading cause of mortality and morbidity in Africa (*Bradshaw et al. 1996).* In a study done in KwaZulu-Natal (*Hardcastle et al. 2013*), data obtained from caseloads extending from March to September 2010 was used to assess the trauma burden in that particular province. Based on their results, they predicted that the national trauma burden in the public sector was in the range of 750 000 cases per year. This places an emphasis on the need for cost-effective trauma care in South Africa. In the Bulletin of The World Health Organization published in 2007, Norman et al. showed that age- standardized mortality rates in South Africa were seven times greater than the international rate. Their data also indicated that road traffic accidents in South Africa are double that of our international counterparts (Norman et al. 2007).

Injury accounts for the highest daily percentage of hospital bed occupancy in most countries, including first world nations like the United States of America (*Murray et al. 1997*). Despite the World Health Organization's (WHO) Decade for Action for Road Safety (2010-2020) (*WHO 2010*), South Africa ranked as the worst out of 36 in a global road safety report published by the International Transport Forum (ITF). Road fatalities per 100 000 inhabitants were at 27.6 deaths in 2011 – a shocking statistic when compared to developed countries like North America with 10.4 or Australia with 5.6. Developing countries included in the report did not exceed South Africa's road death toll. Both Argentina and Colombia reached around 12, while Malaysia came off second worst at 23.8 deaths per 100 000.

The report also estimated the economic cost of South Africa's road crashes to be R307 billion each year – more than Transnet's budget to fund its ambitious seven-year infrastructure build programme (*WHO 2010).*

According to Hardcastle, (*Hardcastle et al. 2011)* existing trauma services are delivered in a postcode lottery: where you live determines your chance of timely, appropriate, high-quality trauma care. The only sensible health service response is through the development of an integrated trauma system (*Sampalis et al. 1999, Mann et al. 2001*). A trauma system involves the interaction of pre-hospital care, emergency centre care and definitive care (including prevention and rehabilitative services), providing an organised approach to acutely injured patients within a defined geographical area, from primary care to advanced care (*Goosen et al; Sampalis et al).*

2.2 Trauma Factors Affecting Mortality

This study focused on trauma and factors affecting mortality. After examining relevant literature and from empirical analysis, the following areas were identified:

1. Injury prevention
2. The implementation of trauma systems
3. The presence of dedicated trauma centres
4. Trauma teams
5. Trauma registries
6. Advanced trauma life support (ATLS) training
7. The level of experience of treating doctors

8. Time (transport, resuscitation and definitive care)
9. Adequate management of the physiological response to trauma
10. Presence of closed intensive care units (ICU) with protocols

2.2.1 Injury Prevention

Basic interventional strategies have been identified to reduce vehicular trauma mortality (e.g. headlights on, controlled speed, the use of dedicated walkways, helmets, alcohol intake) *(Robertson et al. 1983; Walker et al. 1985; Thompson 1996, Traffic safety facts 1995, Child passenger restraint use 1989-1990*). The problem is that despite these strategies being logical, the trauma population on the whole chooses to reject them (*Esposito et al. 1995, WHO 2010*). People are not compliant with active trauma prevention strategies. The preventive strategies most effective are those that occur spontaneously (passive) (*Robertson et al. 1983).* Studies show that wearing a helmet whilst cycling reduces injury (*Thompson et al. 1996),* 'kiddie-locks' on car doors and child-proof caps on medication are more effective than a parent remembering to lock the door or put the tablets on a higher shelf. Injury prevention strategies generally consist of a combination of passive and active strategies. It would, however, seem that the passive strategies are the most effective because of compliance. For example, well maintained roads have a greater effect on reducing mortality than improved safety precautions taken by the driver (*Robertson et al. 1983, WHO 1984).*

Alcohol remains a significant factor in trauma. Between 1983 and 1993 there was a significant reduction in the quantity of alcohol-related mortalities in the

United States. This was attributed to harsher penalties for inebriated drivers and social conscience groups such as Mothers against Drunk Driving (*Child passenger restraint use and motor vehicle mortalities, 1989-90*). Up to 41% of fatal road traffic accidents worldwide are alcohol-related.

Studies that look at the rate of preventable mortality and inappropriate care allow us to evaluate areas where earlier intervention in the management of the trauma patient may have made a difference in outcome. Esposito et al. (*1995)* conducted a retrospective case review from October 1990 to September 1991. 13% of deaths in this review were preventable. Most of the errors in management occurred in casualty, most were due to poor decision making by a member of the resuscitation team. It would seem that education and training in the protocols pertaining to emergency management would be one of the simplest and most cost-effective areas for reducing trauma mortality.

Prevention of trauma and improved pre-hospital care are the two most cost-effective areas for decreasing mortality (*Wu et al. 1990, WHO 1984).* William Haddon looked at injury from a very different perspective from the classical model of disease causation which looks at “agent, host, and environment” (*WHO 2010, Peek-Asa et al. 2003*). In short he viewed injury as a disease. Individuals have control over the natural history of an injury. They can prevent it (seatbelt), they can limit the damage (antiseptics on wounds, prophylactic antibiotics) they can make changes to the environment (**traffic** lights rather than 4-way stops at intersections). Seatbelts were only introduced in 1968, but a retrospective review of the data shows a predicted 45% reduction in mortality when they were utilised. The 70% reduction in child mortality when ‘baby seats’ are used is self-evident (*Child passenger restraint use and motor vehicle mortalities 1989-1990).*

2.2.2 The Implementation of Trauma Systems

A 'trauma system' is defined as "a system of care consisting of health care personnel and resources organised to deliver the right patient to the right (appropriately trained) doctor (facility) in the right time frame . It consists of the processes of prevention, access to care, pre-hospital care, care in the emergency room, definitive care, recovery and rehabilitation, and continuous quality improvement." (*Goosen et al, Hardcastle et al. 2011, Celso et al. 2006*)

The essence of a trauma care system is to transfer the injured from the scene to the nearest, most appropriate facility, if necessary bypassing facilities that could not provide definitive care at an appropriate level (inclusive system). Such bypass improves survival by up to 25% (*Mackenzie E, NEJM 2006, Hardcastle et al. 2013*) in comparison to an exclusive system, whereby the injured are transferred stepwise from the lowest level to the required level of care, irrespective of needs. In South Africa, far too many emergency medical systems are still stuck in an exclusive system.

Historically, The Committee on Trauma was formed by the American College of Surgeons in 1922; they recognised that there was a need for a systematic approach to trauma management. In 1966 a report entitled 'Accidental Death and Disability - The Neglected Disease of Modern Society' was published in the United States (*National Research Council 1966).* This document resulted in a paradigm shift in the national management of trauma. In 1973 the EMS System

Act identified trauma systems as being essential to the implementation of EMS management (*America Trauma Society*)**.**

Even during the Second World War (WWII), triage systems set up within the military forces moved patients through increasing tiers of a trauma system that led to reduced mortality (*American Trauma Society*).

It was the lessons learned from conflicts in Vietnam and Korea (*Hoff et al. 2004*, *De Bakey 1996*) that helped mould the civilian trauma systems implemented in the United States today (*Eastridge et al. 2006).* The armed forces currently involved in the Iraqi conflict base their trauma management on a similar system (*Eastridge et al. 2006*). Interestingly, they have also audited the management and outcomes of trauma system function in what they call the “theatre of war”. They identified areas such as the transfer of patients to the correct level of facility from point of injury, trauma management guidelines and the establishment of trauma data bases as areas requiring improvement. Continuous audit allows the opportunity for improvement in trauma system development and management. These guidelines in turn impact on civilian trauma management (*Eastridge et al. 2006, Trunkey et al. 2002, Tracy et al 2005, De Bakey et al. 1996).*

Dr B. Celso’s review of the literature showed that the implementation of trauma systems reduced mortality by 15%. Fourteen published articles of significance were reviewed and eight of the fourteen showed an improvement in survival secondary to the implementation of trauma systems (*Celso et al. 2006).* It also showed the continuous need for audit in terms of trauma system management.

The greatest opposition to trauma system implementation has been political will and budgetary constraints (*Gross et al. 1999, American Trauma Society*). The mortally wounded and those with minor injuries do not benefit from trauma systems (*Col. Rosenveld et al. 2002, Celso et al. 2006*). It is the intermediate group, who account for the largest proportion of the trauma burden, that stand to benefit (*Sampalis et al. 1999, Mann et al. 2001*).

One of the greatest concerns is that the development of an effective trauma system could take more than a decade to mature (*Mann et al. 2001*). A Canadian study showed that it took over 10 years to build an effective trauma system (*Moore et al. 2010*).

In an editorial comment in a leading trauma and critical care journal, The Journal of Trauma and Critical care (J Trauma), an important observation was made by the authors (*Celso et al. 2006*). They concluded that the necessity of trauma systems should no longer be debated, that rather this should be the standard of care. However, it is necessary to keep looking at ways to evaluate the performance of trauma systems and improve the quality of care provision. It is particularly necessary to look at the individual components of a trauma system, such as pre-hospital care and emergency room management, and see how these areas can be improved upon. By identifying areas where trauma care can be improved, it is possible to find cost-effective solutions for facilities with limited resources.

In Dr T Hardcastle's article in the South African Medical Journal, entitled "The 11 'Ps' of an Afrocentric trauma system for South Africa - Time for action!", the need for trauma interventions to be both cost-effective and for the components of trauma systems to be patient centred, is highlighted *(Hardcastle et al. 2011)*. In this article he lists the requirements to fulfil these endpoints as the 11 Ps.

1. **Political will**. If the government does not support the creation of effective trauma systems and supply the resources necessary (human and monetary), the system is less effective. It is necessary for the government to acknowledge that the cost of putting such interventions into play is more than compensated by the cost incurred by lost life productivity.
2. **Public Pressure**. South Africans need to realise that they are entitled to a better health system and that as such they need to demand this from their government.
3. **Participation** from multiple sectors. In order for any system to be effective it requires 'buy-in' from a number of parties. In the trauma setting this includes not only the Health Department but also the Police, Department of Transport and the Local Government for each province.
4. **Professional compliance** refers to dedication to not only supplying the best medical treatment, but also interrogating training and advancement in each practitioner's field. In addition, looking at treatment needed and not only the funds that the patient can supply for such treatment.
5. **Provincial restructuring** requires a refinement of transfer protocols and the tier system for referral of major trauma to the right institution (Level 1, Level 2) in order to reduce morbidity and mortality associated with time.
6. **Private sector participation**. In the private sector, specialists are not required to accept patients who are unable to pay for their services. By establishing a national fund, it may be possible to invoke the unconditional

management of trauma patients in the acute setting regardless of the facility where they may present for management.

7. **Professional society accreditation** such as that required for Level 1 status should only be provided by departments like the Trauma Society of South Africa (TSSA) to ensure quality of care.
8. **Proper data management**. South Africa has a wealth of trauma information. The creation of trauma registries as initiated by a number of prominent trauma facilities assists not only with research, but also with the essential audit of care provision. This allows improvement in the quality of trauma care.
9. **Purpose-driven governance**. Studies of pre- and post-trauma system implementation have shown an improvement in trauma care and as such a reduction in the cost associated with trauma.
10. **Post-trauma rehabilitation and support services**. Rehabilitation services are sorely needed in South Africa. Patients who require rehabilitation to return to productivity occupy much-needed beds for the acutely ill and injured (waste of resources).The cost of such centre implementation will be offset by the increased return to productivity of this demographic.
11. **Practice the theory in a financially sound model**. This means South Africa has to build on the experience of international trauma systems while being realistic about the resources available and the need for cost-effective solutions. As such, trauma systems in our country need to be modelled on our own resources.

As in the Mock et al. and Arreola-Risa studies, resources such as dedicated Burns Units and Computed Tomography (CT) scanners are expensive modalities that may diagnose and extend life, but aren't always economically viable.

2.2.3 The Presence of Dedicated Trauma Centres

There are numerous studies that show that treatment of Priority One (P1) severely injured patients in a dedicated unit improves mortality (*Celso et al. 2006, Sampalis et al. 1999, Cheddie et al. 2010, Nirula et al. 2010*). The studies also emphasise the need for delivery of these patients directly to a trauma unit rather than inter-hospital transfer, which delays definitive management (*Nirula et al. 2010*). The creation of trauma centres seems to have assisted in the reduction in mortality in many countries. The study by Mackenzie et al. (*Mackenzie et al. 2006)* looked at the mortality outcomes between hospitals having Level 1 Trauma Units and those without. The basis of their hypothesis was that patients treated in trauma units were less likely to die from their injuries. This was proved by the study outcomes.

2.2.4 Trauma Teams

In the two studies conducted by Driscoll and Vincent, published in 'Injury' in 1992 (*Driscoll et al. 1992*), it was found that the introduction of trauma teams reduced the time taken to resuscitate patients The studies were both based on the concept that 'horizontal organization' *(Lanzetta in 1981, Trauma.Org*) is a more effective way of conducting resuscitation. By definition, this means that each individual involved in resuscitation is allocated a task which is applied simultaneously in a co-ordinated fashion. Alternatively, a vertical structure means that tasks are performed by one medical professional in succession and are therefore more time consuming. Both studies positively support the institution of resuscitation teams within the concept of horizontal organization, and provide significant evidence for their instigation.

Driscoll and Vincent (*Driscoll et al. 1992*) looked at the effect of time taken to resuscitate a patient on the eventual outcome of the resuscitation. There was significant variation in the time taken to conduct various parts of the resuscitation process, particularly time taken to conduct lifesaving procedures. This impacted negatively on outcome. The study emphasized that experience and training may be more important than the seniority of the resuscitator, and that an increase in team numbers does not necessarily make a team more efficient. The findings by Driscoll and Vincent are supported by a South African study. It was a retrospective study that looked at pedestrian vehicle accident admissions in two separate three month periods. The time frame extended from July to September 1993 and 1994 respectively. The data showed that smaller trauma teams, made up of experienced individuals who were used to working with each other, obtained the same outcomes as larger trauma teams *(Deo et al. 1997*).

2.2.5 Trauma Registries

All records within a patient's files are medico-legal documents. Good records allow continuity of care between different health care providers. Often patients are unsure what treatment they have received, and when the 'chain of evidence' is lost it makes it difficult to administer optimal care. Research that allows the evolution of medical management is impeded. The observation made by the investigator during the study was that nursing notes were an invaluable source of continuous information, whilst documentation by doctors was either illegible or minimal. One of the limitations to research is that documentation, in the form of patient files and other demographic data, is either illegible or lost (*Steeves et al. 1965*). Despite the institution of trauma registries, these registries often lack data that is imperative to the academic process. This then impacts on the conclusions that can be drawn from the research.

Audit and accountability

In the United States, large corporations have created consortiums like the Leapfrog Group. They demand that health care facilities document their commitment to high quality care. This group was developed because of a report by the American Institute of Medicine that stated that there was an inexcusable amount of preventable errors being made in American hospitals. The corporations represented by the Leapfrog Group wanted to ensure that their employees were receiving an acceptable standard of medical care. The Leapfrog Group has become a watchdog for medical service provision in America. It collaborates with both medical aid providers and government health organisations, including those responsible for hospital accreditation. The American health care system looks at incentivising to obtain the best level of care. In South Africa, because of poor documentation and the loss of information (old filing systems), it is not always possible to audit patient management.

2.2.6 Advanced Trauma Life Support® (ATLS) Training

The Advance Trauma Life Support (ATLS) Course of the Committee on Trauma of the American College of Surgeons Committee on Trauma provides evidence-based training to:

- Assess a patient's condition rapidly and accurately;
- Resuscitate and stabilize patients according to priority;
- Determine whether the patient's needs exceed a facility's resources and/or doctors' capabilities;
- Arrange appropriately for a patient's inter-hospital or intra-hospital transfer (what, who, when, and how);
- Ensure that optimal care is provided and that the level of care does not deteriorate at any point during the evaluation, resuscitation, or transfer process.

The course is now taught in more than 60 countries, and has been taught in South Africa since 1992. To date, more than 14 000 South African doctors have been trained in ATLS. All South African medical undergraduates receive ATLS-based training as part of their surgical training. All emergency medical practitioners and nurses receive ATLS-based training for the trauma components of their courses

Ali et al. conducted a study *(Ali et al. 1993*) that examined the effect that Advanced Trauma Life Support (ATLS) training had on reducing mortality in a developing nation. It was one of the few studies that looked at how effectively a 'first world' training programme, like ATLS, could be implemented in a developing country. Analysis revealed that for all ISS (Injury Severity Scores) groups, the mortality rate was significantly lower post ATLS training. In both the pre-trained and post-trained ATLS groups, the observed mortalities were still higher than those calculated based on the Major Trauma Outcome Study (MTOS) conducted in the United Kingdom (*Yates et al. 1992*). In all areas, from emergency room to Intensive Care Unit (ICU), there was a significant reduction in mortality after the introduction of ATLS training.

