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TRAUMA SYSTEMS

Development Strategies in Emerging Nations

Trauma Systems:

Development Strategies in Emerging Nations

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‘There is only one good, knowledge,
and one evil, ignorance.’

SOCRATES (470-399 BC)

‘To all frontline healthcare workers globally
during COVID-19 pandemic.’

List of Abbreviations

AAST	American Association of Surgery for Trauma
ACCP	American College of Chest Physicians
ACO	Accountable Care Organization
ACS-COT	American College of Surgeons Committee on Trauma
AHTR	Alfred Hospital Trauma Registry
AITR	Acute Intensive Trauma Rehabilitation
ALS	Advanced Life Support
ATLS	Advanced Trauma Life Support
ATCN	Advanced Trauma Care for Nursing
AUROC	Area Under the Receiver Operating Characteristic
AVF	Arteriovenous Fistula
BCVI	Blunt cerebrovascular Injury
BLS	Basic Life Support
CAG	Clinical Advisory Group
CBAHI	The Saudi Central Board for Accreditation of Healthcare Institutions
CDC	Center for Disease Control
CDG	Care Design Group
CTA	Computed Tomographic Angiogram
DCL	Damage Control Laparotomy
DCR	Damage Control Resuscitation
DR	Definitive Repair
DS	Definitive Surgery
DSTC	Definitive Surgical Trauma Care Course
DVT	Deep Vein Thrombosis
EAST	Eastern Association of Surgery for Trauma
ED	Emergency Department
EMS	Emergency Medical Services
EMT	Emergency Medical Technician

ERC	Endoscopic Retrograde Cholangiography
FCBT	Foley Catheter Balloon Tamponade
FOCUS-PDCA	Find, Organize, Clarify, Understand, Select-Plan, Do, Check, and Act
GLI	Gunshot Liver Injury
GSEST	Groote Schuur Emergency Surgery Triage
GSHTC	Groote Schuur Hospital Trauma Center
HREC	Human Research Ethics Committee
ICU	Intensive Care Unit
IPC	Intermittent Pneumatic Cuff Compressor
IRB	Institutional Review Board
ISS	Injury Severity Score
IVC	Inferior Vena Cava
KAMC	King Abdul-Aziz Medical City
KFMC	King Fahad Medical City
KPI	Key Performance Indicator
KSA	Kingdom of Saudi Arabia
KSMC	King Saud Medical City
LMWH	Low Molecular Weight Heparins
LOS	Length of Stay
MOH	Ministry of Health
MOC	Model of Care
MTP	Massive Transfusion Protocol
MVC	Motor Vehicle Crash
NOM	Nonoperative Management
NTP	National Transformation Program
PE	Pulmonary Embolism
PHAP	Program of Health Assurance and Purchase
PHTLS	Prehospital Trauma Life Support
PM&R	Physical Medicine and Rehabilitation
RT	Response Time (Chapter 5)
RT	Resuscitative Thoracotomy (Chapter 11)
RTA	Road Traffic Accident
SCFHS	Saudi Commission for Health Specialties
SHC	Saudi Health Council
SI	Shock Index

SOC	System of Care
SRCA	Saudi Red Crescent Authority
SSI	Surgical Site Infections
STAR	Saudi Trauma Registry
SW	Stab Wound
TBI	Traumatic Brain Injuries
TSSA	Trauma Society of South Africa
UFH	Unfractionated Heparins
VAI	Vertebral Artery Injury
VRO	Vision Realization Office
VRP	Vision Realization Program
VTE	Venous Thromboembolism

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CHAPTER 1

Introduction and Outline of the Thesis

Introduction

Trauma or physical injury is one of the leading causes of death and disability, and it has a significant impact on people's lives and puts a strain on healthcare systems around the world [1]. Road traffic accidents (RTAs) alone were the sixth leading cause of death in 195 nations and territories between 1980 and 2017 [2]. Trauma is a global public health problem with economic ramifications. Trauma systems, which provide an organized approach to acutely injured patients within a defined geographic area, from primary care to advanced care, have been shown in numerous studies to improve outcomes [3–12]. A trauma system comprises prehospital treatment, emergency room care, and definitive care (including preventative and rehabilitation programs).

South Africa is witnessing a quadruple burden of disease, including the HIV/AIDS pandemic, infectious diseases, new chronic ailments, and injuries arising from violence, RTAs, and other trauma [13]. Western Cape Province is severely affected and increasingly burdened by trauma due to the escalating use of alcohol and substance like 'tik' [14]. Compared to global norms, injury-related fatality rates in the Western Cape are roughly tenfold higher for males and sevenfold higher for females [15], with homicide and traffic-related fatalities in Cape Town remaining among the highest globally [16]. The greatest factor contributing to the Western Cape's high injury rates is violence. It is responsible for 12.9% of all premature deaths, compared to 6.9% for road traffic injuries [13]. The Western Cape has a higher ratio of premature mortality due to violence versus road traffic injuries than most other provinces, apart from the Northern Cape and Gauteng, which have comparable ratios. After HIV/AIDS, violence is the second leading cause of years of life lost (YLL) in the province, accounting for 14.1% of YLL, with higher mortality rates for males (129 per 100,000 versus 115 national average) and females (25 per 100,000 versus 21 national average) [13]. Donson and Peden discovered that most patients injured violently had abused alcohol and/or drugs prior to their injuries. More than 60% of patients were intoxicated at the time of presentation during a prospective study at the Groote Schuur Hospital Trauma Centre [17]. Bourne et al. confirmed the association between high homicide and traffic-related fatalities and alcohol and substance abuse among young males in Cape Town [16]. RTAs in South Africa are a prominent and underserved public health challenge that necessitates the participation of all sectors, including health [18]. Due to RTAs in

South Africa, the YLL trend was 5%, with the Western Cape already ahead of the trend at 6.9% YLL in 2000. Male deaths, pedestrian deaths, alcohol consumption related to drivers, pedestrian deaths, and weekend peaks are all high mortality patterns associated with traffic-related injuries in Cape Town [18].

In Saudi Arabia, trauma in the first four decades of life is the most significant cause of death. It is also the leading cause of disability among Saudi society's young and productive citizens [19]. With population growth, increased car ownership, and rapid highway infrastructure development, the frequency of major trauma and accompanying mortality has grown in Saudi Arabia in recent years [19,20]. RTAs are the second leading cause of death for men and children, with incidences increasing by 8.5% between 2005 and 2016 [21,22]. RTAs (52%) and falls (23.4%) were the most common types of injury between 2001 and 2010, with RTAs accounting for 7,661 fatalities in 2013 (88% M, 12% F) [23,24]. There were over 27,000 RTA-related emergency admissions and over 120,000 non-RTA-related trauma admissions in the Riyadh region in 2017, demonstrating the severity of the problem [24].

Although South Africa is one of the only countries on the African continent with a formal prehospital care system, many South Africans have limited access to basic trauma care due to distance and time constraints, as in most of the developing world [25]. South Africa lacks a cohesive nationwide trauma system. Prehospital care is provided by paramedics who offer basic or advanced life support and transport patients to the nearest hospital due to the scarcity of trauma centers. In-hospital care is inclusive, with only a few accredited trauma centers [26].

Despite being a prosperous country and trauma being a major health burden, no organized trauma system was available in Saudi Arabia until 2018 [27]. The nationwide trauma system development initiative started in the Riyadh region and was recently aligned with Saudi health care transformation and the Kingdom's Vision 2030.

The aim of the thesis is to look at various aspects of trauma systems in two emerging nations: Saudi Arabia, a high-income country, and South Africa, a middle-income country, particularly in the areas of prehospital, in-hospital, and rehabilitation.

Outline of the Thesis

Part 1 describes the background and development of trauma systems in two developing nations: South Africa and Saudi Arabia. Chapter 2 discusses the historical and contemporary contexts in which trauma systems operate in both countries. Chapter 3 narrates the recent transformation of Saudi healthcare and the new model of care in the Saudi healthcare system, which laid the foundation of trauma system development in the Kingdom. Chapter 3 portrays the design, development, and initial adoption of the Saudi Arabian trauma system, in line with the Kingdom's Vision 2030.

Part 2 describes the prehospital portion of trauma systems. Chapter 5 analyzes the effects of delays in emergency medical service responses on trauma outcomes. Chapter 6 explains that the administration of tranexamic acid in a hospital setting for bleeding trauma patients is often not feasible due to the longer prehospital time, especially in lower- and middle-income countries.

In-hospital trauma management starts in the emergency department (ED). **Part 3** concentrates on the improvement of trauma management in the ED. Chapter 7 emphasizes regular trauma resuscitation training, especially for healthcare professionals managing trauma patients. Chapter 8 discusses the importance of the shock index—a simple calculation based on initial vital signs—as a screening tool during presentation to the ED.

Part 4 details various aspects of the management of admitted trauma patients. Chapter 9 describes the selective nonoperative management of liver gunshot injuries. Chapter 10 is a pilot randomized controlled trial on laparoscopy versus clinical follow-up to detect occult diaphragm injuries following left-sided thoracoabdominal stab wounds. Chapter 11 explains how to deal with lethal penetrating trauma to the mediastinal vessels, and Chapter 12 outlines how to diagnose and manage blunt cerebrovascular injury.

Part 5 is a report on the complications of in-hospital trauma management. Chapter 13 describes surgical site infections following trauma laparotomy, and Chapter 14 describes the incidence and nature of venous thromboembolism in patients with polytrauma.

Part 6 describes the outcomes of in-hospital trauma management. Chapter 15 looks at the effects of a delay in surgery after scheduling, based on the emergency surgery triage system. Chapter 16 analyzes the outcomes of damage-control surgeries. Chapter 17 compares trauma management between two major trauma services in Riyadh, Saudi Arabia, and Melbourne, Australia. The findings are the first to report a significant trauma profile from a single center in the kingdom and to compare trauma outcomes with an international level 1 trauma center.

Finally, in **Part 7**, the rehabilitation portion of the trauma system is described. Chapter 18 emphasizes the early incorporation of acute intensive trauma rehabilitation into trauma programs.

Chapter 19 summarizes the findings presented in this thesis and presents a general discussion and future perspectives. The future perspective focuses on improvement in certain areas of trauma systems in both South Africa and Saudi Arabia, implementing a national trauma database, research and development, and trauma quality improvements in care processes and outcomes.

Chapter 20 presents a Dutch version of the summary of the thesis.

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PART 1 Trauma System

CHAPTER 2

Historical and current perspectives of two developing trauma systems: South Africa and Saudi Arabia

Sharfuddin Chowdhury,
Mark van Baal,
Luke Leenen

Under review

Abstract

The trauma system optimizes the management of trauma patients in a particular location. Simplifying all phases of trauma care from prehospital to rehabilitation enables more targeted treatment that improves patient outcomes. This article describes the history and current state of trauma systems in two emerging nations on two continents: South Africa, a middle-income country in Africa, and Saudi Arabia, a high-income country in Asia, focusing on prehospital, in-hospital, rehabilitation, trauma quality assurance, and research and development. South Africa's trauma system has evolved from a purely nonemergency-oriented, communicable disease hospital-centric approach to one with defined levels of care, national core standards for care, and quality assurance guidelines implemented by the national health department, which are applicable to both public and private healthcare facilities. On the other hand, Saudi Arabia lacked an organized trauma care system until 2018. Trauma was managed similarly to other medical or surgical emergencies. In late 2017, in accordance with the Kingdom's Vision 2030, a national initiative to develop a trauma system was launched. As a result, the Riyadh region has established a trauma network. King Saud Medical City, the region's largest hospital, is located in the heart of Riyadh and is the country's first level 1 trauma center designated by the Ministry of Health. Both countries' current trauma systems have some strengths, such as personnel education and training. Several critical components are missing that would enable them to achieve a superior outcome.

Introduction

A trauma system maximizes the management provided to trauma patients within a specific location. Streamlining all phases of trauma care (from patient transport through rehabilitation) enables a more tailored treatment that is most beneficial to patients' outcomes. All facilitators (political and medical) and trauma treatment providers must work collaboratively within the system to accomplish this goal. Establishing an effective trauma care system is a lengthy process that depends on a variety of elements and multiple authorities. Healthcare facilities, the structure of prehospital care, the type of injury, and the geographic and demographic context all play a role. These characteristics vary by location and are coordinated by several authorities [1].

Globally, the burden of trauma is disproportionately skewed toward Africa, with about 90% of trauma deaths occurring in Africa and the Near East, particularly in lower-middle-income countries (LMICs) with the least-developed healthcare systems [2]. With rare exception, most African countries have an underdeveloped or nonexistent trauma system. Due to a plethora of conflicting health goals, there are a few centers of excellence within a sea of apathy to the fate of the injured [3,4]. In Saudi Arabia, trauma is the leading cause of death in the first four decades of life and the second leading cause of death across all age groups. Trauma is also the leading cause of disability among Saudi society's young and productive members [5]. Major trauma and associated fatalities have increased in recent years in Saudi Arabia as a result of population growth, increased vehicle ownership, and rapid development of highway infrastructure. Saudi Arabia's Road fatality and injury rates are nearly tenfold those of other developed countries [5,6]. Saudi Arabia has recognized this avoidable health burden and the critical need for trauma centers and systems.

The article aimed at the history and current state of trauma systems in two emerging nations on two continents: South Africa, a middle-income country in Africa, and Saudi Arabia, a high-income country in Asia, focusing on prehospital, in-hospital, rehabilitation, trauma quality assurance, and research and development.

South African trauma system

The South African trauma system has progressed from a completely nonemergency-oriented, communicable disease hospital-centric approach to a system with defined levels of care, national core standards for care, and quality assurance guidelines implemented by the national health department, which are applicable to both public and private healthcare facilities [3,4]. South Africa was a few years ahead of the United States in establishing a specialized trauma center. Dr. A. E. (Fred) Wilkinson was sent to Birmingham in 1960 to study trauma management. After his return to South Africa, he opened the first trauma center, the Accident Service, at Johannesburg Hospital in 1962, where trauma could be treated in an independent setting with funding from the University of Witwatersrand Medical School [4]. However, until the early 1980s, no African country had a structured trauma system, and even prehospital emergency care was in its infancy. Except in South Africa, ambulances had very little equipment and required only a driver and no professional training. In South Africa, a minimum of a basic first-aid certificate was necessary, and most vehicles had two people on board: a driver and an attendant [7].

Emergency paramedic treatment began to spread across the Atlantic in the 1980s, with the United States and the United Kingdom leading the way. Emergency services in Cape Town and KwaZulu-Natal hired doctors to establish paramedic programs, and the first true emergency medical service (EMS) was born. The first paramedic programs in the country were started by Drs. Alan McMahon in Cape Town and Alan White and John Keenan in KwaZulu-Natal [8]. As a result of these programs, specialized medical rescue services were developed across the country as part of either the ambulance service or the fire service. C. van der Merwe, M. Morris, and J. White developed the first postgraduate medical qualification in emergency care in 1986 [3], when they established the Diploma in Primary Emergency Care (originally as part of the Faculty of Family Medicine, now under the College of Emergency Medicine) as part-time higher education in emergency care for nonspecialists. This diploma has been shown to be popular among general practitioners working in prehospital treatment and emergency department, and it continues to be so [3].

The Trauma Society of South Africa (TSSA), a nongovernment organization was created in 1983 to bring professionals together from many fields under one umbrella organization. Doctors, nurses, allied health workers, prehospital practitioners, and intensivists are among the members dedicated to better care for the injured. In 1992, the TSSA was appointed as the custodian of the Advanced Trauma Life Support (ATLS™) program in South Africa and in 1999, the Definitive Surgical Trauma Care course (DSTC). The TSSA determined a set of trauma center accreditation requirements that was first published in 2011. These requirements are currently being revised and updated. Following Johannesburg's lead, hospital programs in Cape Town (Groote Schuur and Tygerberg Hospitals) were among the first recognized trauma centers in the southern hemisphere. Trauma care was subsequently developed as part of general surgical services at many other regional and teaching facilities, either as undifferentiated general surgical emergency services or as defined trauma units, such as the one at Inkosi Albert Luthuli Central Hospital in Durban, the country's first TSSA-accredited public level I trauma center [3,4].

Given the country's high trauma load, research and teaching programs at local institutions have grown to stress the vital theoretical and practical aspects of trauma care to students and registrars. Much of this progress has been stimulated by the World Health Organization's (WHO) Essential Trauma Care and Prehospital Trauma Care initiatives [9,10], as well as the African Federation of Emergency Medicine, the TSSA, and other professional societies [3].

Prehospital care has progressed even more dramatically, with basic and then short course-based advanced paramedic programs in the 1980s and 1990s replaced by three-year diplomas and, more recently, four-year paramedic degree programs. Various universities of technology also provide master's and doctoral programs. They currently have an independent professional board, nationally controlled practice scopes, and evidence-based practice guidelines [11,12].

The implementation of emergency medicine programs in 2004 and the training of emergency medicine specialists in 2007 enhanced intrahospital trauma care. This has shifted emergency care from interested amateurs to consultant-led services at major referral centers across the country that have improved initial trauma care. Some obstacles remain, such as timely surgical team involvement or a lack

of surgical team availability in the operating room. However, the availability of emergency blood, the development of low-cost autotransfusion systems [13], and the surgical skill training of emergency specialists have helped to minimize mortality in certain areas. The first academic trauma units were developed in the early 1990s, and several surgical departments acknowledged trauma care as an academic field. It became evident in the 1980s and late 1990s that trauma surgery was distinct from general surgery and focused on physiology rather than anatomy. Thus, the South African College of Surgeons mandated a trauma training curriculum of three to nine months for all surgical disciplines, leading to the formation of a post-fellowship Certificate in Trauma, a two-year program including 12 months of exposure in both trauma operations and critical care [14]. These trauma surgeons currently spearhead the system's development in the public and commercial sectors. In South Africa, emergency nursing and critical care nursing are recognized as specialist nursing qualifications, and there is a continual need for training [15].

Allied health professionals, particularly those in physiotherapy and occupational therapy, play an essential role in trauma recovery. These and other disciplines (dietetics, speech and audio therapy, and psychology) are vital in trauma patient care. Most of these disciplines have only recently developed advanced trauma or intensive care (ICU) training. Major disasters are not uncommon in South Africa. More recently, when the country hosted the 2010 FIFA World Cup, there was a lot of progress in disaster medicine. This resulted in the establishment of the Major Incident Medical Management and Support (MIMMS) and Hospital Major Incident Medical Management and Support (HMIMMS) response systems at the national level. These have served the country well in planning and mobilizing a response to the current SARS-CoV-2 pandemic [16,17].

There is no single nationwide trauma system in place in South Africa; instead, each of the nine provinces has a mix of public and private EMSs that collaborate and coordinate to varying degrees [18]. To coordinate the dispatch of public paramedic ambulances and rescue services, a national EMS phone number (now 112) has been in place since 1985. This number connects to the nearest provincial EMS control center. Conversely, private EMSs operate independently. In metropolitan areas, the required response time for basic or advanced life support (BLS or ALS), fire, and rescue services is within 15 minutes, and in rural

areas, 45 minutes [19]. Aeromedical transportation in South Africa is a mix of private and public services. EMS uses field triage, but its effectiveness is limited due to the severe scarcity of ALS providers and patient flow protocols in public sector services. Communication networks and command centers linking the on-scene practitioner with the receiving hospital exist at the state level and some of the more prominent nationally active private providers (Netcare911 and ER24), as mandated by various pieces of legislation. Most patients are transported to a nearby hospital after obtaining life-saving care at the scene due to a shortage of trauma centers [20].

There are no dedicated trauma hospitals in South Africa. The TSSA accredits trauma centers within hospitals [21,22]. Emergency medicine is responsible for the early management of trauma, followed by the multimodal definitive treatment provided by other disciplines. Academic hospitals and accredited private units are the primary locations for trauma surgery [4]. Most hospitals delay surgical care due to a lack of beds and access to ICU facilities, as well as competition from other emergency or elective surgical cases [4,23]. Many public hospital emergency departments are still staffed by non-doctors and junior doctors; in addition, they lack senior leadership, particularly at the district level, where primary care, disease prevention, and public health are prioritized. As a result, gradual referral to regional and tertiary/quaternary facilities is required, delaying definitive care for the injured.

A robust and competitive private sector component has emerged within the private healthcare sector. The fee-for-service private sector in South Africa serves roughly only 15% of the population, yet consumes up to 50% of the country's healthcare GDP [4]. Apart from a small number of accredited private level I and II trauma units, which are currently found only in Cape Town, Durban, Pietermaritzburg, and Johannesburg, most private hospitals lack dedicated trauma wards and ICUs, and patients are accommodated in the wards or ICUs of specialists caring for them [4,22]. The public sector continues to have limited access to rehabilitation, whereas the private sector fares substantially better in this area of trauma care [23,24].