Training is an intrinsic part of the development of an optimally functioning trauma system. Continued medical education is essential for the improvement of the system as a whole, and the skill set of the medical trainee as an individual (*Steeves et al. 1965).* Unfortunately, more advanced training also means more expenditure. In a resource-constrained environment it becomes necessary to examine what level of training will best benefit the trauma population most cost-effectively. This is particularly applicable to the South

African environment where health care budgets are over-extended. Messick et al. investigated the effect of Advanced Life Support (ALS) training on mortality. The study particularly focused on the training of pre-hospital practitioners and whether or not there should be more medical intervention in the field, colloquially known as ‘scoop and run’ or ‘stay and play’. The authors’ hypothesis was that ALS reduced mortality. In the study the following factors were identified as being predictors of mortality: rural demographic, race (other than white), unemployment and the availability of ALS training versus basic life support. Articles have been published on the effect that ALS training has on the management of medical emergencies (*Messick et al. 1992*). There is no research confirming or negating its effect on trauma outcomes (*Szczygiel et al. 1981).*

There are some specialists who believe that Emergency Medical Services (EMS) should act merely as transporters to hospital with very basic pre-hospital intervention e.g. spine board and oxygen. They support the ‘scoop and run’ concept and also believe that too much pre-hospital intervention can be dangerous and even contribute to mortality due to a delay in transport or the EMS practitioner performing procedures for which they are not adequately trained (*Gervin et al; Smith et al. 1985; Trunkey et al. 1984*). The counter-argument is that ALS training can save lives, particularly in areas with extended transport time due to distance from facilities such as rural environments. Trunkey et al. *(Trunkey et al. 1984)* believe that time is of the essence and therefore the job of EMS personnel is to get the trauma victim to hospital expeditiously (*Smith et al. 1985*). Lewis believes that interventions in the pre-hospital setting do not favour better outcomes (*Lewis et al. 1983*).

There are many arguments and much literature to support both views. The study by Messick et al. (*1992)* showed higher per capita trauma mortality rates in rural areas. They concluded that it may very well be that ALS is best applied in a rural setting where there are long transport times. However, with regard to urban and rural trauma, time is of the essence and limiting pre-hospital time is also important. A balance must be obtained between 'scoop and run' and 'stay and play' principles. The interventions most likely to reduce mortality e.g. a definitive airway, were not factored into the study.

Major R King (*Maj. King et al. 2006*), a medical doctor involved in the training of Forward Surgical Teams (FSTs) in America, looked at the value of simulated training exercises (STX). These were aimed at both training the teams that would act as the first point of stabilisation and assessing how they performed when placed in a high-stress environment. FSTs include multidisciplinary teams of doctors, nurses and technicians who deliver point-of-care treatment in military mass casualties (generally at the war front). They are highly trained and highly specialised units and they are required to stabilise patients before transfer to more definitive care. The STXs are not equivalent to civilian training simulations because they add obstacles like increased casualty times and limited resources while frustrating administration in an austere environment. Interestingly, even among these highly trained professionals, the stress placed upon them by simulated high-stress environments resulted in many breaches in ATLS management and triage. This resulted in a 20% increase in preventable deaths.

The value gained from these exercises by both the participants and the instructors was that it not only investigated ways to improve management, but also future training. The protocols for trauma response are easily learned by rote, it is very different when applying them in high stress environments where one's own fear mingles with that of colleagues and patients.

Careful documentation was another area noted by King et al. as requiring improvement. One of the criticisms that observers had of the FSTs was of insufficient communication (triage to theatre, theatre to ICU) resulting in a waste of resources or delay in the treatment of the severely injured. There was also a waste of skill utilisation, with more than one individual performing the same task.

In short, the horizontal organisation model was not applied. Identified deficiencies indicate ways to improve care. It is interesting that even the most highly trained trauma teams felt overwhelmed by the mass casualty simulations. It also proves that adherence to specific trauma protocols such as ATLS assists in taking away some of the chaos in trauma management.

These simulations allow the trainee to not only experience a realistic trauma environment, but to do so in a place where there is no loss of human life and qualified instructors are present to contribute to learning. This has become a training standard in the United States. In South Africa, only laparoscopic training applies simulation. There would be benefit in developing a simulated training programme for South African registrars, given the South African Trauma burden.

Marshall et al. (*Marshall et al. 2001*) studied the effect of ATLS training and the use of Human Patient Simulators (HPSs) on the development of trauma management skills in interns. The interns were initially given two scenarios with the HPS. Thereafter, they underwent ATLS training followed by further simulation training and then completed a questionnaire on whether the training had enhanced their confidence in trauma management. The interns showed a great improvement in both their critical decision making and their confidence levels. The conclusion of the study was that HPS used with ATLS training improves the development of trauma management skills and also enhances confidence in those undertaking the course (*Marshall et al. 2001*). Being able to make mistakes in a simulated environment allows the trainee to experience reality without the associated risk of morbidity or mortality. Not all studies lead to the same conclusion as that conducted by Marshall (*Jayaraman et al. 2014).* In a Cochrane Review conducted by Jayaraman and colleagues, they looked for randomised controlled trials that compared the impact of ATLS trained versus non-ATLS trained staff on injury mortality and morbidity. None of the studies met the review inclusion criteria. The author's conclusion was that there were no studies that could conclusively prove that ATLS impacted on the outcomes from injury. They did, however, conclude that improved educational initiatives could impact on care because of increased knowledge.

2.2.7 The Level of Experience of Treating Doctors

Trauma care has always been approached as efficiently as a military operation (*Hoff et al. 2004, American Trauma Society*). Most of the specialist trauma surgeons have a military background (*Hoff et al. 2004, American Trauma Society*). O'Keefe (*1999)* supported the widely held perception that increased experience in trauma management reduced mortality. The reality of the South African situation is that although Level 1 Trauma Centres with extremely experienced staff exist, the majority of trauma patients find their way to facilities with junior and inexperienced staff in regional facilities or clinics (a postal code lottery) (*Driscoll et al. 1992, Hardcastle et al. 2011).*

The Royal College of Surgeons of England found an association between increased mortality and emergency management by inexperienced doctors (*Royal College of Surgeons, England, 1988).* A study by Wyatt et al. found a positive correlation between the seniority of the doctor and a decrease in mortality. This was particularly true when a consultant was present at the beginning of resuscitation (*Wyatt et al. 1999*). South African doctors are faced with a greater trauma burden than their international colleagues and therefore are often required to be better equipped to handle these emergencies. The reality is that junior doctors are often the first point of contact for the severely injured. There is often no experienced doctor on site.

2.2.8 Time

In both the Sampalis and Hardcastle studies (*Sampalis et al. 1999, Hardcastle et al. 2013*), time to intervention and the distribution of resources was a significant contributor to successful care provision. In both the wars in Korea and Vietnam, time was not wasted. The severely injured were directly transferred to 'acute care military field hospitals'. These were capable of administering the initial care necessary to manage life-threatening injuries (*American Trauma Society*). This provided support for the direct transfer of the severely injured to trauma units.

S Cheddie et al. *(2011*) looked at trauma patients admitted to the Inkosi Albert Luthuli Hospital. The article showed that there was a 50% reduction in mortality for equivalent ISS for those who survived more than twelve hours in both the transfer and direct admission groups. The ISS for the non-survivors in the direct group was higher than for those in the transfer group.

Time in casualty

Surgeons with a military background are often Trauma specialists. However, there are still significant differences between the management of civilian trauma and the management of trauma in military conflict. Trauma surgeons have always spoken about the tri-modal death distribution in trauma victims. Those who die within minutes or at the scene, those who die within hours of admission (e.g. severe head injuries) and those who take time to succumb, usually because of sepsis and multi-organ failure. Interestingly, this does not apply in military conflict (*Lieut. Col. Parker et al).* Soldiers are either so severely injured that they die at point of injury, or their injuries are mild enough for them to survive. Tri-modal distribution is rare. As with civilian trauma, the main causes of death are head injuries and hypovolemic shock. The only intervention that has definitively been shown to improve mortality rate is the rapid sequence intubation and definitive airway control en route to definitive care (*Lieut. Col. Parker et al*.). This applies particularly in patients with severe head injuries. The ‘golden hour’ does not apply to military conflict. The question asked was whether having a surgeon literally on the battlefield had a role to play in reducing mortality. The conclusion was that it did not. In the UK, the military uses a system called ‘1:2:4 hour rule’. This constitutes ATLS-based resuscitation in hour 1, life-saving surgery within hour 2 and definitive surgery within hour 4.

This is in stark contrast to the reality of South African urban trauma systems, where patients may wait hours for definitive care. In World War I (WWI), Casualty Clearing Stations (CCS) were introduced to shorten time to surgery. To do so, hospitals were placed in close proximity to the trenches. The evacuation of the severely injured could take more than 20 hours.

In 1918 the first Field Surgical Pocket Book was published. It stated that “the rule at the front is to get the wounded man to the casualty clearing station as soon as possible”. Even as far back as WWI, casualty times were recognised as a predictor of mortality. In World War II and the Korean conflict, the time to get the injured to surgery had been reduced to 10 hours.

Melson and Volkers (*Melson et al. 1975*) noted that the use of helicopters and the proximity of ambulances saved valuable time. Two main factors assisted in reducing mortality; good resuscitation and reduced casualty times.

In military conflict there needs to be a balance between the rapid evacuation of severely injured patients and the use of resources on unsalvageable patients. They refer to a ‘timeline’. If it is too short, resources may be wasted on patients who will succumb to their injuries regardless. If it is too long, those with survivable injuries will suffer. The conclusion of the review was that the severely injured should be in the operating theatre within a maximum of two to three hours. At four hours the salvageable severely injured will begin to die.

Is it possible that this could also relate to severely injured patients in the civilian setting in South Africa, particularly because of limited resources in government facilities? A severe head injury that is rapidly transported to a trauma unit may occupy a precious ventilator, only to be deemed ‘not a candidate for intervention’.

There is a great deal of debate as to what constitutes withdrawal of care and whether or not this can be referred to as ‘passive euthanasia’. Dr Muckart, in his commentary in the SAMJ, compares two very common patient scenarios (*Muckart et al. 2014).* A patient with a severe head injury in a rural setting dies before he reaches hospital. A patient with a severe head injury, with direct access to definitive care, becomes brain dead despite undergoing craniotomy. In the case of the second patient, care is deemed non-beneficial and further care is withdrawn. In both cases the outcome is the same. In both cases the causation of death is the severe head injury, however certain legal entities will argue that in the second case, causation is the withdrawal of care. Whilst this debate is being had, a valuable resource is occupied pending outcome.

2.2.9 Adequate Management of the Physiological Response to Trauma

Hypotension

Pre-hospital hypotension in itself can predict mortality even if the blood pressure upon arrival in casualty is normal. Franklin et al. found a 12% early mortality rate and a 32% late mortality rate, which was believed to be related to systolic blood pressures (SBP) of less than 90mmHg in the pre-hospital setting (*Chan et al. 1997, Franklin et al. 2000*). Zenati et al. (*2002)* studied the duration of hypotension and its outcomes including mortality. They researched patients admitted to the ICU from 1999 to 2000. The lowest SBP and the duration of all episodes where the blood pressure fell below 90mmHg were recorded. Those having an episode with a systolic blood pressure of less than 90mmHg during the first 24 hours of admission had an increase in mortality, even if the duration of hypotension was less than a few minutes (*Sauiaia et al. 1994, Cryer et al. 1999, Chan et al. 1997, Franklin et al. 2000).*

Temperature

In an article published by Jurkovich et al. in J Trauma in 1987 (*Jurkovich et al. 1987*), the mortality rates for patients with varying degrees of hypothermia were compared to those who were warmed (temperature greater than thirty-four degrees celsius). The purpose of their study was to see if there was a direct relationship between hypothermia and mortality rate when looking at patients with a variety of Injury Severity Scores (ISS). Warming techniques included standard emergency room resuscitation such as Baerhuggers and warmed fluids. Regardless of the degree of hypothermia, mortality rates for the hypothermic patients were always higher than those of warmed patients. The investigators also noted higher degrees of hypothermia and an increase in mortality rate for those patients with higher ISS and greater fluid requirements. The investigators posed the question as to whether mortality was higher because of the severity of the patients' injuries (only patients with an ISS≥ 25 were included) or because of the hypothermia.

A study done by Eastridge et al. (*Eastridge et al. 2006*) studied the way in which physiological criteria could predict the best resource allocation and patient mortality in a combat setting. In the combat setting, resources are limited so it is necessary to assign those resources to the demographic that will benefit the most. It was a retrospective study looking at the Joint Trauma Theatre registries for all casualties admitted during the period January to July 2004. Amongst the physiological criteria examined were blood pressure, temperature, pulse rate, base deficit and haematocrit. There was a significant association between hypothermia (temperature less than thirty-four degrees celsius) and the subsequent need for surgery. Hypothermia also predicted an increase in mortality rate. Total blood transfusion requirements correlated with the temperature, base deficit, haematocrit and ISS. The conclusion of the researcher was that physiological criteria could be used to predict not only mortality but also the degree of resource utilisation.

In an article published by Luna et al. in The Journal of Trauma and Critical Care, the researcher looked at the frequency of hypothermia in severely injured patients and how it affected the outcome. The study was a prospective study conducted at a Level 1 trauma centre. They defined normothermia as a temperature above thirty-six degrees celsius, mild hypothermia as a temperature between thirty-four and thirty-six degrees celsius and severe hypothermia as a temperature less than thirty-four degrees celsius. They looked at variables such as age, blood requirements, alcohol use, injury severity and time (Emergency Room, Operating Room or pre-hospital) and how they related to hypothermia and therefore mortality. The investigators concluded that age, blood requirements and injury severity correlated with increased risk and incidence of hypothermia. Interestingly, pre-hospital time was also mentioned as a factor that could greatly impact on both temperature maintenance and resuscitation and therefore on mortality. Again, investigators emphasised the necessity for aggressive resuscitation in the management of hypothermic patients.

Conversely, Shafi et al. hypothesised that hypothermia actually had a positive effect on mortality in trauma patients (*Shafi et al. 2005*). They supported this hypothesis by citing the positive effect that hypothermia has on limiting oxygen consumption in cardiac, neurosurgical and transplant patients during surgery (*Bernard et al. 2002, Nozari et al. 2004*). One study in particular looked at the role of hypothermia in preventing brain damage in dogs that were in hypovolemic shock (*Nozari et al. 2004*). The Shafi study included all patients registered in a national trauma database from 1994-2002. The study compared the mortality rate of normothermic patients (temperature above thirty-five degrees celsius) and hypothermic patients (temperature below thirty-five degrees celsius). The patients enrolled were stratified by their ISS and whether or not they were in shock (taken as a BP<90 mmHg). Even when confounding variables such as age, gender, GCS and ISS were accounted for, it was found that hypothermia was an independent risk factor for mortality. The investigators concluded that hypothermia alone, without taking into account the severity of the patients' injuries and other physiological predictors of mortality, was a predictor of mortality. It implied that every effort should be taken to prevent hypothermia in the trauma patient.

Multiple studies have shown that there is a direct relationship between temperature and the need for increasing blood product and fluid requirements during resuscitation (*Bernabei et al. 1992, Gintellelo et al. 1997*). Hypothermic patients have a higher probability of becoming coagulopathic *(Wolberg et al. 2004).*

Heart rate variability

In a study by *Ryan et al*. 2011, heart rate variability was seen as a possible predictor of mortality in the pre-hospital setting in mass casualty trauma. In their study they used pre-hospital echocardiograms (ECG) to evaluate heart rate variability. Physiological predictors like haemoglobin, blood pressure, Glasgow Coma Score (GCS) and heart rate may initially be compensated for in the pre-hospital setting and therefore not help with the rapid triage of severely injured patients.

Heart rate variability shows the response of the autonomic nervous system to trauma. The autonomic nervous system is responsible for the maintenance of total peripheral resistance and, as such, vasoconstriction is necessary in the maintenance of blood pressure. The control for all other physiological variables indicated that lower pulse pressures and increased parasympathetic versus sympathetic activity separated those who died from those who survived. This was seen to be a possible pre-hospital triage tool that could assist in predicting mortality and thus allow those patients that would survive to be prioritised.

Trauma scoring systems

- **Trauma Score/Revised Trauma Score**

The Revised Trauma Score (RTS) was developed by Champion et al. in 1989. It is a scoring system combining the first systolic blood pressure (SBP) in casualty, respiratory rate (RR) and the Glasgow Coma Scale (GCS). Teasdale and Jennett published the Glasgow Coma Scale (GCS) in The Lancet in 1974 as an aid in the clinical assessment of post-traumatic unconsciousness. It was devised as a formal scheme to overcome the ambiguities that arose when information about comatose patients was presented and groups of patients compared. The GCS has three components: eye (E), verbal (V) and motor (M) response to external stimuli. The best or highest responses are recorded. The scale consisted of 14 points, but was later adapted to 15, with the division of the motor category 'flexion to pain' into two further categories. Each category is given a value of 0-4 (http://www.coma.ulg.ac.be/). The GCS is given the heaviest rating followed by the SBP and then the RR. It is seen as an early predictor of mortality in the casualty ***(****Champion et al. 2011*). In a study by Cancio et al, the RTS was compared with the new Field Triage Score (FTS). They specifically wanted to ascertain their efficacy as predictors of mortality and the need for massive transfusion (defined as more than 10 units of blood). 690 cases were chosen, although only 536 had complete data. The conclusion to the study was that the RTS was the best predictor of mortality in the combat setting.