There is currently no national trauma databank or registry in South Africa. There are facility-based registers and one large private hospital emergency registry,

all of which collect diverse patient characteristics and use different electronic platforms or even paper-based methods [23].

There is currently no national health identity system, which means that a patient record from one area of the country cannot be retrieved in an emergency from another part of the country; this poses significant difficulty in providing appropriate care to the injured. In South Africa, trauma research activities face additional obstacles, such as funding, infrastructure requirements, and the risk of litigation, as well as the reality of competing priorities, such as maternal–child health, communicable disease (particularly tuberculosis and HIV-AIDS), and noncommunicable lifestyle diseases, all of which are constrained by a limited GDP available for healthcare spending [23]. South Africa lacks national governance for trauma care. Trauma management is governed in a multifaceted manner by the government, with professional buy-in, private and public compliance, and a dual-payor structure. Trauma quality assurance and trauma qualifications are defined by the Health Professions Council, Nursing Council, TSSA, and College of Surgeons [4,14].

Saudi Arabian Trauma System

Until 2018, Saudi Arabia lacked an organized trauma care system [25]. Trauma is treated in the same way as other medical or surgical emergencies. In late 2017, a national initiative to develop a trauma system was launched in accordance with the Kingdom's Vision 2030. As a result, a trauma network was established in the Riyadh region [25]. King Saud Medical City (KSMC) is the largest hospital in the region, with a capacity of 1500 beds including 200 ICU beds. It is located in the heart of Riyadh and is the first level 1 trauma center designated by the Ministry of Health (MOH) [26].

Since 1934, the Saudi Red Crescent Authority (SRCA) has provided prehospital care as a national service in Saudi Arabia. The SRCA provides free prehospital care to the public and contributes to humanitarian relief efforts abroad. According to the SRCA's most recent statistics, the country had 384 ambulance stations in 2015, with 77 (20%) of these stations located in the Riyadh region [27]. Each station had an average of 5.11 ambulances [27]. Ground-based emergency services

responded to approximately 8500 incidents per month in the Riyadh region, with approximately 2000 incidents involving motor vehicle crashes. The average time required to reach the scene was not available due to the lack of a national trauma registry that would have collected this type of prehospital data. All SRCA calls, both emergency and nonemergency, are routed through a single phone number (997) [27].

Emergency medical technicians (EMTs) and paramedics are the two primary levels of EMS personnel in the country. Physicians may also be part of the EMS in major cities. The ambulance service covers the majority of regions with BLS in addition to ALS; however, ALS units do not operate in all regions [27]. BLS is provided by EMTs with limited but critical skills, such as airway management, cardiopulmonary resuscitation with the help of an automatic external defibrillator, temporary bleeding control, and rapid patient transport to the nearest hospital. The ALS service is provided by highly skilled paramedics and/or physicians who have access to equipment and medications to treat life-threatening conditions, such as advanced airway compromise. ALS units respond to serious incidents and may be deployed in conjunction with a BLS unit. Patients are typically transported to the nearest healthcare facility, regardless of the facility's level of trauma care. Injured patients frequently arrive at hospitals via private transportation without prior notification to the hospital [28,29]. The Saudi Commission for Health Specialties (SCFHS) oversees EMS personnel, which includes registration and licensing, as well as monitoring and regulating EMS courses [30]. EMTs and paramedics must possess current Prehospital Trauma Life Support (PHTLS), ALS, and BLS certifications.

Currently, there are no clear written guidelines for field triage or trauma destination protocols, such as trauma bypass. Physicians at the resource command center provide medical direction. Although prehospital patient records are available, the limited information contained in them currently precludes the establishment of a hospital-based, regional, or national trauma registry to document prehospital or hospital variables.

Saudi Arabia's major cities each have one to two tertiary hospitals capable of responding to major trauma cases. KSMC is the country's oldest hospital and is a major trauma center. King Abdulaziz Medical City (KAMC) is the other major

hospital in Riyadh under national guard health affairs. It is equivalent to a level I trauma center, but it has limited access to the general population [27]. There are no additional hospital verification or accreditation processes in place to oversee trauma care.

In almost all hospitals, trauma care is provided by a multidisciplinary team. Only KSMC has a dedicated trauma surgery unit led by a group of nationally and internationally trained trauma surgeons. Emergency medicine postgraduate residency training programs are available at 22 tertiary hospitals in ten different regions. Surgeons can pursue postgraduate training in 13 tertiary hospitals located in nine regions. The SCFHS regulates all residency and postgraduate training programs, including registration and licensing. Recently, following general surgery board certification, King Saud University established a two-year fellowship program in trauma and acute care surgery, which was later accredited by the SCFHS [30].

Three public rehabilitation hospitals with a combined capacity of 311 beds are located throughout the country and are supervised and funded by the MOH [27]. The largest rehabilitation center in Saudi Arabia is located in Riyadh's Sultan Bin Abdulaziz Humanitarian City, which is a private not-for-profit hospital and medical center with 510 beds for inpatient and outpatient rehabilitation [31]. Other hospitals, on a smaller scale, also have an in-house rehabilitation unit/center [28].

In the Kingdom, there is currently no national trauma registry. In late 2017, KSMC introduced the Saudi Trauma Registry (STAR), which was developed in partnership with Alfred Hospital in Australia. At KAMC, there is another trauma registry [32]. There are no particular quality assurance programs for trauma care in the country; nevertheless, the MOH documented a proposal to build a statewide injury surveillance system in 2015 [33]. Following a major casualty catastrophe in the Kingdom in 2003, a predesigned trauma quality improvement program was tested in a pilot trial. Quality improvement across all stages of care could result in a 9–10% reduction in preventable or potentially preventable morbidity and mortality, according to the pilot study [34]. Another pilot study conducted in the Asir region after the implementation of a predesigned trauma registry indicated that the register was valid, trustworthy, practicable, and necessary for effective

trauma care [35]. When it comes to trauma research, the Kingdom lags behind when compared to its trauma load and international norms. KSMC and KAMC mostly conduct trauma research on a small scale and have published a few papers in recent years.

The current trauma systems in both countries have some strengths, such as personnel education and training; however, several aspects are missing that would enable them to attain a superior outcome. The establishment of trauma systems in developing countries is complicated, requires meticulous planning, and should be guided by a national policy. Geographical, demographic, and socioeconomic characteristics, as well as communication networks and financial resources, will all have a substantial impact on how trauma systems develop in emerging nations.

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CHAPTER 3

Transformation of health care and the new model of care in Saudi Arabia: Kingdom's Vision 2030

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Abstract

The Kingdom of Saudi Arabia espoused 'Vision 2030' as a strategy for economic development and national growth. The vision demonstrated the Kingdom's objectives to become a pioneer nation globally by achieving three main goals: a vibrant society, a thriving economy, and an ambitious nation. To fulfill this, the Kingdom launched a national transformation program (NTP) as outlined in 'vision 2030' in June 2016. The health care transformation is one of the eight themes of the NTP's. The history of health care facilities in the Kingdom is almost a century. Although the Kingdom has made notable progress in improving its population's health over recent decades, it needs to modernize the health care system to reach the 'vision 2030' goal. This article aims to describe the new Model of Care (MOC) according to the recent Saudi health care transformation under the Kingdom's vision 2030. The MOC concept started with understanding the current state and collecting learnings. It is based on the six systems of care (SOC)- keeping well, planned procedure, women & children, urgent problems, chronic conditions, and the last phase of life. The SOC is cut across different 'service layers' to support people's stay well and efficiently get them healthy again when they need care. The new MOC describes a total of forty-two interventions, of which twenty-seven split across the six SOC and the rest fifteen cut-across the multiple SOC. Implementation of all MOC interventions will streamline the Saudi health care system to embrace the Kingdom's 'vision 2030'.

Introduction

The Kingdom of Saudi Arabia is the largest country in the Arabian Peninsula, with a landmass of 2250,000 square kilometers and an estimated 33.4 million population [1, 2]. It is considered an energy superpower and one of the world's top twenty economies [3]. The Kingdom espoused 'Vision 2030' as a strategy for economic development and national growth. The vision demonstrated the Kingdom's objectives to become a pioneer nation globally by achieving three main goals: a vibrant society, a thriving economy, and an ambitious nation. In April 2016, the Kingdom launched its 'Vision 2030', comprised of 96 strategic objectives, governed by several Key Performance Indicators (KPIs). A few initiatives, known as vision realization programs (VRPs), were developed in this regard and under the different governmental, private, and non-profit organizations' implementation processes to achieve that goal. A practical and integrated governance model was set up by the Council of Economic and Development Affairs to translate 'Vision 2030' into multiple VRPs working parallel to achieve the strategic objectives & realize the vision [4,5]. In June 2016, the National Transformation Program (NTP) was launched as a VRP involving 24 government agencies to build the capacity and capabilities required to achieve the ambitious goals of 'Vision 2030' [4, 5].

The NTP aims at three main goals: achieving governmental operational excellence by raising the quality of services; improving economic enablers by supporting the growth of the private sector, raising labor market attractiveness, ensuring the sustainability of vital resources, and developing the tourism and non-profit sectors; and enhancing living standards with improved systems of social services, health care, and safety. The NTP consists of thirty-seven strategic objectives under eight themes, as shown in figure 1. The health care transformation is one of the eight themes of the NTP [4, 5].

This article aims to describe the new Model of Care (MOC) according to the recent Saudi health care transformation under the Kingdom's vision 2030.

Figure 1: The Themes of the National Transformation Program

Materials and methods

Data relating to the Saudi Arabian vision 2030, the national transformation program, the Saudi health system, the transformation of healthcare, and the new MOC, were extracted from the Ministry of Health (MOH) and other relevant websites or portals. A further search of the material and published literature in several databases, including Wikipedia, Google Scholar, PubMed, and Medline, was carried out. We analyzed all the relevant studies, government reports, and documents for their contents, and the information was synthesized and reported.

Results

Saudi Health System

The history of health care facilities in the Kingdom is almost a century. The public health department was established first in Mecca in 1925 [6]. After the second world war, the Saudi economy was growing due to the dramatic increase in oil production, and more health care infrastructure was built. In 1950, the MOH was formed with various health care institutions [6]. In the year 2018, Saudi Arabia had 75,225 beds in 484 hospitals, which was 22.5 beds/10,000 population. The total health budget reached 90 billion SR (9.2% of total governmental budget) in 2018 [2].