- **Injury Severity Score**

The Injury Severity Score (ISS) is an anatomical scoring system that provides an overall score for patients with multiple injuries. Each injury is assigned an Abbreviated Injury Scale (AIS) score and is allocated to one of six body regions (head, face, chest, abdomen, extremities (including pelvis), external). Only the highest AIS score in each body region is used. The three most severely injured body regions have their score squared and added together to produce the ISS score (*Baker S. P. et al. 1974*).

- **Trauma Score - Injury Severity Score : TRISS**

TRISS determines the probability of survival (Ps) of a patient from the ISS and RTS using the following formulae:

$$Ps = 1 / (1 + e^{-b})$$

Where 'b' is calculated from:

$$b = b0 + b1(RTS) + b2(ISS) + b3(AgeIndex)$$

The coefficients b0 - b3 are derived from multiple regression analysis of the Major Trauma Outcome Study (MTOS) database. Age Index is 0 if the patient is below 54 years of age or 1 if 55 years and over. b0 to b3 are coefficients that are different for blunt and penetrating trauma. If the patient is less than 15, the blunt coefficients are used regardless of mechanism.

http://www.trauma.org/archive/scores/triss.html accessed 10/10/14

In effect, TRISS methodology can be used to calculate the probability of survival for an injured patient compared to a large database, in this case the USA Major Trauma Outcome Study, which contains data on well over 1 million patients.

2.2.10 Presence of Closed Intensive Care Units (ICU) with Protocols

In the United States, beds in the ICU account for up to 10% of total hospital bed occupancy. At many hospitals it can cost up to $3 000 per day to take care of a patient admitted to the ICU. The American model uses a concept referred to as 'value-based purchasing (VBP)'. One of the purposes of this concept is to allow the general public access to the best outcomes of their medical system. It offers incentives to those facilities that meet certain performance standards. This could be considered in the South African setting. The model has shown that dedicated care, given by multidisciplinary teams consisting of highly trained intensivists, reduces mortality rates in the ICU. An intensivist is not the primary physician involved in the care of a patient, but once the patient is admitted to a 'closed' ICU, the responsibility for care is transferred to the intensivist and the primary care physician consults. In an 'open' ICU, the specialist responsible for the care of a patient admits the patient to an ICU and is responsible for the care of that patient whilst they are in ICU (*BMC surgery 2011, Gutsche et al. 2007).*

In a Dutch study conducted in 2011 (*BMC surgery*), the effects of conversion from a closed to an open system on outcomes in one of their medical centres were evaluated. The patients of interest were all high-risk surgical patients. The outcomes measured were mortality, morbidity, the length of the entire hospital admission and the length of ICU admission. To evaluate the open format they looked at admissions from 1996 to 1998. In 2000 the closed system was adopted and so they evaluated admissions from 2003 to 2005. Mortality and morbidity decreased significantly when the closed format was adopted. The length of ICU admission, surprisingly, increased in the new format. The conclusion was that for high-risk surgical patients, closed ICUs were considered the standard of care.

In a systematic review published in JAMA in 2002 (*Pronovost et al. 2002*) the effect of physician staffing on outcomes such as the length of hospital stay and overall mortality was examined. The study divided evaluation into what was referred to as ‘low-intensity’ and as ‘high-intensity’ staffing. They defined ‘low-intensity’ as no intensivist or elective intensivist consultation, while ‘high-intensity’ included mandatory intensivist consultation or closed ICU. They concluded that ‘high-intensity’ staffing reduced hospital and ICU mortality as well as the total length of stay in both the ICU and general hospital ward.

Young et al. questioned whether an ‘intensivist model’ reduced mortality (*Young et al. 2000*). Under these circumstances an intensivist model refers to a closed ICU format. Under the intensivist model, patient mortality rates dropped by 15-60%, leading the authors to conclude that the ‘intensivist-model’ did indeed reduce mortality. They did, however, express concern that workforce constraints, for example the number of trained intensivists, might limit the universal introduction of this model as a standard of care.

A study published in *Critical Care Medicine* in 2001 (*Dimick et al. 2001),* interrogated the effect of intensive care staffing (closed ICU model) on cost, length of stay and complications after oesophageal surgery. They investigated how daily rounds by an intensivist could affect outcomes. The outcomes measured were: in-hospital mortality rate, hospital cost, complications and length of stay after major oesophageal surgery. Improvement was seen in all four measured variables, reinforcing the need for intensivist management in an

ICU setting.

In many developing countries, because of resource constraints, patients are still managed in open ICU formats. This is particularly true in the case of surgical patients, where specialized expertise is not always available. This fact was expressed in an article published by Thai doctors K. Chittawatanarat and T. Pamorsinlapathum (*Chittawatanarat et al. 2009*). They looked at the effect of a closed ICU model on mortality in a general surgical ICU. As with the Dutch study, the outcomes were compared retrospectively, by looking at two separate periods in the hospital's history, pre-closed format and post-closed format. Their results were statistically significant, a 27.4% mortality rate vs 23.4% p=0.03. Of particular interest was the finding that the greatest effect on mortality rate reduction was seen in patients admitted for more than 48 hours.

In the researcher's study, those patients from Facility A who were admitted to ICU were always managed in a closed ICU, while those admitted to ICU in Facility B were always managed in an open system.

In an article entitled 'Guidelines on critical services and personnel: Recommendations based on a system categorization of three levels of care' (*Haupt et al. 2003*), the authors looked at the regionalisation of intensive care in a similar way to that seen in the structuring of trauma units within a trauma system. As with the structuring of a trauma system, the structuring of an ICU depends on the resources available, the skill set of the specialities providing services and the needs of the demographic population served by the facility. Again, the concept of delivering the right 'type' of patient to the right 'type' of care resonates. The article discusses three levels of ICU care. Level 1, often affiliated with an academic facility, provides care from the full medical spectrum required, such as Cardiothoracic, Trauma surgery or Neurosurgery as well as the auxiliary care fields such as dietetics, occupational therapy and physiotherapy. Level 2 also services a wide variety of medical fields, but might not cater for all fields. This level of ICU may or may not be affiliated to an academic facility. In this particular setting, it is necessary for specific transport agreements between Level 1 and 2 so that patients who require a level of care that exceeds the capabilities of the facility can be transferred appropriately and with minimal delay. Level 3 facilities often only have the resources to stabilise patients before transfer to a Level 1 or Level 2 facility. Again, it is extremely important that protocols be put in place so that transfer delay is minimalized.

CHAPTER 3

STUDY DESIGN AND METHODOLOGY

3.1 Introduction

This study **aimed** to show the significant difference in the mortality rates of trauma patients in a Level 1 equivalent Trauma Centre in a South African hospital compared to those of trauma patients at a South African regional facility. These patients presented with similar injury severity, physiological profiles and Probability of Survival (PS). The study also examined those trauma system factors that potentially impact mortality.

The hypothesis states that the mortality rate in a Level 1 equivalent Trauma Centre is significantly lower than that of a regional facility without a separate Trauma Centre. A reduced mortality rate supports the argument for implementing systematized trauma care e.g. triage protocols, ATLS-based resuscitation, resuscitation by teams and early surgical consultation.

The purpose of the study was to motivate for scrutiny of the individual components of the trauma systems at both facilities, so that improvements can be made that will impact on overall trauma care provision in South African hospitals and thereby reduce mortality. This enables the examination of possible avenues for improvement in trauma system management in South Africa. It opens discussion on a number of critical issues pertaining to the management of this large health care burden in South Africa. In doing so, one is mindful of constraints on resources prevalent in a low-to-middle-income country with a huge burden of disease. It is not about more trauma care or Trauma Centres, but about smarter trauma care, using existing resources.

3.2 General Methodology

3.2.1 The Facilities

Outcomes in two hospitals in the Gauteng Province in the Republic of South Africa were determined. Facility A is a tertiary facility with a Level 1 equivalent Trauma Centre. Facility B is a regional hospital without a separate Trauma Centre. These two hospitals are representative of tertiary and regional facilities throughout South Africa (*Hardcastle et al. 2011*). The facilities were chosen as they are included in the surgical training rotation for registrars and surgeons from the University of the Witwatersrand in Johannesburg. This is a retrospective observational study, reviewing data from the months January, February, November and December 2012.

3.2.2 Resource Differences Comparing Facility A with Facility B

Facility A is a Level 1 equivalent Trauma Centre serving the greater Johannesburg area, Gauteng, Republic of South Africa. It is technically only meant to accept Priority 1 (severely injured) and some Priority 2 (P2) patients but on many occasions resources are expended on patients that should be managed at regional hospitals and primary health care facilities.

Facility A is part of the surgical training programme for registrars at the University and in addition is one of the training centres for emergency medicine registrars. The Trauma Centre is run separately from the general Emergency

Department. It has direct access to a 24-hour operating theatre but must often compete with general surgical and orthopaedic emergencies. However, as a policy, unstable trauma patients are prioritised by the anaesthetists. The anaesthetics teams consist of at least two anaesthetic registrars and a qualified anaesthetist for after-hours emergencies. There are also additional anaesthetists available for call when necessary.

This Trauma Centre is involved in exchange programmes with international surgical training facilities, and as such has numerous international doctors visiting and working in the unit. There are dieticians, occupational therapists and physiotherapists to assist with rehabilitation. There are computed tomography (CT) scanners, X-ray and ultrasound facilities available on a 24-hour basis with a registrar available to interpret results for the whole hospital.

It has six potential resuscitation bays available for P1 patients requiring intubation, ventilation and continuous monitoring. There are eight trauma trained nurses working during each twelve hour shift (7am-7pm; 7pm-7am) when there is a full complement of staff. On average only seven nurses are generally available, as one nurse is allocated as the shift leader, one to CPS (an area for less severely injured patients awaiting investigations, generally P2) and one nurse to each resuscitation bay. If only seven nurses are available the shift leader is required to assist in the resuscitation bays.

Facility A has its own closed nine bed intensive care unit with 1:1 nursing by intensive care certified nurses. It has a minimum of two medical officers in the resuscitation area, one medical officer in the ward and one medical officer in the ICU. One registrar is on site and there is one fully qualified trauma surgeon, on site, for 24-hour shifts. The medical officers in the resuscitation area do 12-hour shifts and on the weekend three medical officers are allocated to the evening shifts. All of these doctors are ATLS trained. If a code red (mass casualty incident) is called, all available doctors within the facility (medicine, anaesthetics and surgery, including consultants) are called, as are all the medical officers and registrars currently working in the trauma unit at the facility. Only those 'on call' the following day are not required. A registrar on call in the main ICU is also available to assist for these events.

Facility B is a regional hospital serving a community approximately 100 km south of Johannesburg. It is the referral hospital for a number of primary health care clinics in the surrounding area, which in turn support an extensive rural community. It has surgical capabilities, orthopaedics, urology, gynaecology and obstetrics, paediatrics and general medicine, but no separate Trauma Centre. It has a neurosurgical clinic on a weekly basis but no neurosurgeon is permanently on site. Neurosurgical emergencies are referred to a Level 1 Facility, not Facility A, almost an hour's drive away.

At Facility B, trauma patients are seen in a general casualty and there are six resuscitation bays that have to be shared with emergencies in other medical disciplines. The surgical staff quota for a call consists of one intern and two other doctors of varying levels of qualification. An example of the on-site surgical team for a typical call could consist of a surgical registrar and one to two medical officers, one of whom may be a community service doctor. These doctors are not necessarily trauma trained.

As the ICU is an open ICU, as is the High Care Facility, the doctors are required to manage emergencies in this area of the hospital as well as in the wards (**one** female and **one** male ward). Due to a shortage of ICU beds at other hospitals, patients may have to be transferred in to Facility B, despite it being a less specialised (open) ICU, whilst trauma patients with head trauma have to be transferred out of Facility B because of a lack of neurosurgical expertise. Very few of the nurses have any trauma training.

One anaesthetic medical officer on call (not necessarily holding a diploma in anaesthetics), provides services to the orthopaedic, urology and surgical departments. Although this is included as a training hospital in the University of Witwatersrand surgical training programme, it is not on the training circuit for training anaesthetists, despite the need. It has qualified surgeons on call but not on site. It can take up to an hour for a consultant to reach the hospital. A Computed Tomography Scanner (CT) and X-ray facilities are available, but no radiologist is available to interpret the scans, which are interpreted by relatively junior staff. Ultrasounds are generally undertaken by sonographers and not radiologists. A dietician, occupational therapist (OT) and physiotherapist (PT) facility are available for rehabilitative services.

Facility A is representative of most Level 1 equivalent Trauma Centres in South Africa whilst Facility B is representative of regional facilities where resources may impact on outcomes in the trauma setting. Therefore the two facilities have been selected as representative facilities, to determine factors affecting outcomes.

3.2.3 Population Sample

The study compares mortality rates for all severely injured trauma patients with an ISS ≥ 12, over the age of eighteen, admitted to both facilities during the study period. Both genders and all ethnic groups are included, as are patients transferred in from primary health care clinics. Patients transferred in from other facilities and then transferred out from the study facilities are excluded. Patients with minor injuries or incomplete data have also been excluded regardless of their ISS. An ISS of 12 was chosen because, given the number of missing files or inadequate data, patients with a lower ISS had to be included to increase the sample sizes.

3.2.4 Sample Size Calculation

The proportion of patients dying at Facility A was approximately 0.12. The proportion of patients dying at Facility B was approximately 0.16. Power of 90% and significance was set to 0.05.

Statistical significance was achieved with 183 patients from Facility A and 57 patients from Facility B, at the end of the four-month period.

3.2.5 Data Collection

Data sheets have been created based on criteria used in the trauma registry used at Facility A. The names of both facilities have been kept confidential. Information was obtained by scrutinising pre-hospital transport forms, casualty notes, resuscitation forms, ward file notes, operative notes and ICU files. These were then collated on an Excel spreadsheet. A separate spreadsheet used a study number, commencing at 1, for each patient to anonymise the patients enrolled. SAS V9.2 statistical package was utilised to analyse the data. Data was reported as frequency, mean ± standard deviation or median [range]. Continuous data was analysed by the Student's t-test and categorical data by the Chi-squared test, Multiple Logistic Regression was carried out on factors potentially influencing mortality.

3.2.6 Limitations to the Study

The overall small sample size

This retrospective comparative study has been undertaken as a research requirement for the completion of a Masters of Medicine (MMed) qualification. The investigator is engaged as a Senior Registrar in the Department of Surgery, University of the Witwatersrand. Therefore, time and access to data and resources was limited. Co-operation from the regional facility was difficult to obtain. The population sample size was determined once it obtained minimal statistical significance. All data was hand collected and compiled by the investigator.

Inequality in sample size

Inequality in sample size between the two facilities is primarily due to lost or unrecorded data. Incomplete and inaccurate record keeping at both facilities excluded potential subjects. This affected the sample size, particularly at the regional hospital (Facility B). A considerable amount of time was expended searching for missing records at both facilities, but in particular at Facility B.

This was further exacerbated by the distance of Facility B from the investigator's surgical rotation.

The study was geographically limited

The two facilities are situated in Gauteng, one serving Greater Johannesburg and its environs, and the other an industrial community to the South of Johannesburg. While the two facilities are representative of the broader South African context, environmental factors could influence results. The findings therefore need to be assessed against a broader geographic analysis.

Variable standards in data capture

Basic physiological parameters such as temperature were not recorded despite the necessity of this information in predicting outcome. The investigator was required to continuously subjectively evaluate the reliability and validity of the available records. It is also apparent from the data that in some instances the mechanism of injury was also not apparent and there could be several important pieces of information missing from the patient's records. This in itself could influence the analysis of the data and the resultant statistics.

Restricted data capture

The investigator would have preferred to conduct the study as a prospective study to ensure all data was recorded, but the human resources and co-operation for collection and data capture were not available.

3.3 Ethics

Ethics Approval was obtained from the Ethics Department of The University of the Witwatersrand. Ethics clearance certificate number M120608.

3.4 Factors Effecting Trauma Mortality

Based on key factors identified in research and policy documents on trauma systems, as shown in the literature review, the following system factors were identified as impacting on outcome after major injury. These were compared between patients from the regional and Level 1 facilities.

The following parameters were documented and compared between those patients from Facilities A and B.

3.4.1 Pre-hospital

1. Distance to hospital from site of injury (access to place of injury)
2. Mechanism of injury (blunt and penetrating)
3. Pre-hospital time
4. Advanced life support: pre-hospital intervention (intubation, intravenous cannulation, CPR, drugs utilised)

3.4.2 Casualty

1. ATLS training of receiving doctor
2. Seniority of receiving doctor (postgraduate years of training: intern, medical officer, registrar, etc.)
3. Lowest blood pressure in ER for those who demised

4. Average RTS of the mortalities (could death have been predicted in the Emergency Department)
5. Time in the Emergency Department (from arrival to definitive care)
6. Injuries and associated RTS, ISS, AIS (Anatomical Injury Scale) and NISS (New Injury Severity Score)
7. Probability of survival (based on ISS and NISS) (with focus on the averages for both groups). Probability of Survival (PS<50 and PS>50 for both groups)

3.4.3 Definitive Care

1. Time to definitive care (time to surgery, transfer to ICU) from time of injury
2. Level of training of anaesthetist and surgeon (qualified versus postgraduate in training as registrar)
3. Damage control (Y/N)
4. Time from arrival to surgery if haemorrhaging (25)

3.4.4 ICU

1. Days in ICU
2. Interventions in ICU (if data available)
3. Missed injuries (if possible) pathology reports

The above parameters were recorded on the trauma bank sheet devised by the investigator.

CHAPTER 4

RESULTS

The study included 239 patients who were admitted to the Emergency Department at the two centres. Of the 239 patients included in the study, 43 did not survive. Survival was 85.2% at Facility A compared to 71.9% at Facility B. To determine the reason for this discrepancy between the facilities, factors affecting overall survival were identified. It was then determined whether these factors explained the difference in survival between the facilities.

4.1. Factors Affecting Overall Survival

4.1.1 Patient Demographics and Mechanisms of Injury

To determine the factors influencing overall survival, the demographic characteristics and injury mechanism of all surviving and non-surviving patients was compared (Table 4.1). The average age of the mostly male (90.4%) patients of African descent (92.4%) was 32 years, with older age associated with poorer survival ($p<0.05$). The majority of the patients had penetrating injuries resulting from stabbings (26.5%) and gunshots (15.1%), with these and pedestrian (19.3%), motor vehicle (9.7%) and falls from heights (8.4%) making up most of the injuries. The mechanism of injury did not affect survival although, overall, stabbed patients had better survival. Burn injuries accounted for 3.4% of admissions and burns were not associated with better or worse survival. In some cases the mechanism of injury was not recorded. This may have impacted the statistical results.

4.1.2 Admission, Emergency Department and Intensive Care Parameters

Admission

The time to reach the hospital, and clinical parameters upon admission, including blood pressures, pulse and respiratory rates and the experience of the paramedic or other individuals caring for the patient in the pre-admission period were not different between patients surviving and those not surviving. Temperatures upon admission were not recorded for many patients. As expected, GCS, ISS, RTS and survival probabilities were significantly worse in patients who did not survive.

Table 4.1: Patient demographics and mechanisms of injury between the two hospitals. Data as number (frequency), mean ± standard deviation or median and range [ ]. Abbreviations: m/f: male/female; B/C/I/W: Black (African)/Coloured (mixed race)/Indian (Asian)/White (Caucasian).

Parameter	All (n=239)	Survivors (196)	Non-survivors (n=43)	Difference χ^2 or Wilcoxon (p)
Patients				
Age (y)	32.1±11.1	31.2±9.9	35.5±14.7	**0.0242**
Gender (m/f)	216/23	176/19	39/4	0.92
Race (B/C/I/W)	221/1/2/15	180/1/2/12	40/0/0/3	0.87
Injury*				
Blunt	99 (43.0%)	104 (43.9%)	26 (11.0%)	0.56
Penetrating	131 (57.0%)	84 (35.4%)	15 (15.2	0.35
Mechanism of injury				
Stab	63 (26.5%)	58 (29.9%)	5 (11.6%)	**0.0155**
Pedestrian	46 (19.3%)	36 (18.6%)	9 (20.9%)	0.70
Gun shot	36 (15.1%)	26 (13.4%)	10 (23.3%)	0.10
Assault	27 (11.3%)	19 (9.8%)	8 (18.6%)	0.09
Motor vehicle	23 (9.7%)	20 (10.3%)	3 (7.0%)	0.51
Fall from height	20 (8.4%)	16 (8.3%)	4 (9.3%)	0.81
Motor bike	7 (2.9%)	6 (3.1%)	1 (2.3%)	0.79
Train	3 (1.3%)	3 (1.6%)	0 (0%)	0.41
Bicycle	2 (0.8%)	2 (1.0%)	0 (0%)	0.50
Sjambok	1 (0.4%)	1 (0.5%)	0 (0%)	0.60
Blunt force	1 (0.04%)	0 (0.0%)	1 (2.3%)	0.64
Burns	8 (3.4%)	6 (3.1%)	2 (5.3%)	0.60

Table 4.2: Admission, casualty and ICU parameters for patients who survived and those who did not. Results as mean±std or median [range] and sample size (n). Data was not recorded in some cases and not statistical analysis was performed. Abbreviations:

	All (n=239)	**Survivors (n=196)**	**Non-survivors (n=43)**	**Difference p**
Admission				
Time (min)	39±27 (n=124) 33 [4 – 128]	39±26 (n=100) 33 [4-128]	41±29 (24) 32 [10-110]	0.99
GCS	12.8±3.7 (146)	13.2±3.3 (122)	10.5±4.9 (24)	**0.0011**
ISS	24.6±13.2 (239)	22.1±9.3 (195)	35.7±21.0 (43)	**<0.0001**
RTS	6.9±1.5 (178)	7.3±1.0 (140)	5.4±2.1 (37)	**<0.0001**
Survival probability (%)	85.0±26.9 (167)	93.3±14.5 (129)	58.6±38.3 (37)	**<0.0001**
SBP (mm Hg)	120±24 (125)	121±23 (100)	114±27 (22)	0.17
DBP (mm Hg)	74±16 (125)	74±15 (94)	73±19 (21)	0.67
Pulse rate (bpm)	89±20 (126)	89±20 (103)	89±20 (23)	0.96
Respiratory rate (ipm)	20.1±4.4 (74)	20.2±4.6 (61)	18.8±3.8	0.73
Temperature (ºC)	36.8±0.4 (8)	36.8±0.4 (8)	nr	
Paramedic training	n=154	n=134	n=31	-
BLS (L1/L2)	79/2 (48.9%/1/2%)	69/2 (51.5%/1.5%)	10/0 (32.3%/0%)	1.0
ILS (L 2)	11 (6.7%)	9 (6.7%)	2 (6.5%)	ns
ALS (L1/L3)	3/28 (1.8%/17.0%)	2/19 (1.5%/14.2%)	1/9 (3.2%/29.0%)	1.0
BLS+ILS (L2)	12 (7.3%)	10 (7.5%)	2 (6.5%)	ns
BLS+helicopter (L2)	2 (1.2%)	2 (1.5%)	0 (0%)	1.0
BLS+ALS (L3)	12 (7.3%)	10 (6.1%)	2 (6.5%)	ns
BLS+ALS+ILS (L3)	4 (2.4%)	1 (0.6%)	3 (1.8%)	ns
None (police+private)	12 (7.3%)	10 (7.5%)	2 (6.5%)	ns
Casualty				
Time (min)	443±441 (180) 333 [20-3097]	466±449 (142) 388 [20 – 3097]	363±405 (37) 216 [30-1920]	**0.0214**
Time to surgeon (min)	69±159 (101) 20 [0 - 1190]	77±176 (79) 20 [4 - 1190]	41±66 (22) 18 [0 - 240]	0.49
GCS	12.8±3.7 (147)	13.2±3.4 (122)	10.0±4.9 (34)	**<0.0001**
Lowest SBP (mm Hg)	114±26 (199)	116±23 (164)	106±34 (34)	0.055
Lowest DBP (mm Hg)	69±19 (191)	70±18 (158)	64.4±23.5 (33)	0.19
Pulse rate (bpm)	93±28 (173)	92±26 (137)	98±34 (35)	0.30
Respiratory rate (ipm)	20.8±5.3 (201)	21.8±5.3 (162)	21.0±5.4 (38)*	0.71
Temperature (ºC)	35.9±1.4 (69)	36.0±1.3 (57)	35.5±2.1 (12)	
Doctor training				
Registrar	2 (1.1%)	0 (0.0%)	2 (5.0%)	**0.0292**
<5	67 (35.6%)	56 (37.8%)	11 (27.5%)	
>5	119 (63.3%)	92 (62.2%)	27 (65.5%)	
ATLS Yes (%)	187 (85.0%)	161 (89.4%)	26 (65.0%)	**<0.0001**
ATLS No (%)	33 (33.0%)	19 (10.6%)	14 (35.0%)	
Nurse L1	57 (25.3%)/	41 (21.5%)	16 (37.2%)	**0.0283**
Nurse L2	178 (75.7%)	151 (78.7%)	27 (62.8%)	
ICU				
Time (min)	165±85 (74) 154 [15 – 480]	168±86 (61) 160 [15 – 480]	154±84 (12) 143 [55 – 325]	0.49
SBP (mm Hg)	127±27 (76)	129±22 (59)	119±41 (17)*	0.20
DBP (mm Hg)	73±21 (76)	74±19 (59)	69±28 (17)	0.40
Pulse rate (bpm)	100±27 (73)	97±24 (56)	111±35 (17)	0.08
Respiratory rate (ipm)	17.9±5.5 (68)	18.2±5.1 (53)	16.9±7.0 (15)	0.44
Temperature (ºC)	36.5±1.0 (54)	36.4±1.0 (46)	37.1±0.7 (8)	0.08
Anaesthetist:				
MO/Reg/Consult	29/29/20 (78)	23/21/18 (62)	6/8/2 (16)	0.33
Surgeon::				
MO/Reg/Consult/Special	11/28/38/3 (80)	10/25/26/3 (64)	1/3/12/0 (16)	0.13

Emergency department

GCS scores in the Emergency Department remained worse ($p<0.0001$) in patients who did not survive. Once the patient was admitted in the Emergency Department, GCS scores were worse in non-survivors but other clinical parameters were similar between survivors and non-survivors. The time to move patients from casualty to ICU was less for those patients who did not survive. Furthermore, the time delay to see an attending surgeon was similar for surviving and non-survivors.

Although the number of years of training of the attendant clinician was similar, significantly more non-surviving patients were attended to by non-ATLS trained doctors ($p<0.0001$). The level of nurse training was less in the non-surviving group ($p<0.03$).

Intensive care unit

Fewer patients were seen in ICU. Clinical parameters, time in ICU and level of training of both anaesthetist and surgeon were similar between surviving and non-surviving patients.

4.2. Factors Affecting Survival at the Facilities

The data presented in Tables 4.1 and 4.2 was presented for each facility in tabular form. Patient demographics and mechanisms of injury are shown in Table 4.3. The demographic data and injury mechanism of patients being admitted was similar between the facilities. More males who survived were admitted at **Facility B**, and at **Facility A**, non-surviving patients were older than the patients who survived.

Admission parameters (Table 4.4.a.)

GCS and ISS scores were similar between Facilities. As was expected, GCS ($p<0.005$), ISS, RTS and the probability of survival (all with $p<0.0005$) were significantly worse in non-survivors than survivors at Facility A. In contrast, only the RTS and probability of survival, not GCS or ISS, were worse at Facility B with less significance ($p<0.05$). ISS was worse in non-surviving patients at Facility 1 ($p<0.05$).

Time to admission was longer at Facility B ($p<0.05$) for surviving patients and the training of the paramedics was similar between Facilities (Fig. 4.1a.). Patient blood pressure, respiratory rates and temperatures, where these were recorded, were not different between the Facilities (Table 4.4).

Emergency department (Table 4.4.b.)

Overall GCS scores were similar between Facilities, as were the scores for the survivors and non-survivors between Facilities. GCS scores were significantly different for survivors and non-survivors at each Facility. Survivors spent less time in the Emergency Department at Facility B than Facility A and this was attributed to the surviving patients, as the time spent in casualty by the non-surviving patients was similar between the Facilities. The time taken to be seen by a surgeon was significantly longer at Facility B, with a median time of two and a half hours. Surviving patients at Facility A waited only 15 minutes

($p<0.0001$) whereas the non-survivors were seen by the surgeon within 15-20 minutes at either Facility ($p=0.84$).

Clinical parameters showed significant differences between Facilities, as blood pressures were lower at Facility B (for survivors SBP: $p<0.05$ and DBP: $p<0.005$) and pulse rates higher (overall $p<0.05$ for all patients).

Although clinicians had more years of experience at Facility B, only half had received ATLS training ($p<0.0001$ between Facility A and B). Furthermore, all nurses had Level 2 training at Facility A, whereas at Facility B all nurses were trained only to Level 1 (difference between Facilities $p<0.0001$) (Table. 4.4b. and Fig. 4.1b).

Theatre parameters (Table 4.4b)

Operating theatre parameters were similar between Facilities. The time in theatre and clinical parameters were similar for all patients, systolic blood pressure was significantly lower ($p<0.05$) at Facility B. The numbers of non-surviving patients at Facility A were too small to analyse this observation further. The data shown in Figures 4.1c and 4.1d indicates that patients at Facility A were attended by anaesthetists and surgeons who were better qualified.

Table 4.3: Patient demographics and mechanisms of injury between the two hospitals. Data as number (frequency), mean±standard deviation or median and range [ ]. Abbreviations: m/f: male/female; B/C/I/W: Black (African)/Coloured (mixed race)/Indian (Asian)/White (Caucasian). Statistical differences have been determined as appropriate. * Significance of difference between survivors and non-survivors at each facility: p<0.05. Rounding decimals and missing data may result in numbers of percentages not adding up.

	Facility A			**Facility B (n=57)**			**Difference between facilities (p)**			
Parameter	**All (n=182)**	**Survivors (n=155)**	**Non-survivors (n=27)**	**All (n=57)**	**Survivors (n=41)**	**Non-survivors (n=16)**	**All**	**Surv-ivors**	**Non-surv-ivors**	**Survivors vs non-survivors**
Patients										
Age (y)	31.8±11.2	31.0±10.0	36.0±15.8*	32.9±10.9	32.9±10.9	34.6±13.3	0.55	0.53	0.76	
Gender (m/f)	161/21	135/19	25/2	55/2	41/0	14/2	0.12	**0.0151**	0.62	
Race (B/C/I/W)	166/1/2/13	141/1/2/10	24/0/0/3	55/0/0/2	39/0/0/2	16/0/0/0	0.79	1.0	0.28	
Mechanism of Injury										
Blunt	70 (38.9%)	61 (33.9%)	9 (5.0%)	29 (50.9%)	23 (40.4%)	6 (10.5%)	0.89			0.36
Penetrating	105 (58.3%)	87 (48.3%)	18 (10.0%)	25 (43.9%	17 (29.8%)	8 (14.0%)	0.067			0.10
Burns	5 (2.8%)	5 (2.8%)	0 (0.0%)	3 (5.3%)	1 (1.8%)	2 (3.5%)	0.30			0.11
Fall from height	17 (9.4%)	14 (7.8%)	3 (1.7%)	3 (5.3%	2 (3.5%)	1 (1.8%)	0.24			0.51
Gun shot	27 (15.0%)	21 (11.7%)	6 (3.3%)	9 (15.8%)	5 (7.0%)	5 (8.8%)	0.23			0.11
Motor bike	6 (3.3%)	5 (2.8%)	1 (0.6%)	1 (1.8%)	1 (1.8%)	0 (0.0%)	1.0			1.0
Motor vehicle	18 (10.0%)	17 (9.4%)	1 (0.6%)	5 (8.8%)	3 (5.3%)	2 (3.5%)	0.11			0.11
Pedestrian	39 (21.7%)	30 (16.7%)	9 (5.0%)	6 (10.5%)	6 (10.5%)	0 (0.0%)	0.32			0.32
Assault	17 (9.4%)	14 (7.8%)	3 (1.7%)	10 (17.5%)	5 (8.8%)	5 (8.8%)	0.10			0.10
Bicycle	2 (1.1%)	2 (1.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	-			-
Sjambok	1 (0.6%)	1 (0.6%)	0 (0.0%)	0 (0.0%)	0.(0.0%)	0 (0.0%)	-			-
Stab	43 (23.8%)	40 (22.2%)	3 (1.7%)	20 (35.1%)	18 (31.6%)	2 (3.5%	0.64			0.65
Train	3 (1.7%)	3 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	-			-

Table 4.4(a): Clinical parameters for patients at each facility. Numbers as frequency (n) or mean±standard deviation. Differences between survivors at each facility are indicated: * p<0.05; ** p<0.005; *** p<0.0005. Numbers were too small to compare groups (-).