The Kingdom of Saudi Arabia has made notable progress in improving its population's health over recent decades, particularly in the areas of child

and maternal mortality and the reduction of infectious diseases. Average life expectancy at birth improved from 64 years in 1970 to 75 years in 2016 [7], with new targets set to ensure it increases to 80 years by 2030 [4]. Despite these advances, many health issues still need to be addressed. For example, the rates of avoidable injury and non-communicable disease remain high by regional and international standards. There remains considerable scope to reduce preventable mortality and avoidable morbidity in both the working and elderly populations. All amenable to reduction are areas of concern, including heart disease, stroke, diabetes mellitus, respiratory disease, mental health, road traffic accidents, and congenital diseases [8].

Transformation of Healthcare

With the growing population, the Saudi health sector faces enormous challenges and is undergoing significant reform following regional and global trends. The First Theme of NTP is 'Transform health care,' which aims to restructure the health sector to become a comprehensive and helpful system. A new MOC will promote public health that focuses on the prevention and health awareness of society. It will ensure access to health services through optimal coverage, equitable geographical distribution, and comprehensive & expanded e-health services and digital solutions. Moreover, it will target the continuous improvement of health services by focusing on the beneficiaries' experience and satisfaction in line with international standards and best practices [4, 5].

Leading organizations involved in health care transformation are the MOH, Saudi Health Council, King Faisal Specialist Hospital and Research Center, Saudi Food and Drug Authority, The Saudi Red Crescent Authority, and the Ministry of Education. Three significant challenges were identified in the health care system: 1) difficult access to health services, 2) limited quality and inefficient health services, and 3) inadequate preventive health care. Different strategies were developed to overcome these challenges. Firstly, to enhance the accessibility of health care services for the citizens, the plan was to expand health facilities, including improving infrastructure and increasing the numbers of beds and health care professionals. Adequate geographical distribution ensures affordable services, easy specialized consultation through workforce planning, redistributing responsibilities, improving referral system and appointments, and easy access to emergency medical care by promoting related medical professions were

also planned in this regard. Secondly, to improve the quality and efficiency of health care services, the plan was to increase clinical effectiveness, enhance safety, improving patient experience, and improve sustainability and financial transparency. Finally, regarding promoting prevention against health risks, control communicable and non-communicable diseases, and improve readiness to confront health disasters [4, 5].

The new Model of Care (MOC)

Definition and background

The new MOC theme is a focal point for improved treatment and care modalities individually. There is a global trend of shifting from activity-based to outcome-based payment structures that incentivize better performance and care quality. The health providers are incentivized to manage the population's health care cost over the long term and help people live healthier lives longer. A shift to increasingly autonomous and Accountable Care Organization (ACOs), delivering care through greater collaboration and integration, and budgetary responsibility are also evident. A National MOC will unlock multiple benefits that are core to the health care Transformation. The main advantages of the MOC, as shown in Table 1 [9].

The MOC concept started with understanding the current state and collecting learnings. The global health care developments and key directional trends also inspired this. More than 60,000 citizens participated in the public survey around the patient-centric design, 2500+ health care professionals engaged in e-discussions, and 1000+ health care professionals surveyed to identify improvement opportunities. The MOC answers six questions from the people's perspective:

1. How will the health system support the people to keep them well?
2. How will it help during an urgent problem?
3. How will it support them to have an excellent outcome for any planned procedure?
4. How will it help to deliver a healthy baby safely?
5. How will it support during the chronic health conditions?
6. How will it provide them compassionate care during the last phase life?

These questions resemble the MOC's Six Systems of Care (SOC). The SOC is the configuration/set-up of all available services to a patient to address a need: Keeping well, planned procedure, women & children, urgent problems, chronic conditions, and the last phase of life. Again, the SOC is cut across different 'service layers' to support people's stay well and efficiently get them well, too, when they need care (Figure 2) [9].

Table 1: The benefits of the new Model of Care (MOC).

Set a blueprint for ACO's to build service provision capabilities and plans on unlocking intrinsic value through integrated services.
Improve patient experience by introducing clear citizen-centric pathways delivering quality, timely and accessible services.
Organizes large scale transformation by regulating and directing a multitude of initiatives towards a common goal.
Enables Value-Based Financing of health care by linking payment mechanisms to Model of Care pathways and outcomes.
Facilitates national knowledge and capability sharing, patient flow between ACO's, and economies of scale efficiency generation.

Activated people are at the core of the MOC. It emphasizes the role that individuals and their families will play in keeping well and taking care of their health through self-care, awareness, and empowerment. Healthy communities will support activated people by encouraging them to lead healthy lifestyles, providing them with the appropriate information, and providing them with access to community care and wellness facilities. Virtual care will be an authoritative source of health advice. In most instances, virtual care will serve as people's first point of contact with medical care providers, improving people's access to medical information and guiding them to navigate the health care system and seek appropriate care. Primary care, secondary care, and tertiary and quaternary care will still be the primary source of care beyond virtual care [9].

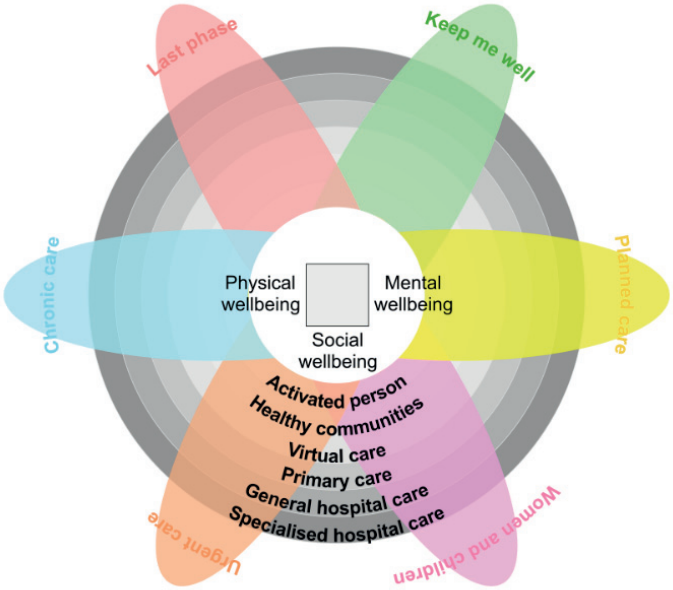

Figure 2: Model of Care: The 'Six Systems of Care' and 'Service Layers'

Although the MOC describes a comprehensive care system for meeting the health needs, implementing it will require six key enablers. These include workforce, eHealth, corporatization, governance, health care financing, and private sector participation.

The Vision Realization Office (VRO) at MOH has primarily been tasked with ensuring the successful execution, monitoring, and evaluation of health care transformation initiatives, as shown below, of which the MOC brings all these initiatives together. The MOC mainly describes a comprehensive care system for meeting health needs and implementing it will require support from six key enablers, shown in Table 2 [9].

Table 2: The six key enablers and initiatives by VRO

Key enablers	Initiatives
Private Sector Participation	• Increase private involvement by facilitating ownership, or management of MOH hospitals. • Actively support localization of pharmaceutical and medical devices – leveraging MOH procurement.
eHealth	• Provide digital tools (apps) for patient self-services, prevention, connected care, and workforce efficiency. • Accelerate IT infrastructure build-up at MOH to reach 100% deployment by 2020.
Workforce	• Enhance the quality and quantity of workforce through increased capacity, improved licensing criteria, and making profession attractive. • Establish a National Health care Workforce Planning Unit to coordinate actions across crucial stakeholders.
Health care Financing	• Establish a value-based provider payment system. • Set up National Health Insurance with a gradual rollout.
Corporatization	• Split MOH to corporatize delivery, creating independent provider networks with operational autonomy. • Create local clusters that bring providers together, ultimately forming accountable care organizations.
Governance	• Strengthen MOH mandate to lead sector reform with strong oversight over regulatory agencies ("super-regulator") and transform the role of MOH to be more strategic. • Create a range of new development and regulatory bodies at arm's length from the MOH.

How was the MOC designed and developed?

The first phase of the MOC project focused on understanding the current situation, designing the new MOC, and defining interventions required for the new national MOC for the Kingdom. From October 2016 to April 2017, the MOH and the VRO led a national effort to transform the health care sector across the Kingdom. Three national workshops (three care design groups; the CDG) were held with the key stakeholders' participation, including over 450 Saudi doctors, nurses, pharmacists, dentists, and patients (plus an additional 2000 involved in virtual discussions). They worked together to design a comprehensive care system

for meeting health needs throughout the Kingdom. In the first workshop (the CDG 1), the participants from different regions and different health care sectors in KSA came together to agree on the key issues facing the current health care services and critical areas of improvement. Based on the key issues and priorities developed in CDG 1, the second workshop participants in the CDG 2 designed and suggested the initial list of interventions for each of the six Systems of Care (SOC) included as part of the new MOC. In the third workshop, the CDG 3, the National SOC Leaders, and international experts, along with other participants, finalized the new MOC design for the Kingdom. It included detailing each of the six SOC's design that constitutes the MOC and considering how the MOC would be adjusted to serve in different contexts, including the City, Town, Rural, Hajj & Umrah, Mental Health, Children's needs. His Excellency, the Minister of Health, launched the new MOC on 23 April 2017 [9].

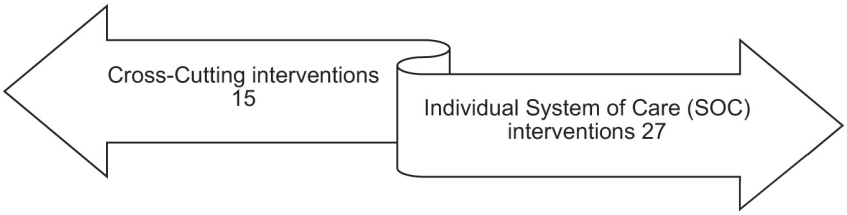

Figure 3: The Forty-two MOC interventions

The new MOC describes a total of forty-two interventions (Figure 3), of which twenty-seven split across the six SOC (Figure 4) and the rest fifteen cut-across the multiple SOC (Figure 5). An intervention is a combination of program strategies designed to produce behavior changes, improve individuals' health or the population, and/or reduce the cost. Each cross-cutting intervention may be applied to the SOC's two or more and need to be developed further without isolation within a single SOC [9].