	Facility A (182)			Facility B (n=57)			Difference between facilities			
Parameter	**All (182)**	**Survivors (155)**	**Non-survivors (27)**	**All (57)**	**Survivors (41)**	**Non-survivors (16)**	**All**	**Surv-ivors**	**Non-survivors**	**Survivor vs non-survivor**
Admission										
Time (min)	38±26 (100) 32 [4 – 128]	36±25 (81) 32 [4 – 128]	44±30 (19) 35 [10 – 110]	33±11 (54) 37.5 [13 – 98]	50.4±27.5 (19) 40 [18 – 98]	33±27 (5) 22 [13 – 80]	0.13	**0.0262**	0.35	
GCS	12.0±5.6 (26)	13.1±3.4 (99)	9.8 ±5.4 (18)**	10.9±5.6 (35)	13.7±2.9 (23)	12.7±2.3 (6)	0.63	0.68	0.41	
ISS	25.0±13.9 (182)	22.2±9.7 (154)	40.4±22.2 (27)***	23.4±10.9 (57)	21.7±7.6 (41)	27.6±16.3 (16)	0.86	0.76	**0.0141**	
RTS	7.0±1.5 (133)	7.4±0.9 (109)	5.0±2.2 (23)***	6.8±1.5 (45)	7.2±1.1 (31)	6.0±1.9 (14) *	**0.0163**	**0.0091**	0.16	
Survival probability (%)	86±26 (125)	94±14 (101)	50±39 (23)***	79±33 (42)	89±23 (28)	72.9±33.1 (14) *	**0.0386**	0.14	0.058	
SBP (mm Hg)	121±25 (96)	122±24 (80)	115±30 (15)	117±20 (29)	119±20 (22)	111±20 (7)	0.48	0.78	0.97	
DBP (mm Hg)	75±16 (86)	75±16 (72)	75±21 (14)	73±15 (29)	74±15 (22)	69±16 (7)	0.64	0.91	0.91	
Pulse rate (bpm)	89±20 (98)	87±21 (82)	92±20 (16)	87±16 (28)	89±16 (21)	80±18 (7)	0.59	0.77	0.13	
Respiratory rate (ipm)	20.3±4.9 (47)	20.4±5.2 (41)	19.6±3.0 (5)	19.9±3.3 (27)	19.9±2.9 (20)	19.9±4.6 (7)	0.73	0.54	0.93	
Temperature (^oC)	36.8±0.3 (4)	36.9±0.3 (4)	nr	36.8±0.5 (4)	36.8±0.5 (4)	nr	-		-	
Paramedic training	n=118	n=98	n=20	n=35	n=26	n=9				
BLS (L1/L2)	53/0 (44.9%/0.0%)	48/0 (49.0%/0.0%)	5/0 (25.0%/0.0%)	26/2 (74.3%/5.7%)	21/2 (80.8%/7.7%)	5/0 (55.6%/0.0%)	0.11	0.10	1.0	-
ILS (L 2)	10 (8.5%)	9 (9.2%)	1 (5.0%)	1 (2.9%)	0 (0.0%)	1 (11.1%)	-	-	-	0.18
ALS (L1/L3)	3/27 (2.5%/23.9%)	2/19 (2.0%/19.4%)	1/9 (5.0%/40.0%)	0/1 (0.0%/2.9%)	0/0 (0.0%/0.0%)	0/1 (0.0%/11.1%)	1.0	-	1.0	
BLS+ILS (L2)	9 (7.6%)	7 (7.1%)	2 (10.0%)	3 (8.6%)	3 (11.5%)	0 (0.0%)	-	-	-	1.0
BLS+helicopter (L2)	2 (1.7%)	2 (2.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	-	-	-	-
BLS+ALS (L3)	11 (9.3%)	10 (10.2%)	1 (5.0%)	1 (2.9%)	0 (0.0%)	1 (11.1%)	-	-	-	0.17
BLS+ALS+ILS (L3)	3 (2.5%)	1 (1.0%)	2 (10.0%)	1 (2.9%)	0 (0.0%)	1 (11.1%)	-	-	-	1.0
None (police+private)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	-	-	-	-

Table 4.4(b): (continued, legend as above)

	Facility A			Facility B			Difference between facility A & B			
Parameter	**All**	**Survivors**	**Non-survivors**	**All**	**Survivors (38)**	**Non-survivors (16)**	**All**	**Surv-ivors**	**Non-survivors**	
Casualty										
Time (min)	490±475 (127)	518±483 (104)	380±428 (22)	328±324 (53)	324±303 (38)	338±383 (15)	**0.0193**	**0.0123**	0.89	
	420 [20 – 3097]	435 [20-3097]	268 [20-1920]	216 [30-1560]	238 [31-1328]	215 [30-1560]				
Time to surgeon (min)	20±19 (73)	20±20 (60)	21±18 (13)	196±264 (28)	256±298 (19)	70±96 (9)*	**<0.0001**	**<0.0001**	0.84	
	15 [3 – 139]	15 [4 - 139]	16 [3 - 74]	124 [0 -1190]	152 [25-1190]	20 [0 - 240]				
GCS	12.9±3.8 (143)	13.3±3.2 (121)	9.8±5.4 (21)***	13.2±3.3 (51)	14.2±2.3 (38)	10.3±4.2 (13)***	0.49	0.07	0.99	
Lowest SBP (mm Hg)	116±25 (146)	119±23 (124)	101±134 (21)**	109±26 (53)	107±23 (40)	116±35 (13)	0.08	**0.0158**	0.20	
Lowest DBP (mm Hg)	72±19 (138)	73±17 (118)	64±24 (20)*	64±20 (53)*	62±19 (40)*	68±23 (13)	**0.0112**	**0.0026**	0.41	
Pulse rate (bpm)	91±22 (132)	91±21 (108)	90±27 (23)	103±40 (41)	98±40 (29)	113±41 (12)	**0.0159**	0.68	0.13	
Respiratory rate (ipm)	20.8±6.2 (148)	20.9±5.9 (122)	21.2±6.6 (24)	20.6±2.5 (54)	20.5±2.5 (40)	20.7±2.7 (14)	0.65	0.61	0.76	
Temperature (ºC)	35.9±1.5 (61)	36.0±1.3 (51)	35.2±2.1 (10)	36.3±0.9 (8)	36.1±0.8 (6)	37.2±0.6 (2)	0.51	0.73	-	
Doctor training	N=132	N=107	N=24	N=57	N=41	N=16	**<0.0001**	**<0.0001**	**<0.0001**	
Reg	2 (1.5%)	0 (0.0%)	2 (8.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)				
<5	67 (50.8%)	56 (52.3%)	11 (45.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)				
>5	63 (47.8%)	51 (47.7%)	11 (45.8%)	57 (100.0%)	41 (100.0%)	16 (100.0%)				
ATLS Yes (%)	161 (98.2%)	136 (97.8%)	24 (100.0%)	27 (47.4%)	25 (61.0%)	2 (12.5%)	**<0.0001**	**<0.0001**	**<0.0001**	
ATLS No (%)	3 (1.8%)	3 (2.2%)	0 (0.0%)	30 (52.6%)	16 (39.0%)	14 (87.5%)				
Nurse L1	0 (0.0%)/	0 (0.0%)/	0 (0.0%)/	57 (100.0%)	41 (100.0%)	16 (100%)/	**<0.0001**	**<0.0001**	**<0.0001**	
Nurse L2	179 (100.0%)	51 (100.0%)	27 (100.0%)	0 (0.0%	0 (0.0%)	0 (0.0%)				
Theatre										
Time (min)	168±89	173±91 (39)	141±84 (6)	160±79 (28)	158±78 (22)	168±89 (6)	0.95	0.66	0.34	
	151 [20 – 480]	160 [20 – 480]	[57 – 300]	160 [15 – 330]	160 [15 – 330]	168 [55 – 325]				
SBP (mm Hg)	137±18 (25)	135±17 (22)	153±22 (3)	122±29 (51)*	125±23 (37)	112±41 (14)	**0.0310**	0.15	-	
DBP (mm Hg)	78±20 (25)	76±19 (22)	96±27 (3)	70±21 (51)	73±19 (37)	63±25 (14)	0.15	0.53	-	
Pulse rate (bpm)	94±21 (24)	93±21 (21)	104±9 (3)	104±30 (49)	100±25 (35)	112±39 (14)	0.38	0.45	-	
Respiratory rate (ipm)	18.7±4.3 (24)	18.9±4.3 (21)	17.0±4.4 (3)	17.5±6.1 (44)	17.8±5.6 (24)	16.9±7.7 (12)	0.61	0.67	-	
Temperature (ºC)	36.7±0.5 (25)	36.7±0.4 (22)	36.8±0.8 (3)	36.3±1.2 (29)	36.1±1.3 (24)	37.2±0.8 (5)`	0.57	0.30	-	

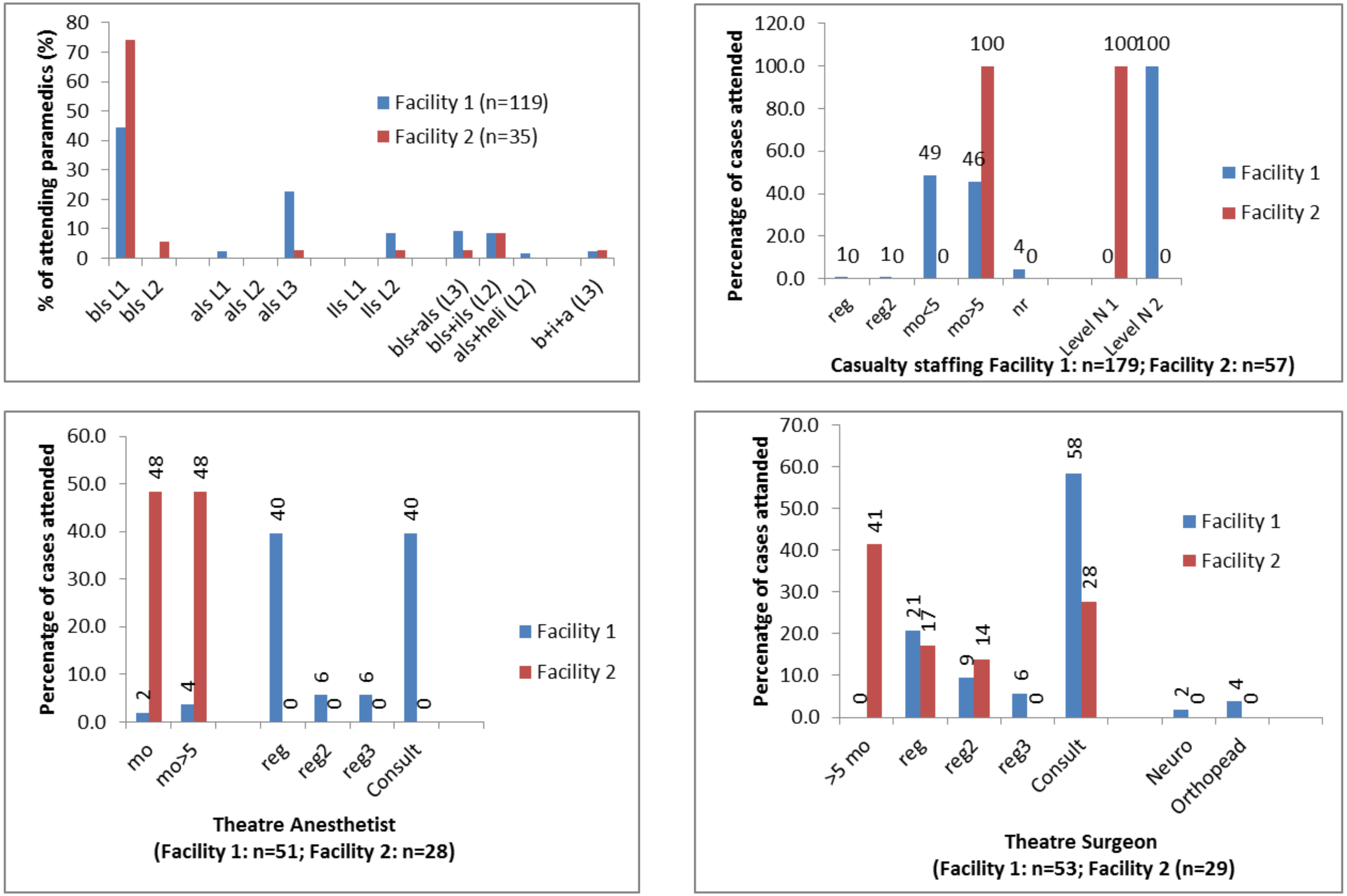

Figure 4.1: Differences in training of attending paramedics (top left) ($p<0.0043$); casualty (top right), and ICU anaesthetists and surgeons (bottom) ($p<0.0001$). Numbers as percentages not actual patients treated.

4.3. Effect of Staff Training on Survival Outcomes

The results presented here suggest that the training of staff may be a factor in determining survival at the Facilities. In the South African setting, doctors are often 'thrown in at the deep end' as interns. They are often not supported by more senior personnel because the workload is so great that the attention of more senior doctors is required elsewhere. This creates very strong clinical skills in those who survive the process, but at what physical, emotional and psychological cost to all concerned?

Paramedic training was not shown to be different between surviving and non-surviving patients or between Facilities. However, once patients were in the Emergency Department, the level of training of the clinicians and surgeons appeared to impact on survival. In particular, whether the attending clinician/surgeon had received ATLS training appeared to be a factor. The training level of attending nurses also appeared to be different between surviving and non-surviving patients.

To determine the impact of ATLS training on outcomes, the data was re-analysed according to ATLS training (Table 4.5). The data shows:

1. ATLS trained doctors attending to younger patients ($p<0.05$) and older age patients was still associated with poorer survival ($p<0.05$; Table 4.1).
2. 86% of doctors at Facility A were ATLS trained compared to 9% at Facility B.
3. The demographics of patients presenting were similar with respect to gender, ethnicity, GCS, ISS, RTS and probability of survival and

clinical parameters when dichotomised according to whether the treating doctor was ATLS trained.

4. Non-ATLS trained doctors took significantly longer to attend to patients ($p<0.05$).
5. In casualty, the GCS score and clinical parameters of patients treated according to ATLS training was similar.
6. Once in theatre, blood pressure in non-ATLS treated patients had dropped significantly ($p<0.05$ for both systolic and diastolic pressures) and pulse rate had increased ($p=0.07$).
7. Overall survival of patients treated by ATLS trained doctors was 86% compared to 58% survival in patients treated by non-ATLS doctors ($p<0.0001$; Fig. 3.2).

The effect of nursing had a small impact on survival in this study (Figures 4.2 and 4.3). In regression analysis it was shown not to significantly impact survival.

Table 4.5: Admission, casualty and ICU parameters for patients treated by ATLS and non-ATLS trained doctors. Results are presented as mean±std or median [range] and sample size (n). Data was not recorded (nr) in some cases and no statistical analysis was performed. Differences between groups were determined using general linear model (glm) and non-parametric analysis (Kruskal-Wallis test) for non-normally distributed data.

	ATLS Trained (n=188)	**Not ATLS trained (n=33)**	**Difference p (glm; (KW))[1]**
Age (years)	32±11 (n=188)	34±11 (n=31)	**0.0206**
Gender (m/f)	169/19	31/2	0.75
Race (B/C/I/W)	171/1/2/14	32/0/0/1	0.68
Facility (A/B)	161 (85.6%)/27 (47.4%)	3 (9.1%)/30 (52.6%)	**<0.0001**
Admission			
Time (min)	40±28 (n=100) 33 [4-128]	33±18 (n=13) 27 [13 – 80]	0.10 (0.47)
GCS	12.8±3.6 (125)	13.7±2.0 (14)	0.35 (0.56)
ISS	24.6±13.0 (187)	24.1±12.6 (33)	0.85
RTS	7.0±1.5 (134)	6.7±1.6 (29)	0.34
AIS	6.4±2.9 (91)	4.7±0.7 (12)	0.0450 (0.06)
Survival probability	87±25 (127) 97.4 [0.2 - 99.8]	84±26 (27) 94.8 [14.4 – 99.2]	0.55 (0.13)
SBP (mm Hg)	119±24 (104)	120±26 (14)	0.88 (0.76)
DBP (mm Hg)	73±15 (95)	77±19 (14)	0.49 (0.42)
Pulse rate (bpm)	90±20 (101)	85±19 (14)	0.38 (0.41)
Respiratory rate (bpm)	20.2±4.6 (61)	19.9±3.9 (12)	0.84 (0.72)
Temperature (°C)	36.8±0.4 (8)	- (nr)	-
Time to surgeon (min)	45±78 (70) 17 [0 – 399]	173±301 (21) 20 [0 – 1190]	**0.0016** (**0.0417)**
Casualty			
Time (min)	469±469 (132) 378 [20-3097]	343±378 (32) 211 [30 – 1560]	0.16 (
GCS	13.0±3.7 (194)	12.6±3.7 (28)	0.64
Lowest SBP (mm Hg)	114±25 (153)	111±27 (30)	0.49 (0.79)
Lowest DBP (mm Hg)	70±19 (145)	67±20 (30)	0.51 (0.49)
Pulse rate (bpm)	92±23 (134)	104±47 (24)	0.056 (0.61)
Respiratory rate (/min)	20.8±6.1 (155)	20.5±2.0 (31)	0.76 (0.88)
Temperature (°C)	36.0±1.5 (56)	36.3±1.0 (6)	0.60 (0.83)
Theatre			
Time (min)	161±82 (56) 151 [15 – 480]	167±81 (17) 165 [45 – 330]	0.68 (0.75)
SBP (mm Hg)	133±21 (48)	116±33 (28)	**0.0060 (0.0357)**
DBP (mm Hg)	77±17 (48)	66±25 (28)	**0.0179** (0.10)
Pulse rate (bpm)	96±23 (46)	108±32 (27)	0.07 (0.11)
Respiratory rate (/min)	18.7±4.2 (43)	16.8±7.2 (25)	0.15 (0.0465)
Temperature (°C)	36.6±0.9 (41)	36.2±1.1 (13)	0.22 (0.07)
Survival	161/187 (86.1%)	19/33 (57.6%)	**<0.0001**

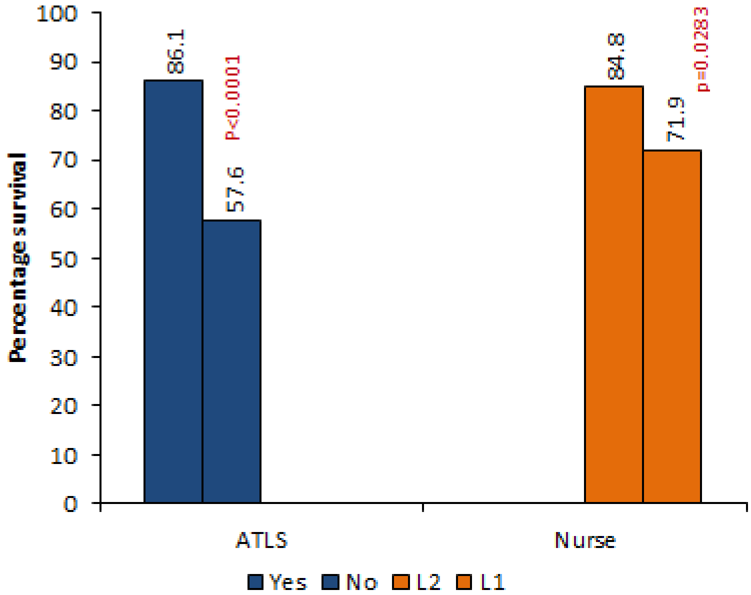

Figure 4.2: Graphic presentation of the effect of ATLS training and the level of nurse training (L2 = trauma trained) on trauma patient survival at the Facilities.

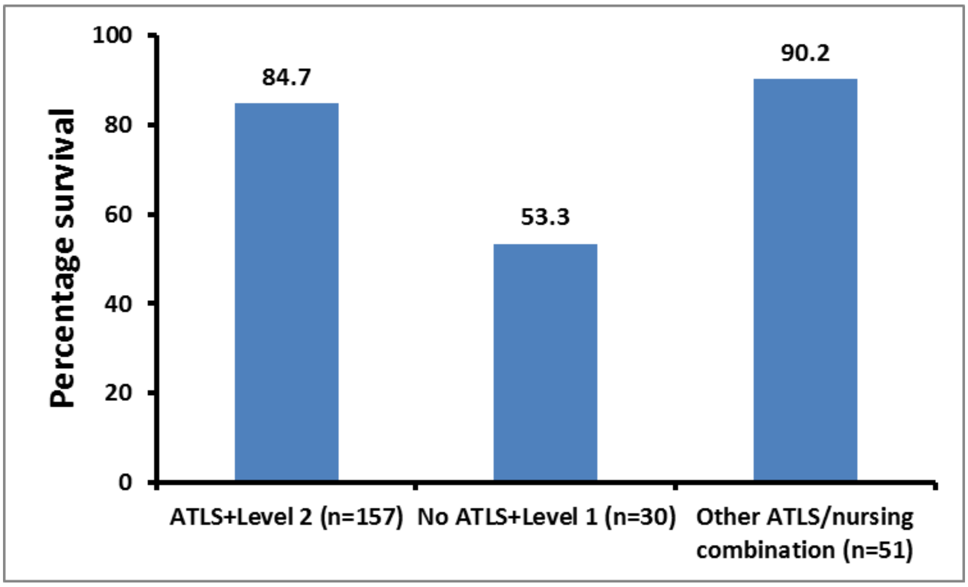

Figure 4.3: Effect of ATLS training with the level of nursing training on patient survival at the Facilities showing that the level of nursing has a small impact on survival (compare to Fig. 4.2 above).

Figure 4.4 summarises the impact of ATLS training on blood pressure in patients in the study. Blood pressures were nearly identical upon admission and were maintained in casualty but were not maintained by non-ATLS trained doctors.

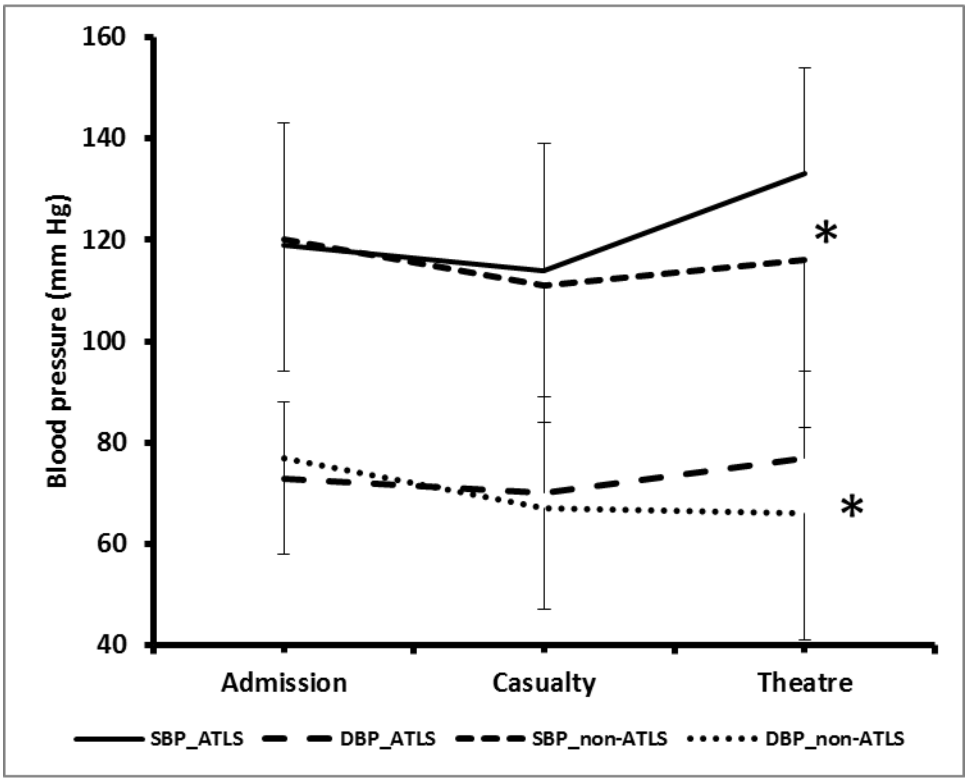

Figure 4.4: Blood pressure changes from admission, casualty and theatre for patients treated by ATLS and non-ATLS trained doctors. Data as mean ± standard deviation (error bars).
* $p<0.05$

Finally, using regression analysis and modelling the probability of survival, ATLS training (p=0.0010), but not the hospital facility was found to be significant predictors of survival.

CHAPTER 5

DISCUSSION

5.1 Introduction

A large proportion of surgical training in South Africa is dedicated to trauma. Trauma is the ‘bread and butter’ of most general surgical practices, particularly in the government setting. One of the reasons for the lack of literature, despite the wealth of experience of South African surgeons in the management of trauma, is that data is still not being accurately documented or collated. Some Level 1 Units have started their own trauma registries (*Laing et al. 2014*), but even in these facilities, if information is not documented at point of care (in the resuscitation bay; in the ward) the value of the data is lost. It is also difficult to assess the performance of regional facilities because the information that is essential to audit is lost within the administrative system.

One of the main limitations to this study was lost or unrecorded data. This led to smaller sample sizes especially at Facility B and excluded patients from the study that may have been admitted and contributed important information to the outcomes. The importance of training has been emphasised in numerous studies but never been proven to be statistically significant (*Ali et al. 1993).*

5.2 System Factors

5.2.1 Demographics

The data supported the generally accepted demographic trend. The majority of patients are young, potentially economically productive, black males *(Celso et al. 2006, Mock et al);* however, a large percentage of both populations were unemployed and, as studies have shown (*Sache et al. 2008, UNICEF 2012,Tshigovuyho et al. 2008),* unemployment and poverty as well as low socioeconomic status correlate with the degree of violence in a community.

5.2.2 Mechanism of Injury

Facility B presented with more penetrating trauma than A (45.3% vs 26.6%), but this was not statistically significant. It may be explained by the fact that the drainage areas to Facility B are located in more rural settings and therefore have greater interpersonal violence compared to road traffic accident ratios.

5.2.3 Injury Prevention

Analysing the results and associated breakdown for the mechanism of injury, there is clearly a need for effective interventions. Up to 41% of all road traffic **collisions** are alcohol-related (*Child passenger restraint use and motor vehicle fatalities among children, 1991*) and despite efforts to improve roads and implement seatbelt, baby seat and helmet laws, it would seem that modification of human behaviour is the area that requires the greatest intervention. Despite best efforts, looking at the results of this study, this does not appear to be effective. It is important not to underestimate the contribution of poverty and its effect on the psychology of the trauma population. Some of the cases that enter a hospital are the product of pure violence whilst others merely reflect desperation. This is an area that requires government intervention on a larger scale and has a direct effect on the level of trauma that is seen in South Africa.

5.2.4 Trauma Systems

There are numerous arguments for and against the role of the pre-hospital care givers. Trunkey and other trauma specialists (*Trunkey et al. 1984, Smith et al. 1985, Lewis et al. 1983)* expressed the opinion that the job of the EMS was to get the patient to a facility as fast as possible and not waste time applying advanced life saving techniques (‘scoop and run’ vs ‘stay and play*’, Nirula et al. 2010*). Messick et al. *(1992)* felt that there was value in applying certain advanced life support skills, while other authors (*Ornato et al. 1982, Nirula et al. 2010, Szcygiel et al. 1981)* inferred that perhaps the middle ground was the application of ALS in areas where pre-hospital times would be long (rural areas), yet transporting patients proximal to hospitals as quickly as possible without ALS interventions. The majority of patients at both Facility A and B were brought in by BLS paramedics but there were more ALS paramedics involved at Facility A than at Facility B and this was statistically significant (p=0.043).

It could be that Facility A favours the Messick opinion, especially given the fact that this facility had a lower mortality rate. Messick’s opinion was that there was some value in applying certain advanced life support skills, such as intubation, in situations where the injured patient had to be transported a substantial distance. This favours the training and utilisation of advanced life support crews. Trunkey and colleagues believe that EMS should only be utilised as transportation for the severely injured and that time should not be wasted applying advanced life support skills. In the case of Facility B, the opinion of Trunkey and colleagues is refuted. Facility B services a large proportion of rural patients that may be injured a substantial distance from the hospital. These patients may require life-saving advanced life support measures in order to survive transport to hospital. It took 50±27min for survivors and 39±28 min for non-survivors to reach Facility B. This is not a bad pre-hospital time given that Facility B serves an extensive rural population. Regionalisation of care was better practised at Facility B than at A. Patients at Facility B were referred from primary health care clinics or from the scene of the collision by paramedics. Referrals were not inappropriate to the level of care provided by the facility.

Trauma systems are designed to deliver the right type of patient to the right level of facility to ensure not only adequate clinical care but acceptable resource utilisation (*Goosen et al, Celso et al. 2006*).

5.2.5 Trauma Units

Facility A has a dedicated Trauma Centre. Studies show that the care of severely injured patients in a dedicated Trauma Centre decreases mortality (*Celso et al. 2006, Sampalis et al. 1999, Cheddie et al. 2011).* This is proven in this study by the fact that the mortality rate at Facility A was almost half that of Facility B (no dedicated trauma unit). The studies by Mackenzie et al. (*Mackenzie et al. 2006, O'Keefe et al. 1999)* supported the concept of Trauma Centres. They proved that the severely injured treated in Trauma Centres were less likely to die from their injuries. The outcomes at Facility B support the above studies and motivate for the implementation of Trauma Centres as part of the development of an effective trauma system in South Africa.

5.2.6 Trauma Teams

Facility A runs its Trauma Centre using trauma teams and models itself on a horizontal care provision model (*Lanzetta et al. 1981, Trauma.Org).* The implementation of trauma teams at this facility is supported by a study conducted by Driscoll and Vincent (1992) that showed that the utilisation of trauma teams not only reduced resuscitation times but also mortality, resulting in quicker delivery to definitive care.

The study by Driscoll and Vincent (*1992*) showed that time taken to implement life-saving procedures and prolonged resuscitation impacted negatively on patient outcomes. This is a logical conclusion. It also showed that it was experience and not numbers that affected the final outcome of these patients (*Deo et al. 1997*). Limited staffing may therefore not be an excuse for poor service delivery. The study emphasised the role of organised protocol-driven teams as being a key ingredient in reducing mortality rates. This is exemplified by the system implemented at Facility A.

5.2.7 Trauma Registries

One of the greatest frustrations for the researcher was the lack of adequate data capture and the loss of data at both facilities. Facility A has a dedicated trauma bank with dedicated data capturers and even at this facility important information was missing. If the data is not recorded on the resuscitation sheets it is impossible for it to be captured. At Facility B it was almost impossible to obtain the files of patients who fulfilled the population profile for the study. At Facility B, 150 potential participants were identified but only 57 could finally be included in the study. A number of factors interfered with a patient's inclusion in the sample population:

- the patient was not recorded as even having been in the **Emergency Department,** or the ward/ICU/theatre;
- no file could be located for that patient;
- an old file with absolutely no information on the patient's trauma admission was recorded (only visits to clinics for hypertension documented);
- there was a file with no information whatsoever;
- the file was illegible;
- there was poor note-keeping as the patient passed through the hospital.

A larger sample size, particularly at Facility B, may have significantly impacted on the study outcomes.

5.2.8 Training

At Facility A it is a pre-requisite for all doctors working in the Trauma Centre to not only have ATLS training but to maintain registration. A refresher course must be completed every four years to update knowledge. At Facility B there is no such prerequisite and the doctors and nurses had varying levels of experience and ATLS certification.

Table 4.5 shows that there were more ATLS trained doctors at Facility A than at Facility B ($p<0.0001$). This was highly statistically significant. It also showed that this affected management in the ICU by documenting the trends in both SBP and DBP and proved overall that doctors who were ATLS trained improved the survival rate of their patients.

This supports the study by Ali et al. that showed that trauma outcomes were significantly better following ATLS training and that by Marshall et al. (*2001)* that showed that it improved both the skill set and confidence of junior doctors exposed to this training.

An interesting study conducted by Major King of the United States Army *(Major King et al 2006.)* looked at the effect of simulated training in America's Forward surgical teams. He found that even in these highly trained, highly experienced individuals, there were significant breaches in basic ATLS protocol, record-keeping and communication. Different individuals were performing the same task and wasting human resources. The investigator therefore hypothesises that if these individuals, trained in ATLS, DSTC and other tertiary level training systems, become disorientated in a high-stress environment, the effect on care providers with less trauma experience (Facility B) may be even greater.

Interns working at Facility A are required to spend two weeks in the Trauma Centre and are encouraged to obtain ATLS certification during their surgical block (preferably before commencement.) Facility B also encourages its junior staff to attend ATLS and this is exemplified by the change in confidence, clinical management and improved skill set seen in these individuals after the course. In many circumstances, their knowledge of trauma resuscitation and evidence-based management exceeds that of their more experienced colleagues. Given the nature of South African medicine and the need to send young inexperienced doctors to more rural locations (community service) with less supervision, it is imperative to impart to them as much skill as possible. This is essential to the level of care provision to the patient and also the psychological well-being of these doctors. If they feel more prepared they are less likely to succumb to anxiety, depression and burnout.

5.2.9 Experience

O'Keefe expressed the widely held and logical belief that increased experience improved trauma outcomes (*O'Keefe et al. 1999*). The reality in the South African setting is that smaller more rural hospitals with less experienced staff are not immune to the trauma epidemic. The Royal College of Surgeons showed (*1988)* an increase in mortality when patients were managed by inexperienced doctors, a logical conclusion. At Facility A, there is a trauma surgeon on site. This surgeon is required to be present at resuscitation and to have knowledge of every patient in the Ward/ICU and casualty. The only time the surgeon may not be present is if he/she is in the operating theatre. At Facility B the surgeon on call is a general surgeon who may or may not have extensive trauma experience. As exemplified by Figure 4.1, there were more registrars and consultants working and operating at Facility A than at B. This was also shown to be statistically significant ($p<0.0001$).The majority of anaesthetists and surgeons at Facility B were medical officers with varying levels of experience.

This indicates that the seniority and level of experience of the doctors involved in the surgical management impacts on mortality.