The second phase of the New MOC was conducted in two parallel workstreams over five months (April to August 2017). The first workstream was the regional pathway development focused on working with five pathfinders to develop the national SOC designs into implementable regional pathways. The pathways are the route that a patient undertakes when accessing the health care system based on their need – this is operationally specific in terms of which provider the

patient accesses along this route. The pathfinders refer to the selected Medical Cities (and their surrounding providers) and other hospitals, which have been identified as the first in the country to make the journey towards Accountable Care Organizations (ACOs) and piloting elements of the new MOC. They are King Saud Medical City- Riyadh (KSMC), King Fahad Medical City- Riyadh (KFMC), King Khalid Eye Specialist Hospital- Riyadh (KKESH), King Abdullah Medical City- Mecca (KAMC), and King Fahad Specialist Hospital- Dammam (KFSH-D) (Figure 6) [9].

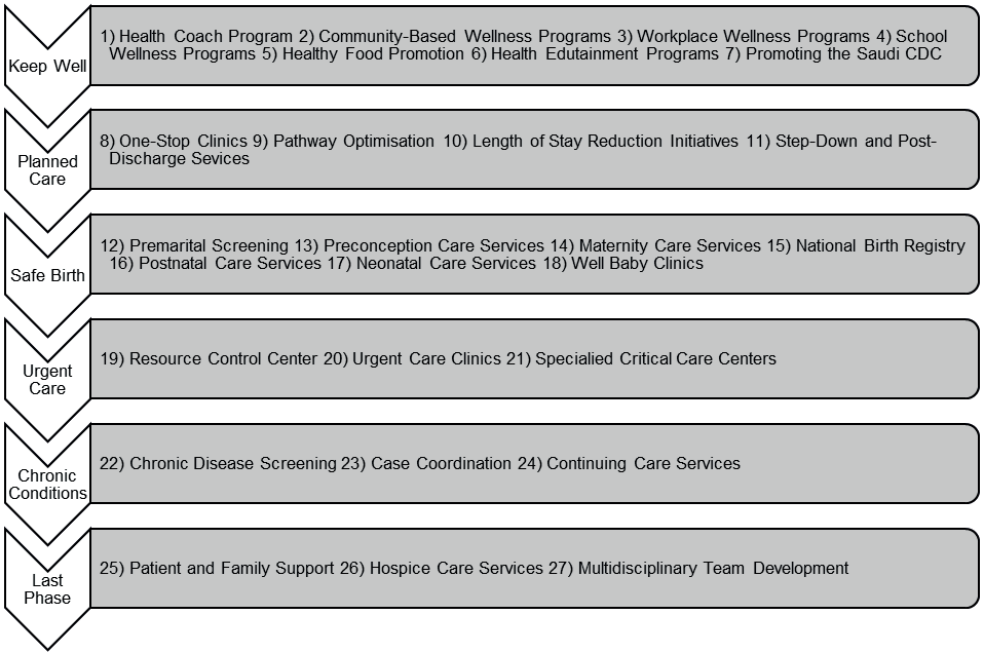

Figure 4: The Twenty-seven Individual SOC interventions

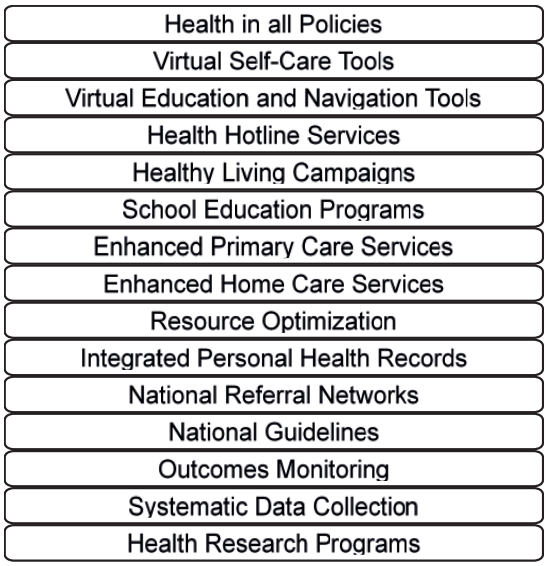

Figure 5: The Fifteen Cross-Cutting interventions

The second workstream was the national implementation planning focused on working with the national taskforces of experts on designing and planning for the national development of six cross-cutting and 'Keep Well' interventions that require standardized national implementation. Based on phase two's approach and planning outcome, the next phase will implement MOC priority solutions. The '100-day plan' was executed, and the high-level implementation plan was detailed out further. The implementation is likely to occur in waves based on clusters. A cluster refers to a group of health care providers who will form an ACO in the future. They are geographically defined around a Medical City or other large hospital as a hub. It is estimated that there will be 20-30 clusters across the Kingdom. Each health care provider (including hospitals, Primary Health Clinics, etc.) within a cluster will be required to coordinate and collaborate to meet a defined population's needs. Each cluster may eventually have a set budget allocation and work under a contract that specifies the outcomes and other objectives required to achieve within that budget [9].

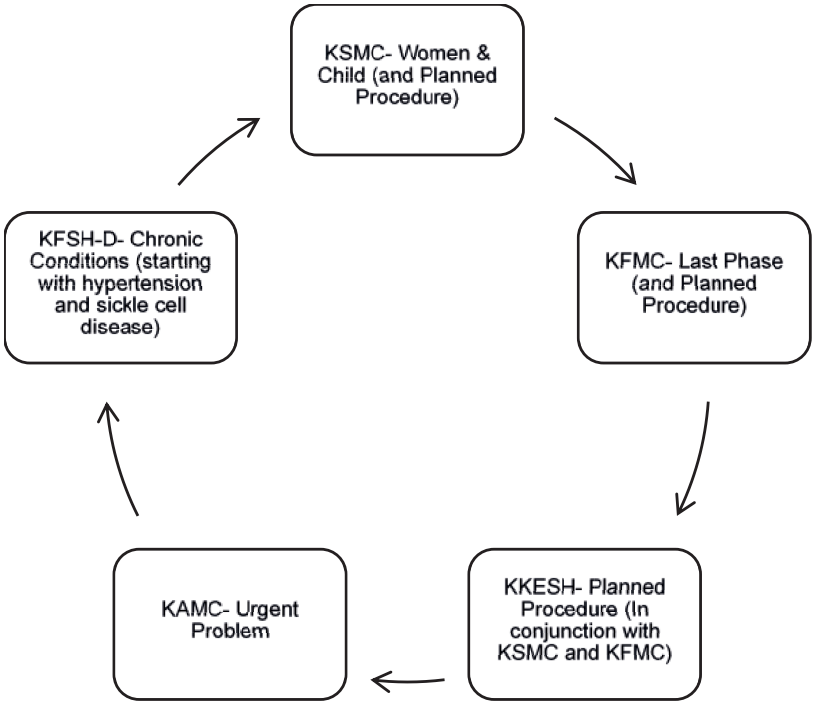

Figure 6: Pathways that each Pathfinder will implement

Discussion

The MOH has struggled to build the inter-ministerial dialogue needed to address some pressing issues. Similarly, other government agencies in the Kingdom do not often consider the health and healthcare ramifications of their decisions while developing major policy initiatives. Over the next decade, significant problems need to be addressed to modernize the Saudi healthcare system and fulfill the 'vision 2030'.

The Kingdom's population continues to rise and is expected to be 39.5 million, including 4.63 million elderly (60-79 years) by 2030. One-third of the Kingdom's population is expatriate (10 million in 2015), primarily adult workers. Many international visitors, particularly during the major religious festivals (Hajj and

Umrah), have an additional health burden on the Saudi health system. In recent years approximately 1.8 million foreign pilgrims arrived, and the overall number of foreign pilgrims visiting Mecca is estimated to be as high as three million in some years [10]. The people living in urban areas are expected to rise from 83.3% (2016) to 85.9% by 2030. The rates of avoidable injury and non-communicable disease in the Kingdom remain high compared to regional and international standards. We must improve non-communicable illness and accident prevention to reduce avoidable illness and death. Significant outbreaks of infectious diseases are still possible, especially during Hajj or in the aftermath of natural or human-made disasters.

Primary healthcare continues to be insufficient and inconsistent in the Kingdom. The Secondary, tertiary, or specialized hospitals and related services are dispersed throughout the Kingdom. The rehabilitation, long-term, and home care services are insufficient throughout the country. There are significant inconsistencies in the quality of patient care. Most of this is due to a lack of standardized treatment plans and pathways and insufficient monitoring of patient processes and outcomes. In 2015, The Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI) found these deficiencies during the Essential Safety Requirements Survey in hospitals of all types [9].

The population measures provision, access, and expenditure served rather than the patients treated; there is unjustified variance. It included both overuse and underuse, resulting in substantial value and efficiency shortfalls. Rather than being patient or individual-centric, the system is now resource and staff-centric. It's also focused on institutions rather than people. A health system must be both open and attentive to the overall well-being of patients. There are significant capacity and skill gaps in the workforce, especially among Saudi employees. Additionally, the health system lacks robust, consistent, and integrated digital information systems across all hospitals. It may help quantify and manage resources, activity levels, product quality, and performance [9].

The New MOC, provider reforms, financing reforms, governance growth, private and third sector engagement, workforce development, and eHealth development are the seven themes that the VRO has focused on for working around. The first three themes can be viewed as enablers of three distinct degrees of worth. The

MOC theme is a focal point for enhancing personal value by improving treatment and care modalities at an individual level. The provider theme is a focal point for enhancing utilization value at an intermediate level, whether at the clinical micro-system, hospital, or local health system level. The financing theme serves as a focal point for improving allocative performance by ensuring that intermediate levels receive optimal resource levels based on patients' needs and capacity to benefit. Financing, it could be argued, plays a direct role in ensuring all three forms of value [9].

Furthermore, patients' needs are often qualified by other factors such as the patients' merits, economic goals to preserve the working population's health, or the patients' capacity and willingness to pay. Previous experience with health transformation initiatives indicates that organizational and financial reforms are unlikely to result in significant performance improvements unless followed by supply-side enhancements, such as increased productivity, efficacy, equity, and public health responsiveness. It's essential to understand how the three value dimensions are interconnected and reinforce each other. Completing all seven work themes would be critical to our transition strategy's overall success [11].

Conclusion

A longer timeframe and additional resources will require to roll out all—the MOC solutions and the enabler workstreams' local implementations. Implementation of all MOC interventions will streamline the Saudi health care system to embrace the Kingdom's 'vision 2030.' Additionally, the health sector would reduce government spending and the diversification of the Saudi economy. It is essential to address the possibility of long-term drops in crude oil prices and the effects on government revenues. As a result, the Kingdom must encourage intervention both inside and outside the health system to minimize accidents and the primary and secondary prevention of non-communicable diseases. Also, implement systematic assessments of population needs and health system efficiency to optimize resource distribution and provide the results that people require.