Wyatt et al. found a positive correlation between the seniority of the doctor and reduced mortality (*Wyatt et al. 1999*). The surgeon at Facility B is not on site and it may take up to an hour for them to reach the hospital. The intern is often the first surgical doctor to see a patient and may be the only doctor available to care for that patient if the attention of more senior staff is demanded elsewhere (theatre).

Facility A has medical officers running its ward/ICU and casualty. Any intern rotating through the unit has full support.

5.2.10 Time

Sampalis stated in his study that time to intervention and resource distribution was a significant predictor of outcomes. The Korean and Vietnamese wars set the standard for pre-hospital care. Patients were rapidly transferred to acute-care field hospitals located on the battle lines, where they were stabilised and subsequently transported to definitive care (*American Trauma Society*). In a review article that looked at casualty evacuation times in the military, the ‘1:2:4 hour rule’ was discussed. ATLS protocol-driven resuscitation in the first hour: life-saving surgery within 2 hours: and definitive surgery within 4 hours of injury. What all the above articles have in common is that time is of the essence. The literature shows that the faster the patient is transported to definitive care, the better the outcome.

Unfortunately, the researcher’s study was unable to support the above literature except with regard to the time it took a patient to be seen by a surgeon in casualty. The standard deviation at both hospitals was extremely variable.

There was a statistically significant difference between time at Facility A and B ($p=0.0016$) in favour of Facility A. At Facility A the longest time taken to see a patient was in the range of 70 minutes, whilst at Facility B there was a standard deviation of more than 300. What is also concerning is that at Facility B the first member of the surgical team to see the patient may be an intern.

Pre-hospital time was not statistically significant based on its p value. In 1918 the first Field Surgical Pocket Book was published. It stated that “the rule at the front is to get the wounded man to the casualty clearing station as soon as possible”. Melson and Volkers noted three things in their publication: the proximity of helicopters and ambulances was important; and good resuscitation, combined with reduced Emergency Department times, reduced mortality (*Melson et al. 1975*). Literature on WWII and the Korean War showed that it could take upwards of 10 hours to transport a patient to definitive care. This impacted on mortality. Looking at the Emergency Department times for both Facility A and B, it can be seen that there is a wide variation. It must be mentioned that regardless of the statistical findings, both sets of patients at both facilities spent an unacceptably long period of time waiting in the Trauma Centre or Emergency Department respectively.

The time to definitive care for a haemodynamically unstable patient (defined as a drop in systolic below 90mmHg on at least one occasion whilst in the Emergency Department) was 334 minutes at Facility A and 117 minutes at Facility B. This implies that hypotensive patients were taken to ICU or to the operating theatre within a significantly shorter period of time at Facility B as compared to Facility A. The concern is that Facility B had the higher mortality rate and it would be expected, as supported by the literature (*Melson et al. 1975, Gervin et al. 1982*), that reduced time would translate into reduced mortality. This is not the case in this study and again points to the degree of clinical care at the individual facilities as being the area that impacts most on trauma mortality. Time in theatre for the haemodynamically unstable patients at both facilities was under three hours, applying the 1:2:4 rule mentioned in the book by Melson and Volkers (*1975*), definitive care falls well outside of the acceptable time period. This is an area for improvement. If damage control principles were being applied, the patients would be out of theatre within a 60-minute cut-off period. The statistical significance of the duration of the unstable patient in theatre points to a lack of resources (i.e. ICU beds) and possibly the degree of skill of the operating surgeon (Consultant vs MO or Registrar) - less experience leads to longer surgeries.

5.2.11 Trauma Scoring Systems

The RTS/GCS/ISS and PS were statistically significant when comparing survivors to non-survivors. However, they showed no statistically significant difference ($p \leq 0.68$.) when comparing Facility A to Facility B. This shows that the probability of survival of both patient groups should be similar because their physiology on arrival is similar. There is, however, a marked difference in the predicted probability of survival (PS) and the actual probability of survival (PS) at Facility B.

The predicted PS (72.89±33.08) was actually on average very good for those patients who eventually demised. The two clinical factors that were identified as being important in the management of these patients was blood pressure as they transitioned from casualty to ICU and GCS on arrival in casualty. Again the inference is on recognition of shock and acting to stop the bleeding as soon as possible, and perhaps managing major head injuries to a simple, evidence-based protocol (Brain Trauma Foundation Guidelines). Implementation of Brain Trauma Foundation Guidelines speaks to maintaining physiological parameters and not necessarily additional equipment. The implementation of Brain Trauma Foundation Guidelines was associated with decreased mortality and shorter hospital stay compared to outcomes preceding implementation.

The ISS for non-survivors at A was higher and therefore implied greater injury, whilst the ISS for non-survivors at B was almost half that of A and not statistically significant when comparing it to the ISS for survivors at B (p=0.31). Therefore the severity of the injuries of non-survivors at A was in keeping with the calculated PS (49±39%), whilst that at B was not (73±33%). Again, this begs the question as to how aggressively these patients are being resuscitated. When the average ISS of the non-survivors at Facility A (40.44±22.22) is compared with the average ISS of non-survivors at Facility B (27.63±16.25), the ISS is significantly lower and the probability of survival is higher. However, the overall mortality rate at Facility B is higher when compared to Facility A. This is concerning because it points to the level of observation and management of patients as they transition through the facility.

Glasgow Coma Scale (GCS)

There was a statistically significant difference in GCS comparing survivors with non-survivors on admission to the Emergency Department (p<0.011) (Table 4.2). GCS is the most heavily weighted component of the RTS and therefore this indicates it as a significant predictor of mortality rate in the trauma population.

5.2.12 Physiology

There was a statistical difference between the DBP (p=0.0112) and pulse rate (p=0.0159) when comparing all patients admitted at Facility A and B, in favour of Facility A (Table 4.4). Figure 4.5 also shows that, as patients transitioned from casualty to theatre to ICU, the DBP at Facility B actually dropped whilst at Facility A there was a definite improvement.

Temperature

Temperature is an important predictor of mortality (*Shafi et al. 2005, Luna et al.* 1987*, Jurkovich et al. 1987, Steinmann et al. 1990, Hardcastle et al. 2013)*. It was, however, not statistically significant when comparing survivors and non-survivors between the two facilities (survivors A/B: 36.0/36.1 p=0.74 and non-survivors A/B: 35.2/37.2).Only 36.8% of patients at Facility A had a temperature recording upon arrival in the trauma centre. This is concerning because it is part of this facility's protocol for temperature to be recorded, particularly because its value as a predictor of survival is recognised.

The average temperature for survivors at Facility A was 36.0±1.3. Amongst non-survivors it was 35.2±2.1 (this value lies just short of the definition for mild hypothermia and is therefore expected). At Facility B, 49.1% of patients had a temperature recording. The average temperature for survivors was 36.1±0.8 and 37.2±0.6 for non-survivors. There is very little difference between the two, which again implies that something is happening with the clinical management of patients at Facility B. Why do patients with the same ISS and the same temperature at the same facility show such a difference in outcome (some die and some survive)? What parameter is deciding the outcome? The difference in temperature for those patients who did not survive at A and B was not statistically significant and therefore not a factor affecting mortality. Those patients at Facility A with a temperature below 36 degrees had, on average, higher ISS, with an average ISS of 26. Patients at Facility B with a temperature below 36 degrees also had on average a higher ISS.

5.3 Mortality Rates

The study included 239 patients who fulfilled criteria. Of these, 43 patients did not survive. The overall difference in mortality rates at both facilities was 27/183 (14.8%) and 16/57(28.1%) with a p value ≤0.0298. This is statistically significant.

CHAPTER 6

CONCLUSION

6.1 Introduction

The aim of this study was to determine whether or not there was a significant difference between the mortality rates of trauma patients in a Level 1 equivalent Trauma Centre in a South African hospital compared to those of trauma patients at a South African regional facility. These patients presented with similar injury severity, physiological profiles and predicted mortality. The study also examined those trauma system factors that potentially impact mortality.

The hypothesis stated that the mortality rate in a Level 1 Trauma Centre would be significantly lower than that of a regional facility without a separate Trauma Centre. A reduced mortality rate would support the argument for implementing trauma systems.

Financial assistance in the South African health care system is limited, therefore strategies to improve health care provision must be cost effective. The study aimed to investigate the factors that influence trauma mortality and to highlight cost-effective interventions and best-practice resource distribution such as pre-hospital intervention, casualty response, more (appropriately trained) staff and greater ICU access to maximise the benefit.

In this study the pre-hospital teams were efficient and able to bring patients to both facilities with relative speed. Pre-hospital interventions did not have an effect on mortality. Whilst there appeared to be a greater percentage of penetrating versus blunt force trauma, the mechanism of injury did not affect the mortality rate at either facility. The increase in mortality and therefore the weakness in the system was at the level of the management and monitoring in casualty and time to definitive care. The sample groups presented with similar demographic profiles, with the same level of injuries and the same basic physiological profile. In some cases the patients at facility B had a shorter time to definitive care and yet these were the patients with the highest mortality rates. At Facility A the probability of survival (PS) of the non-survivors was as expected, based on their ISS. Whilst at Facility B the predicted PS was almost double the expected rate based on their RTS and ISS. The RTS was not an accurate predictor of mortality for patients admitted to Facility B because many of the patients who were expected to survive died.

Facility A implemented a horizontal organisation model in its resuscitation protocol and could do so because of its trauma teams. The immediate response of the trauma team as well as the mandatory requirement of specialist and registrar presence within 20 minutes of the start of the resuscitation translates into decision making at the appropriate level and the allocation of tasks that reduce resuscitation times. Facility B has no such protocol and relies on a lottery system whereby the first available person is the one who controls the resuscitation. This could be anyone from a nurse to an intern to the medical officer. The consultant is not on site and therefore is generally not involved in resuscitation. Decisions are often made by junior staff. The literature supports the creation of trauma teams and trauma units as is seen by the response by Trunkey in an article on the regionalisation of care. He felt that the implementation of trauma units and trauma systems should no longer be disputed but rather should be the standard of care.

The international literature supports parameters such as SBP (*Chan et al. 1997),* temperature (*Steinmann et al. 1990*), ISS and pre-hospital time (*Mock et al., Arreola-Risa et al., Gervin et al.*) as factors predicting mortality, but the researcher was unable to duplicate these results because of a lack of adherence to data-recording protocols, particularly at the regional hospital. There is a wealth of information that could have been gleaned, based on the researcher's own experience at both facilities. It would be interesting to investigate whether this is the norm for regional hospitals nationally. The 2013 article written by Hardcastle and published in the *World Journal of Surgery* would suggest that this is the case (*Hardcastle et al. 2013*). It is expected that this is a universal problem. What is important is that as the patients progressed through Facility A, their blood pressures generally stabilised, whilst at Facility B this was not evidenced. As can be seen from Figure 4.4, patients transitioned from casualty to theatre to ICU with significant variability in the stability of their haemodynamic status.

Patients at Facility A were generally in the emergency department for a longer period of time than at Facility B. However, Facility A is able to run its resuscitation bays as Intensive Care Units whilst awaiting transfer to theatre or ICU. This is not the case at Facility B. The majority of surgeons and anaesthetists at Facility B are medical officers and lack the qualifications to deliver the same level of care as provided at Facility A.

Time in ICU was not a factor identified as affecting mortality but there was also a paucity of data available on ICU stay, including physiological parameters, especially recorded temperature. What can be inferred is that the model of a closed ICU, as exemplified in Facility A's ICU and resuscitation bays, improves survival. This is based on the fact that the doctors responding to patients in both these areas are ATLS trained.

ATLS training was the most important factor identified as having an effect on mortality rate when the two facilities were compared. At Facility B all the patients who demised were initially resuscitated by doctors who were not trained in ATLS.

Although most of the factors could not be proven to influence mortality, the investigator infers, on the basis of the above findings, that it is the lack of suitably trained human resources (nurses and doctors) that directly affects the ability of facilities to save life. This may be due to a lack of adherence or rather a lack of protocol at these facilities when it comes to the standard of trauma care applied. Training programs such as ATLS are required. They offer a common language for team communication while providing a simple mantra for the provision of care. Even in the midst of extreme chaos, the health care provider can go back to 'ABCDE': **A**irway, **B**reathing, **C**irculation, **D**isability and **E**xposure. Prevention of injury to the population is obviously the primary strategy to pursue. However, the greatest limiting factor to this solution is the human condition and people's resistance to adhering to basic safety interventions (wearing a seatbelt, adhering to the speed limit, wearing a helmet).

The paucity of available data is in itself an indicator of the status of our health care provision in the trauma setting in South Africa. It is hoped that this study may set the stage for a prospective, longitudinal study with data capture and recording controls at site. This would require human resources and greater co-operation than this investigator was able to obtain.

This study fulfilled the objective of showing that Level 1 trauma care significantly affects mortality and it has demonstrated the requirement for having appropriately ATLS trained doctors supported by trauma-trained nursing support in ensuring the survival of trauma victims.

6.2 Recommendations for Future Interventions at any Facility Administering Trauma Care

1. **Instituting triage protocols**

   CDC or triage sieve/sort or the South African Triage Score to mandate immediate senior response. Trained nurses would triage patients on arrival. The only requirement would be to decide which criteria mandate immediate response by senior doctors. The additional budgetary expense would be overtime pay for nurses. Triage protocols are essential in managing the trauma population *(Eastern Association for the Surgery of Trauma Guidelines, Hunt et al. 2013, Sasser et al. 2011*).

2. **Compulsory ATLS training of doctors and nurses managing trauma patients**

   This forms part of the undergraduate training of medical professionals at all universities and allows for a common language in trauma care. The mandatory training of trauma nurses would be an increased budgetary requirement.

3. **Providing intensive care/ventilation facilities in the emergency department under qualified supervision**

   ICU beds are often not immediately available to the severely injured. It is often necessary to ventilate these patients in the emergency department (ED) for prolonged periods of time. If this is managed according to the protocols of an ICU, it can reduce mortality while patients are awaiting ICU placement.

4. **Instituting a horizontal organisation model during resuscitation**

   Driscoll in 1989 performed a study in four centres, one in the USA, one in the UK and two in South Africa. In terms of outcome, the worst performing units were the South African Units, where trauma resuscitations were performed by individuals in an unorganised fashion. Resuscitation by a team with pre-allocated tasks allows interventions to proceed simultaneously, time to life-saving procedures to be shortened, time to senior decision-making to be shortened, and survival improved. As a result of this study, the concept of a trauma team was implemented at Facility A, using junior doctors with the same seniority, but with ATLS training, practised to a resuscitation protocol. Perhaps this is the central difference.

REFERENCES

1. Ali J, Adams R, Butler AK, et al. Trauma outcome improves following the Advanced Trauma Life Support program in a developing country. .*J Trauma* 1993; 34: 890-898.
2. American Trauma Society. Appendix B-Historical Overview of Trauma System Development (from the Trauma System Agenda for the Future). Washington DC: US Department of Transportation.
3. American college of critical care medicine: Critical care delivery in the Intensive Care Unit: Defining clinical roles and the best practice model. Critical care med 2001; 29: 2007-2019.
4. Arreola-Risa C, Mock C.N, Padilla D, Cavazos L, Maier RV, Jurkovich G.D. Trauma care systems in Urban Latin America: The priorities should be Pre-hospital and Emergency room management. *J Trauma* 1995; 39(3):457-462.
5. Baker SP et al, "The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care", J Trauma 14:187-196;1974
6. Bernabei AF, Levison MA, Bender JS. The effects of hypothermia and injury severity on blood loss during trauma laparotomy. J Trauma 1992; 33:835-839.
7. Bernard SA, Gray TW, Buist MD. Treatment of comatose survivors of out -of -hospital cardiac arrest with induced hypothermia. *N Engl J Med* 2002; 346:557-563.
8. Birkmeyer JD, Birkmeyer CM, Wennberg DE, et al. Leapfrog Safety Standards: Potential Benefits of Universal adoption. Washington, DC, the Leapfrog Group, 2000.
9. Bradshaw D, Schneider M, Dorrington, Bourne DE, Laubscher R. South African cause-of-death profile in transition-1996 and future trends. *S Afr Med J* 2002; vol. 922(8) pp.618-23.
10. https://www.braintrauma.org/coma-guidelines/searchable-guidelines/
11. Bulger EM1, Nathens AB, Rivara FP, Moore M, MacKenzie EJ, Jurkovich GJ; Management of severe head injury: institutional variations in care and effect on outcome. *Crit Care Med* 2002; vol. 30(8): 1870-6.

12. Callese CT, Richards CT, Shaw P et al. Trauma System development in low and middle income countries: a review. *Journal of surgical Research* 2015; 193(1):300-307.

13. Cancio LC, Wade CE, West SA et al. Prediction of Mortality and the Need for Massive Transfusions in Casualties Arriving At Combat Support Hospitals in Iraq. *J Trauma* 2008; 64(2):S26-S55.

14. Carlson RW, Weiland DE, Srivathsan K. Does a full- time 24 hour intensivist improve patient care and efficiency? Crit Care Clin 1996; 12: 525-55.

15. Celso B, Tepas J, Langland-Orban B, Pracht E, Papa L, Lottenberg L et al. A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centres following the establishment of trauma systems. *J Trauma* 2006; 60:371-377.

16. Champion H, Sacco W, Copes W et al. A Revision of the Trauma Score. *J Trauma* 1989 May; 29(5): 623-9.

17. Chan L, Bartfield JM, Reilly JM. The significance of out-of-hospital hypotension in blunt trauma patients. *Acad Emer Med* 1997; 4(8): 785-788.

18. Cheddie S, Muckart DJJ, Hardcastle TC, Den Hollander D, Cassimjee H, Moodley S. Direct admission versus inter-hospital transfer to a level 1 trauma unit improves survival: An audit of the new Nkosi Albert Luthuli Central Hospital trauma unit. *SAMJ* 2011; 100(6): 176-178.

19. Centers for Disease control (CDC). Child passenger restraint use and motor vehicle fatalities among children, United states, 1982-1990. MMWR *Morb Mortal Wkly Rep* 1991; 40: 600-602.

20. Chittawatanarat K, Pamorsinlapathum T. The impact of closed ICU model on mortality in general surgical intensive care unit. *J Med Assoc Thai* 2009 Dec;92(12):1627-1634.

21. **http://www.coma.ulg.ac.be/images/gcs_comments.pdf**

22. Cryer HG, Leong K, McArthur DL, et al. Multiorgan failure: by the time you predict it it's already there. *J Trauma* 1999; 46: 597-606.

23. DeBakey, ME. History, the torch that illuminates: lessons from military medicine. *Mil Med* 1996; 161:711-716.

24. **Deo DS, Knottenbelt JD. Evaluation of a small trauma team for major resuscitation. *Injury 1997*; 28 (9-10): 633-637.**

25. Dimick JB, Pronovst PJ, Heitmiller RF, Lipsett PA. Intensive care unit physician staffing is associated with decreased length of stay, hospital cost, and complications after oesophageal resection. *Crit Care Med* 2001 Apr;29(4):753-758.

26. Driscoll PA, Vincent CA. organising an efficient trauma team. *Injury 1992;* 23(2):107-110.

27. Driscoll PA, Vincent CA. Variation in trauma resuscitation and its effect on patient outcome. *Injury* 1992; 23(2):111-113.

28. DSD, DWCPD and UNICEF 2012. Violence against Children in South Africa. Pretoria: Department of Social Development/Department of Women, Children and People with Disabilities/ UNICEF.

29. Eastern Assosciation for the Surgery of trauma Guidelines.

30. Eastridge BJ, Jenkins D, Flaherty S, Schiller H, Holcomb JB. Trauma system development in a Theatre of War: Experiences from Operation Iraq Freedom and Operation Enduring Freedom. *J Trauma 2006;61(6):1366-1373.*

31. Esposito TJ, Sanndal ND, Hansen JD, Stuart R. Analysis of preventable trauma deaths and inappropriate trauma care in a rural state. *J Trauma* 1995; 39(5): 955-962.

32. Franklin GA, Boaz PW, Spain DA, Lukan JK, Carrilo EH, Richardson JD. Pre-hospital hypotension as a valid indicator of trauma team activation. *J Trauma* 2000; 48:1037-1039.

33. Gentillelo LM, Jurkovich GJ, Stark MS, Hassantash SA, O'Keefe GE. Is hypothermia in the victim of major trauma protective or harmful? A randomized prospective study. *Ann Surg* 1997; 226:439-447.

34. Gervin AS, Fischer RP. The importance of prompt transport in the salvage of patients with penetrating heart wounds. *J Trauma* 22; 483:1982.

35. Goosen JG pers.comm, "Quality of Trauma Care in South Africa".

36. Gross CP, Anderson GF, Powe NR. The relationship between funding by the national institutes of health and the burden of disease. *NEJM* 1999; 340:1881-1887.

37. Gutsche JT, Kohl BA. Who should care for intensive care unit patients? *Critical Care Medicine.* 2007; 35 (2 suppl) S18-23. (PUBMED).

38. Hardcastle TC, Stein E, Boffard K, Goosen J et al. Guidelines for the assessment of trauma centres for South Africa. *SAMJ* 2011; 101(3): 189-194.

39. Hardcastle TC et al. The 11 Ps of an Afrocentric trauma system for South Africa-time for action. SAMJ 2011; 101(3): 160-162.

40. Hardcastle TC et al. An Assessment of the Hospital Disease Burden and the Facilities for the In-hospital Care of Trauma in Kwazulu-Natal, South Africa. *World J Surg* 2013; 37 (7): 1550-1561.

41. Haupt M, Bekes C, Brilli R. Guidelines on Critical Care services and Personnel: Recommendations based on a System of Categorization of Three Levels of care. *Crit Care Med* 2003;1(11):2677-2683.

42. Heckbert SR, Vedder NB, Hoffman W, et al. Outcome after haemorrhagic shock in trauma patients. *J Trauma* 1998; 45:545-549.**

43. Hoff WS, Schwab CW. Trauma System Development in North America. *Clinical Orthop* 2004; 422:17-22.

44. Hunt D, Berg G, Zakula R et al. Treatment provider is most predictive of ED dismissal in minimally injured patients: a retrospective review. *J Trauma Manag Outcomes May 2013*;7:5.

45. Jayaraman S[1], Sethi D, Chinnock P, Wong R. Advanced trauma life support training for hospital staff. Cochrane Database Syst Rev. 2014 Aug 22;8:CD004173. doi: 10.1002/14651858.CD004173.pub4.

46. Jurkovich GJ, Greiser WB, Luterman A, Curreri PW. Hypothermia in trauma victims: an ominous predictor of survival. *J Trauma* 1987; 27:1019-1024.

47. Kane G, Wheeler NC, Cook S, et al. Impact of the los Angeles County trauma system on survival of severely injured patients. *J Trauma* 1992; 32:576-583.

48. MAJ. DR King, MB Patel, AJ Feinstein, SA Earle, et al. Simulation training for a mass casualty incident: Two-year experience at the army trauma training center. *J Trauma* 2006; 61(4):943-8.

49. Laing G, Bruce J, Aldous C, Clarke D. The design, construction and implementation of a computerised trauma registry in a developing South African metropolitan trauma service. *Injury* 2014; 45: 3-8.

50. Lanzetta and Roby, 1956; Hallam and Stammers, 1981.

51. Lewis FR: pre-hospital care: The role of the EMT-paramedic. In West JG(ed): *Trauma care systems, clinical, financial and political considerations.* Westport, CT. Greenwood publications Group 1983;77-85.

52. Luna GK, Maier RV, Pavlin EG, Anardi D, Copass MK, Oreskovich MR. Incidence and effect of hypothermia in seriously injured patients. *J trauma* 1987; 27(9):1014-1018.

53. Mackenzie EJ, Rivara FP, Jurkovich GJ et al. A national evaluation of the effect of trauma-centre care on mortality. *NEJM* 2006; 34(4):366-378.

54. Mann N C, Cahn R M, Mullins R, et al. Survival among injured geriatric patients during construction of a state-wide trauma system. *J Trauma* 2001: 50:1111-1116.

55. RL Marshall, JS Smith, PJ Gorman, TM Krummel, RS Haduck, RN Cooney. Use of a Human Patient Simulator in the development of Resident trauma Management skills. *J Trauma* 2001; 51:17-21.

56. Mathers CD, Stein C, Ma fat D et al. Global Burden of Disease in 2002: Updated projections of global mortality and burden of disease: 2002-2030; data sources, methods and results. Global Programme on Evidence for Health policy Discussion Paper No. 54. World Health Organisation December 2003.

57. Melsom MA, Farrar MD, Volkers RC. Battle Casualties 1975. Ann RCS 56:289-303.

58. Messick WJ, Rutledge R, Meyer A. The Association of advanced life support training and decreased per capita trauma death rates: An analysis of 12,417 trauma deaths. *J Trauma* 1992;33(6):850-855.

59. Mock C.N, Adzotor K, Ellis MB, Conklin E, Denno DM, Jurkovich GJ. Trauma outcomes in the rural developing world: Comparison with an urban Level1 trauma centre. *J Trauma* 1993; 35(4):518-523.

60. Moore L, Hanley JA, Turgeon AF, Lavoie A. Evaluation of the long term trend in mortality from injury in a mature inclusive trauma system. *World J Surg* 2010; 34:2069-2075.

61. Muckart DJJ. Trauma-the malignant epidemic. *SAMJ* 1991; 79:93-95**.**

62. **Muckart DJJ et al. Palliative care: Definition of euthanasia. *SAMJ 2014*; 104(4): 259-260.**

63. Murray CJL, Lopez AD. Alternative projections of mortality and disability by cause 1990-2020.Global burden of disease study. *Lancet 1997; 349* (9064):1498-504.

64. Murray CJL, Lopez AD. Mortality by cause for eight regions of the world: Global burden of disease study. *Lancet 1997*; 349:1269-76.

65. National Research Council. Accidental Death and Disability: The Neglected Disease of Modern Society. Washington DC.: National Academy of Sciences,1966.

66. Nirula R, Maier L, Moore E et al. Scoop and run to the trauma centre or stay and play at the local hospital: hospital transfer effects on mortality. *J Trauma 2010*; 69(3):595-99.

67. Norman R, Matzopoulos R et al. The High burden of injuries in South Africa. *Bull WHO 2007*; 85: 695-702.

68. Nozari A, Safar P, Wu X. Suspended animation can allow survival without brain damage after traumatic exsanguinations cardiac arrest of 60min in dogs. *J Trauma* 2004:57: 1266-1275.

69. O'Keefe GE, Jurkovich GJ, Copass M, et al. Ten-year trend in survival and resource utilization at a Level 1 trauma centre. *Ann Surg* 1999; 229 :409-15.

70. Ornato J, Craren EJ, Nelson NM, et al. Impact of improved emergency medical services and emergency trauma care on the reduction in mortality from trauma. *J Trauma* 1985 July; 22:443, 1982.

71. Lieutenant colonel Paul J Parker. Casualty Evacuation timelines: An evidence Based review. JR Army Med Corps 153(4): 274-277.

72. Peek-Asa C, Zwerling C et al. Role of Environmental Interventions in Injury Control and prevention. *Epidemiological Review 2003 February* ;25:77-89

73. Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA* 2002 Nov 6; 288(17):2151-2162.

74. Rainier TH, de Villers-Smit P. Trauma systems and emergency medicine. *Emerg Med* 2003:15; 11-17.

75. Rivara FP, Wolf ME. Injury Research: Where should we go from here? *Paediatrics 1989; 84*(1): 180-181.

76. Robertson LS. Injuries: causes, control strategies and public policy. Lexington Books. Lexington Mass 1983.

77. Lieutenant Colonel Jeffrey V Rosenveld RAAMC. Training the Military Surgeon: Definitive surgical trauma Course (DSTC) and the development of a military module. *ADF Health* **2002** September Vol 3.

78. Royal College of Surgeons of England 1988. The management of patients with major injuries 1988. *London: RCS*.

79. Rutledge R, Fakhry SM, Meyer A, et al. An analysis of the Association of trauma centers with per capita hospitalizations and death rates from injuries. *Ann surg* 1993; 218:512-524.**

80. Ryan M, Thorson C, Otero C et al. Clinical Applications of Heart Rate Variability in the Triage and Assessment of Traumatically Injured Patients 2011. *Anaesthesiology research and Practice. PMC3038414.*

81. Sampalis JS, Denis R, Lavoie A, Frechette P, Boukas S, Nikolis A, Benoit D, Fleiszer D, Brown R, Churchill-Smith M, Mulder D. Trauma care regionalization: A process- outcome evaluation. *J Trauma 1999;* 46(4):565-581.

82. Sarche M, Spicer P. Poverty and Health Disparities for American Indian and Alaskan native children: Current knowledge and future prospects. *Ann N Y Acad Sci*. 2008 ; 1126: 126-136

83. Sasser S, Hunt R, Faul M et al. Guidelines for Field Triage of Injured Patients: Recommendations of the National Expert Panel on Field Triage,2011. Center for Disease Control and Prevention. Mortality weekly. January 2012/61(RRO1);1-20.

84. Sauaia A, Moore FA, Moore EE, Haenel JB, Read RA, Lezotte DC. Early predictors of post injury multi organ failure. *Arch Surg* 1994;29: 39-45.

85. Shackford SR, Mackensie RC, Hoyt DB et al. Impact of a trauma system on outcome of severely injured patients. *Arch Surg 1987*;122:523-527

86. Shahid Shafi, Alan C Elliot, Larry Gentillelo. 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. *J Trauma* 2005;59(5):1081-1085

87. Smith GS et al. Unintentional injuries in developing countries: The epidemiology of a neglected problem. *Epidemiol Rev 1991;* 13:228.

88. Smith JP, Bodai BI, Hill AS, et al. Pre-hospital stabilisation of critically injured patients. A failed concept. *J Trauma 1985; 25:65*.

89. Smith SM, Goodman RA, Thacker SB, et al. .Alcohol and fatal injuries: temporal patterns. *Am J Prev Med 1989;*5:296.

90. Steeves LC. The need for continuing medical education. *Canada Med.Ass.J* 1965; 92:758-761.

91. Steinemann S, Shackford SR, Davis JW. Implications of admission hypothermia in trauma patients. *J Trauma* 1990; 30:200-202.

92. Szcygiel M, Wright R, Wagner E, et al. Prognostic indicators of ultimate long term survival following advanced life support. *Ann Emerg Med* 1981; 10:566.

93. The impact of closed versus open format ICU admission practices on the outcome of high risk surgical patients: a cohort analysis. *BMC SURG* 2011; 11:18.

94. Thompson DC, Rivara FP, Thompson RS. Effectiveness of bicycle safety helmets in preventing head injuries: a case control study. *JAMA* 1996; 276: 68-73.

95. Tracy, E. Combining military and civilian trauma systems: the best of both worlds. *Top Emerg. Med 2005; 27: 170-175.*

96. Traffic safety facts 1995: a compilation of motor vehicle crash data from the Fatal Accident Reporting system and the General estimates system. Washington, DC: National Highway traffic safety Administration, 1996.

97. Trauma.org website

98. Trunkey, DD. History and development of trauma care in the United States. *Clin Orthop Relat Res* 2000; (374): 36-46.
99. Trunkey DD. Trauma: A Public Health problem. In Moore EE (ed): *Early Care of the Injured patient,* ed 4. Philadelphia, BC Decker, 1990, pp3-11.
100. Trunkey, DD. In search of solutions. *J Trauma.* 2002; 53:1189-1191.
101. Trunkey DD. Trauma: accidental and intentional injuries account for more lives lost in the US then cancer and heart disease-among the prescribed remedies are improved preventive efforts, speedier surgery and further research. *Sci Am* 1983; 249: 28-35.
102. Trunkey DD. Is ALS necessary for pre-hospital care? *J Trauma 1984;* 24:86.
103. Trunkey DD. The medical world is flat too. *World J Surg* 2008; 32:1583-1604.
104. T M Tshiguvho, K Bosilong et al. Developmental Research Africa and CSIR Defence, Peace, Safety and Security Unit. Consolidation Report of the Nature and Prevalence of Domestic Violence in South Africa.2008.
105. Walker, JA. Injury control: a guide to the causes and prevention of trauma. Lexington, Mass.: Lexington books, 1985.
106. Wolberg AS, Meng ZH, Monroe 3rd, Hoffman DM. A systematic evaluation of the effect of temperature on coagulation enzyme activity and platelet function. J trauma. 2004; 56:1221-1228.
107. World Health Organisation: Road Traffic Accidents in Developing countries. WHO Technical Report Series 703. Geneva, World Health Organisation, 1984.
108. World Health Organisation: Road traffic accidents in developing countries. WHO technical report series 703. Geneva, world health Organisation, 1984
109. World Health Organisation. Draft Plan for the Decade of Action for Road Safety. 2010-2020. #Geneva: World health organisation, 2010. http://www.who.int/roadsafety,Decade_of_action.pdf(accessed October 2013).

110. Wu Si, Malison MD. Motor vehicle injuries in Taiwan. *Asia Pac J Public Health* 1990;4:72.

111. Wyatt JP, Henry J, Beard D. The association between seniority of emergency doctor and accident outcome following trauma. *Injury* 1999; 30:165-168.

112. Yates DW, Woodford M, Hollis S. Preliminary analysis of the care of injured patients in 33 British hospitals: First report of the United Kingdom Major Trauma Outcome Study. *Br Med J* 1996; 305:737.

113. Young MP, Birkmeyer JD. Potential reduction in mortality rates using an intensivist model to manage intensive care units. *Eff Clin Pract* 2000 Nov-Dec;3(6):284-289.

114. Zenati M, Biliar T, Townsend R, Peitsman A et al. A Brief Episode of Hypotension increases Mortality in critically ill trauma patients. *J Trauma 2002; 3(2): 232-235*