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CHAPTER 4

Development of the Saudi Arabian trauma system

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Abstract

A dedicated network-based trauma system ensures the provision of optimal care to injured patients. Considering the significant burden of trauma, the Kingdom of Saudi Arabia is striving to develop a nationwide trauma system. This article describes the recent design, development, and implementation of the Saudi Arabian trauma system, in line with Vision 2030. The basis of our strategy was the FOCUS-PDCA model, developed by engaging key stakeholders, including patients. More than 300 healthcare professionals and patients from around the Riyadh region assessed the current system with three solutions and roadmap workshops. Subsequently, the national clinical advisory group (CAG) for trauma was formed to develop the Saudi Arabian trauma system, and internationally recognized trauma systems and guidelines were analyzed and collated by CAG members. The guidelines' applicability in the kingdom was discussed and reviewed, and an interactive document was developed to support socialization and implementation. The CAG team members agreed on the guiding principles for the trauma pathway, identified the challenges, and finalized the new system design. They also developed a trauma care standard document to support and guide the rollout of new trauma networks across the kingdom. The CAG members and other stakeholders are at the forefront of implementing the trauma system across the Riyadh region. Recent trauma system development in Saudi Arabia is the first step in improving national trauma care, and may guide development in other locations, regionally and internationally, to improve outcomes.

Introduction

Worldwide, approximately five million people lose their lives every year due to physical injuries. It constitutes about 9% of the world's total death ratio and represents 1.7 times the number of mortalities resulting from HIV/AIDS, tuberculosis, and malaria combined. The leading causes are violence (homicide and suicide), motor vehicle crashes, falls, burns, drowning, and poisoning. By 2030, motor vehicle crashes alone are predicted to become the 7th leading cause of death worldwide [1]. Effective trauma care can be explained as an incorporated, protocol-driven system of care that addresses the complete trauma care pathway, including prehospital emergency medical care, in-hospital management, rehabilitation, and trauma prevention. The World Health Organization sponsors a variety of activities to reduce injury-related morbidity and mortality [2], including surveillance and basic research through prevention programs and effective strategies for trauma management. Much importance has been placed on preventive measures, such as seatbelts, traffic rules, speed limits, and enforcing the prohibition of driving under the influence (e.g., alcohol breath-testing). There are also significant gains to be made by improving the management of trauma patients, especially in the prehospital arena and initial management upon arrival at the hospital [3,4].

The trauma care system can be inclusive or exclusive. In the inclusive approach, injured patients are managed across the network by organizing the healthcare facilities within the region, and in an exclusive system, patients are transferred directly and managed in a tertiary hospital that is well equipped for trauma management [5]. The implementation of a trauma system can reduce mortality by up to 15% [6–10]. In the Kingdom of Saudi Arabia (KSA), the major reason for death is trauma in the first four decades of life, and it is also the leading cause of disability among young and productive members of Saudi society. The incidence of significant trauma and associated fatalities in Saudi Arabia has increased in recent years with population growth, increased vehicle ownership, and the rapid development of highway infrastructure [11,12]. Motor vehicle crashes (MVCs) are the second-highest cause of mortality for men and children, with incidents rising by 8.5% from 2005 to 2016 [13,14]. Between 2001 and 2010, the most common type of injury was due to MVCs (52.0%), followed by falls (23.4%), with MVCs resulting in 7,661 fatalities in 2013 (88% M, 12% F) [15,16]. In the Riyadh region in 2017,

there were over 27,000 MVC-related emergency admissions and over 120,000 non-MVC-related trauma admissions, emphasizing the scale of the problem [16].

The post-crash care of trauma patients poses a significant challenge. Prompt delivery of severely injured patients to a hospital that can provide the most appropriate care in the least time improves chances of survival [13, 17-19]. The civilian population of the KSA currently lacks access to an organized trauma system that recognizes the complexity, range, and time-critical nature of injuries requiring immediate, integrated care by dedicated trained personnel at specialized trauma centers. Specific challenges, such as vast distances, harsh climate, and limited communication infrastructure, contributed complications in this regard. This article aims to describe the design, development, and initial adoption of the Saudi Arabian trauma system, in line with Vision 2030.

Material and methods

The base of our plan was developed by engaging key stakeholders, including patients. More than 300 healthcare professionals and patients from the Riyadh region assessed the current system in three solutions and roadmap workshops using the find, organize, clarify, understand, select—plan, do, check, and act (FOCUS-PDCA) methodology [20]. Subsequently, a national clinical advisory group (CAG) for trauma, under the supervision of the Vision Realization Office (VRO) of the Ministry of Health (MOH), was formed to develop the Saudi Arabian trauma system (Figure 1).

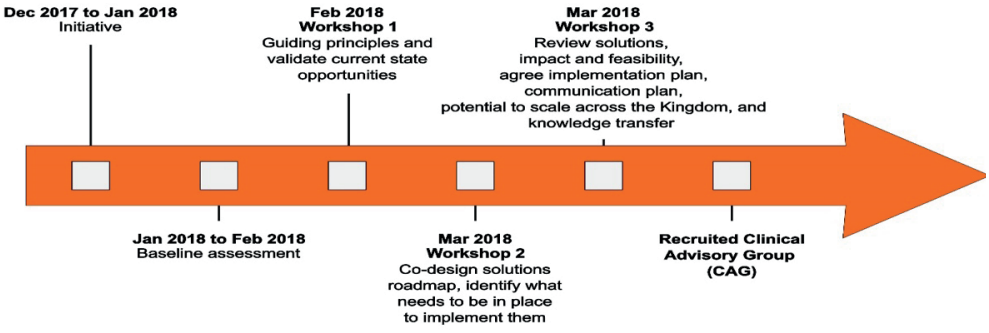


Figure 1: Design phase overview

The CAG for trauma was a team of 11 members consisting of experts from various fields, including emergency medical services (EMS), emergency and disaster management, emergency department, trauma surgery, nursing, pediatric emergency, trauma research, and rehabilitation (Table 1). The CAG members set up the national standard for trauma care.

Table 1: CAG members

Member	Position and Affiliation
Dr. Thamer Nouh	CAG chairman, associate professor of surgery, College of Medicine, King Saud University, Riyadh
Dr. Sharfuddin Chowdhury	Trauma surgeon, director of trauma center, King Saud Medical City, Riyadh
Dr. Ahmed Alburakan	Assistant professor of surgery, College of Medicine, King Saud University, Riyadh
Dr. Talal Altahan	Head of the Department of Surgery, Prince Mohammed bin Abdulaziz Hospital, Riyadh
Dr. Ibrahim Albabtain	Director of Trauma Research Program, King Abdulaziz Medical City, Riyadh
Dr. Jalal Alowais	Supervisor general of the General Directorate of Emergency, Disaster and Ambulance Services, MOH, Riyadh
Ms. Jehad Hassan Alalshikh	Emergency nurse, King Abdulaziz Medical City, Riyadh
Mr. Abdulaziz Alotaibi	Chief of Rehabilitation Services, King Abdulaziz Medical City, Riyadh
Mr. Nasser Almadhi	Emergency health services specialist, emergency services Project Manager, MOH, Riyadh
Dr. Mohammed Azzam	Emergency medicine consultant, Dr. Soliman Fakeeh Hospital, Jeddah
Dr. Ahmed Muneer Althekair	Pediatric emergency medicine consultant, Prince Sultan Military Medical City, Riyadh

The approach adopted was to analyze and collate internationally recognized trauma systems and guidelines, and a thorough review was undertaken by the CAG members. Further analysis workshops and discussions on those guidelines and their applicability in the kingdom were held. These were shared with cluster clinical colleagues for review, and an interactive document to support

socialization and implementation was developed. The guiding principles for pathway development are described in Table 2. These concepts helped guide the transformation trajectory.

Table 2: The guiding principles

Value-based healthcare	Investments in healthcare solutions should be made to maximize patient outcomes and financial sustainability in the short, medium, and long term.
Equity of access	All patients should be treated equally and receive timely, effective care, regardless of status, location, or wealth.
Innovative thinking	The pathway should be created using innovative ideas from colleagues and patients.
Networked staff/ institutions	Collaboration between ministries, providers, and organizations is essential for the pathway's success.
Patient first	Patient safety, outcomes, and needs should be considered at the heart of every decision.
Best clinical practices	The care provided should be standardized and based on international evidence. Data should be collected to allow for continuous improvement, knowledge sharing, auditing, and transparency across the system to ensure best practices are being applied.

Results

The CAG team members agreed on the trauma pathway's fundamental guiding principles, identified the challenges, and finalized the new trauma care system's design. They also developed a trauma care standard document to support and guide the rollout of new trauma networks across the KSA. The CAG members and other stakeholders are also at the forefront of implementing the trauma system across the Riyadh cluster. The trauma pathway development, trauma care standard documents, and adoption of regional trauma systems are described below.

A. Trauma pathway development

During the workshop, the trauma system's four pillars—prevention, prehospital, in-hospital, and rehabilitation—were discussed thoroughly to identify the gaps and areas. Six areas of challenges were identified: prehospital, resource control center, hospitals, rehabilitation and community discharge, rural trauma care, and pediatric trauma care. The deficits in these areas are shown in Table 3.

Proposed solutions to current challenges were 1) appropriate allocation of resources, 2) development of standards and guidelines, 3) establishment of clinical advisory group, 4) development of efficient prehospital transportation, 5) development of rehabilitation and early treatment of disease, 6) development of telemedicine and technology, 7) standardization of training and care across the system, and 8) development of a peer-supported clinical network.

Table 3: Six areas of challenges and gaps

Areas of Challenge	Gaps
Prehospital (hotline + transport)	Transport resources and capabilities
Resource Control Center	No collaborative networks
Hospitals	Lack of transportation
Rehab and community discharge	Number of staff and public awareness
Rural trauma care	Geographic networks
Pediatric trauma care	Hospitals

Subsequently, the CAG for trauma began their work in the Riyadh region. The KSA is divided geographically into 19 clusters, not including Bishah and Najran in the south (Figure 2).

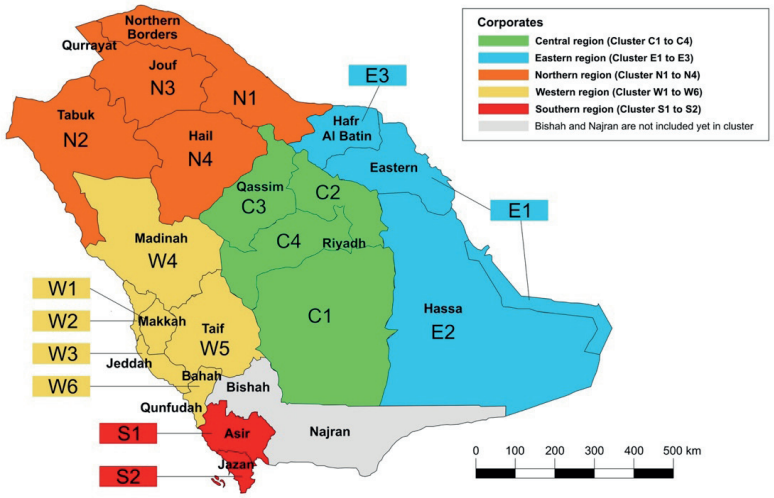


Figure 2: Geographical region and cluster map for health care services in the KSA

The Riyadh (central) region is divided into four clusters (C1–C4). Each cluster will serve as a complete unit for trauma care in Riyadh's regional trauma network, and will have a level 1 trauma center, at least two level 2 trauma centers, and multiple level 3 trauma centers, as per CAG standards. After a trauma event, EMS will be dispatched to the scene through a hotline (997). After triaging, EMS will send a prehospital notification to the appropriate level of trauma center regarding patient arrival. Prehospital activity, as well as interhospital transfer, will be coordinated, regulated, and monitored by the central resource control center. After managing patients in the hospitals, they will either be discharged or sent to home care facilities or short- or long-term rehabilitation facilities. The trauma pathway for each cluster is shown in Figure 3.

B. Development of trauma care standard document

The CAG for trauma formulated the trauma care standards document to support and guide the rollout of new trauma networks across the kingdom. It will provide a framework that will support the development and implementation of dedicated trauma services using fit-for-locality networked provider models across all regions of the KSA. These trauma service standards will help health system administrators, trauma networks, and service providers judge their local services' quality and plan for improvements as needed. The document is designed for all health care professionals, including administrators.

A range of national and international guidelines, standards, and evidence was reviewed, and expert opinions from CAG members were used to develop these standards for the KSA [2,21,22]. While the document sets an optimal endpoint, there are still areas where further recommendations, including clinical care standards for the management of specific traumatic injuries, are required. The standards are geared toward ensuring optimal care for injured patients within acute care facilities specializing in trauma care.

According to these standards, Saudi trauma centers will be at three levels. A level 1 trauma center should be capable of emergency and definitive complex trauma management in the presence of all subspecialty facilities. It will also provide teaching, research, leadership, and outreach programs. A level 2 trauma center will involve emergency trauma reception, resuscitation, and emergency surgical management to save life or limbs. Surgical specialties such as general surgery, orthopedic surgery, neurosurgery, and critical care services are mandatory, and other specialized care is desirable at this trauma center level. A level 3 trauma center will evaluate, assess, and stabilize injured patients before onward transfer to higher-level centers, based on agreed transfer thresholds and protocols.

The document describes the minimum criteria for designation and approval for each level of a trauma center in detail, as well as administrative roles and the formation of trauma committees at different levels, such as regional, network, and cluster levels. The detailed service standards for different specialties involved in trauma management, policy protocol, clinical pathway guidelines, e.g., long-term care and transfer, and performance improvement indicators are also delineated in the document. The VRO at MOH transferred responsibility for this standard document to the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI) for the designation and accreditation of a trauma center. The CBAHI trauma center certification requirements are described in Table 4.

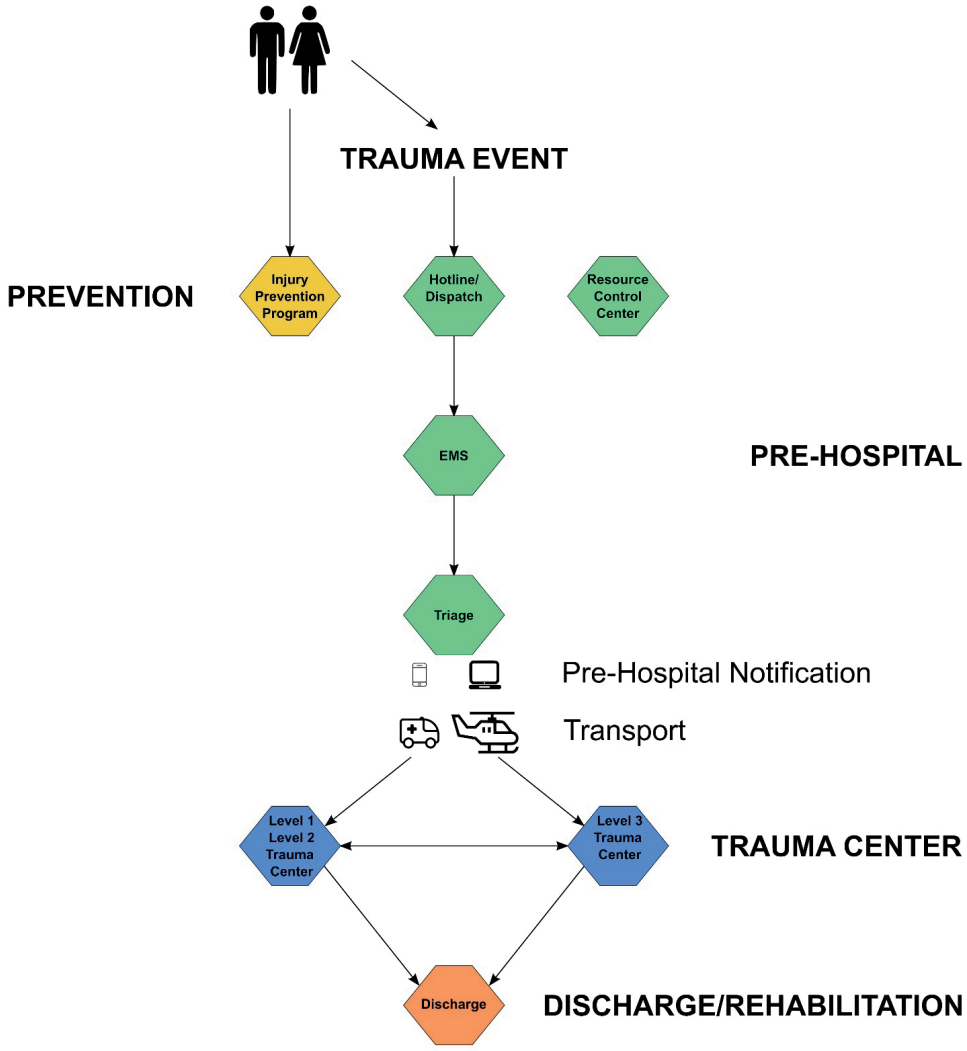


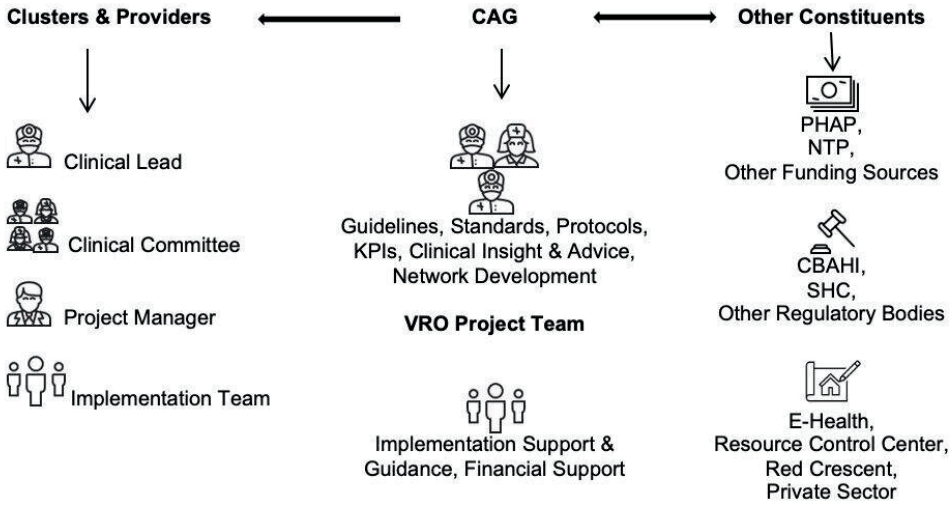
Figure 3: Trauma pathway

Table 4: CBAHI trauma center certification requirements

Program participation requirements
• The original healthcare setting is accredited by CBAHI. • The healthcare organization's infrastructure/official agreements enable the surgical, medical, and rehabilitative management of trauma victims. • The program is active for at least six months before the certification accreditation visit and has managed at least (number to be determined) cases of trauma (types and numbers according to levels).
Program design and management
• Program leaders o Appropriate certification, training, and experience o Roles and responsibilities • Mission and vision o Scope of services o Strategic planning o Other service participation o Admission and discharge criteria (will determine the center level)
Provision of care
• Access to care • Essential requirements for services o Staffing levels o Staff training and competency requirements o Structural requirements of the hospital o Essential equipment o Assessment/reassessment o Essential investigations o Turnaround times for investigations o Turnaround times for consultations o Care planning and consultations o Practice guidelines o Essential support services o Outcome measures
Quality improvement, risk management, and patient safety program
• Program design • Program management and staffing • Performance measurement • Reporting of events and near misses • Resource utilization • Information management

C. Adoption of regional trauma system

After setting up the trauma care pathway, it was a great challenge to implement it cluster-wise and regionally. We followed an inclusive, collaborative approach and involved all stakeholders. The strategies for collaboration and teams for implementation are shown in Figure 4.



CAG: Clinical Advisory Group; VRO: Vision Realization Office; PHAP: Program of Health Assurance and Purchase of Health Services; NTP: National Transformation Program; CBAHI: Central Board for Accreditation of Healthcare Institutions; SHC: Saudi Health Council

Figure 4: Approach for collaboration and team for implementation

The progress of implementing the trauma system in the Riyadh region until December 2019 is shown in Table 5.

Discussion

This report details the significant advances in realizing a trauma system in Saudi Arabia, providing a firm basis for further developing an integrated trauma system. The design phase helped understand the key current state issues, guiding principles for future state design, priorities for implementation, and a draft pathway for trauma. The magnitude of trauma in Saudi Arabia has recently been reduced by primary prevention strategies that attempt to modify the behavioral and environmental factors that lead to injury. The government has implemented prevention programs, such as increased seat belt usage, speed limit enforcement, speed camera surveillance, and workplace safety reforms, which have resulted in a decline in trauma death rates in some cities in Saudi Arabia [23]. Current evidence suggests that a network-based approach providing an effective nationwide trauma care coordination system is the best approach for managing trauma emergencies and improving outcomes. In response to the burden of disease and to fulfill the goals of Vision 2030, under the national transformation program, the VRO of the MOH created the CAG to establish and improve urgent care pathways in the kingdom, including trauma, stroke, and acute coronary syndrome.

In the West, trauma care is better established. The differences between trauma care systems in developing and developed countries are vast. Even in countries with optimum trauma care, there are variations in regional-level organization. An excellent example of such variations can be identified in European Union (EU) states, where there are no current unified standards of trauma care. Each country has its own method for the organization of prehospital care, trauma teams, and rehabilitation, and trauma surgeon training standards are also different. In Austria, there is an isolated department for trauma surgery, while trauma surgery is integrated with other specialties in other EU countries, such as orthopedic surgery in Switzerland and Belgium and general surgery in the Netherlands and Italy. Another variation is found in Britain, France, Germany, Portugal, and Scandinavian countries, where trauma care is covered by different specialties, each with its own area of responsibility [24,25]. Overall, trauma care seems more established in England and Central European countries than in Wales, Scotland, Northern Ireland, Scandinavia, and Mediterranean countries [25].

Table 5: Trauma system implementation progress (until December 2019)

Key Planned Milestones	Status
Readiness assessment, gap analysis, and hospital classification	Completed for C1 and C2. Not started in N3 .
Implementation plan	Completed for C1 only. Not started in C2 and N3.
Network clinical committee	Established for C1 only. C2 and N3 are in progress.
Adequate cluster PMO support	Yes, for C1 and N3. C2 is in progress.
Socialization of standards/guidelines	C1 and N3 are in progress. Not started in C2.

Note: C1: Cluster 1; C2: Cluster 2. We have used N3 for King Khaled University Hospital, as it is not in a cluster, but aims to develop a clinical network C3. PMO: Project Management Office

The efficiency of trauma systems in reducing death from injury has most prominently been documented in the United States (US). Its effectiveness is such that in 1990, the US Congress approved the Trauma Care Systems Planning and Development Act, requiring states to develop trauma care systems. One study found that, on average, mortality due to traffic accidents was reduced by 8% (95%, CI 3%–12%) 15 years after implementation [26]. International evidence shows that the odds of a significant trauma patient's survival can be improved by 63% through the strategic provision of major trauma centers in or close to major population centers. In the US, a study of the 25 largest metropolitan areas in 19 states found that regionalization of care to specialist trauma units decreases mortality by around 25% and stay length to four days [27]. Another US study also found that trauma treatment at a trauma center versus a non-trauma center protected over 3.4 lives per 100 patients treated at a fiscally convenient ratio of $36,000 per quality-adjusted life-year gained [28].

The American College of Surgeons Committee on Trauma (ACS-COT) classifies, designates, and accredits trauma care amenities within a trauma system into five levels (I–V) in the US [22]. In a few states, the state government runs the evaluation process, and some states classify every acute hospital according to the level of care it can deliver. Other states provide trauma care through a limited number of designated level 1 and level 2 trauma centers [29].

Mainland Australia has national and statewide trauma care systems, with designated trauma centers in New South Wales that started in the early 1990s and are still evolving. The trauma network in Australia is divided into metropolitan and rural areas, with three levels in each network. Level 1 (major trauma service) offers a complete range of trauma care in the metro trauma network and acts as a tertiary referral center. It is also a center for trauma research and education and plays a leading role in providing state-of-the-art trauma care in the region. A level 2 urban trauma service delivers preliminary evaluation and stabilization and, when justified, initiates transfer to a level 1 trauma center. The level 3 metropolitan trauma service provides special attention for patients with even minor injuries in the local communities in urban areas.

In the rural trauma network, first-level (regional trauma services) offer definitive care to nonmajor trauma patients according to the hospital's availability of expertise. At the second level, rural trauma services have 24-hour on-duty medical practitioners to deliver trauma care. Remote rural trauma services are at the third level, providing trauma care in remote area hospitals with no immediately available general practitioners [30].

Conclusions

Trauma care systems are a structured, multidisciplinary response to injuries and their prevention through a continuum of care that aims to return those who have been injured to their preinjury state. They are a network of organizations working together in a geographic area to plan, provide, and manage injuries in all aspects of trauma care, from injury prevention to rehabilitation. A uniform network-based method for all acute care facilities to deliver reliable, high-quality care to the injured is essential in any health system. Recent trauma system development in Saudi Arabia is the first step in improving national trauma care. It may guide development in other locations, regionally and internationally, to improve outcomes.

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PART 2

Trauma System: Prehospital

CHAPTER 5

The Effect of Emergency Medical Services Response on Outcome of Trauma Laparotomy at a Level 1 Trauma Centre in South Africa

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Andrew J Nicol

S Afr J Surg. 2016;54(4):17-21

Abstract

Background

Due to resource constrained pre-hospital emergency medical services (EMSs) there is a significant delay in injured patients arriving at Groote Schuur Hospital Trauma Centre (GSHTC). The aim of the study was to examine the effectiveness of EMSs in transferring trauma patients to GSHTC. The effect of any delay to laparotomy from injury was noted.

Method

A prospective audit of patients presented directly from the scene to GSHTC following abdominal trauma over a four-month period was performed. Time from contact to the arrival of EMS at scene - the response time (RT) - was used as an indicator of EMS performance. Postoperative complications were graded according to Clavien-Dindo classification of surgical complications.

Results

A total of 118 patients were admitted to the trauma surgery ward following abdominal trauma. The mechanism was penetrating 101 (85.6%) [stab wounds in 67 (56.8%) and gunshot in 34 (28.8%)], and 17 (14.4%) with blunt injuries. EMSs transported 110 (93.2%) patients. A total of 48 index laparotomies were done during this period, of which 13 patients developed postoperative complications. The median RT of the EMS after contact was 53 min for patients who developed complications. It was significantly longer than for those without complications, 21 min ($p < 0.01$). The median delay to laparotomies from injury for patients with postoperative complications was 10.3 hours and for those without complications was 7.5 hours. The delay from injury to the theatre was also a significant factor in the development of complications ($p = 0.02$).

Conclusion

The response delay by EMS and delay from injury to the theatre increased complications. Therefore, rapid response by EMS in transferring trauma patients needs to be strengthened.

Introduction

Trauma is the leading cause of non-natural deaths worldwide and a major cause of permanent disability. Violence is the most significant contributor to high rates of injury in the Western Cape. It accounts for 12.9% of premature mortality as compared to 6.9% for road traffic injuries [1].

The Groote Schuur Hospital Trauma Centre (GSHTC) is one of two Level 1 trauma centres in Cape Town serving the greater Western Cape. At GSHTC, the sub-specialist surgical and ancillary services are on site and immediately available. This centre serves as a referral resource for designated communities in its region. It offers 24-hour in-house availability of required specialist disciplines: anaesthesiology and critical care, radiology, general surgery, emergency medicine, internal medicine, neurosurgery, oral and maxillofacial surgery, orthopaedic surgery and plastic surgery [2].

At GSHTC, the trauma surgical ward care is run by three full-time trauma surgeons, one general surgeon and four general surgical registrars. There are eight high care beds and a 30-bed general trauma ward for acute admissions. A dedicated trauma theatre is available Monday through Thursday from 8 am to 5 pm. Trauma cases occurring after hours, on Fridays and on weekends, are done in the main emergency theatre. The trauma surgeons operate on the neck, chest, abdominal trauma and on most vascular injuries.

South Africa is one of the few countries on the African continent with an organised statutory system of pre-hospital care. Both the public and private sector run the emergency medical services (EMSs). No formal single emergency call centre exists currently. The vehicles and personnel dispatch independently upon receiving calls from the incident. Most of the EMS vehicles in the public sector are staffed with paramedics trained in basic to intermediate life support. The majority of the population does not have medical insurance and relies on public EMS, which is a significant burden for public EMS [3].

Time since contact to the arrival of EMS at scene -the response time (RT) - is considered an indicator of EMS performance worldwide [4]. Often trauma patients are haemodynamically unstable from hypovolaemic shock following an

injury. The urgent response of an EMS is essential for initiation of resuscitation, rapid transfer of the patient to definitive care facilities and prevention of further physiological deterioration.

The aim of the study was to examine the effectiveness of EMS in transferring patients with abdominal trauma to GSHTC. The effect of any delay to laparotomy was noted.

Methods

The study was a University of Cape Town (UCT) Human Research Ethics Committee (HREC) approved (Ref: 440/2013) observational, non-interventional, and descriptive study based on the prospective analysis of data related to patients presented directly from the scene to GSHTC following abdominal trauma and admitted to the trauma ward from 01 December 2013 to 31 March 2014. Patients' demographic details, geographical area of injury, mechanism of injury, time of injury, injury severity score (ISS), EMS response time (RT), time taken to arrival at GSHTC, time taken to surgery, delay from injury to theatre, total hospital stay and outcome in Postoperative surgical complications were graded according to the updated Clavien-Dindo classification of surgical complications [5,6].

Categorical variables were assessed using frequency tables. Numerical variables were evaluated with summary statistics (median, interquartile range (IQR), etc.). A p-value of < 0.05 was considered to be significant.

Results

A total of 118 abdominal trauma patients presented directly from the scene during the period of study, with a significantly higher male to female ratio of 9:1. The median age was 25 (IQR 21-31) years. One hundred and one patients (85.6%) were admitted following penetrating trauma. Stab wounds comprised 67 patients (56.8%) and gunshot wounds (GSW) 34 (28.8%). The number of admissions due to blunt trauma was 17 (14.4%). The median ISS for a gunshot wound, stab wound, and blunt trauma was 18 (IQR 16-25), 10 (IQR 3-18), and 22 (IQR 17-27) respectively.

Sixty-six patients (56%) were admitted with ISS > 15. EMSs transported 110 patients (93.2%). With respect to different ambulance services, government service (Metro) carried the majority of patients [106 (89.8%)], followed by private ambulance service [4 (3.4%)]. Only eight patients (6.8%) arrived at the hospital in their own or a private vehicle. EMS transported all patients who developed postoperative complications.

Table 1. Management of abdominal trauma by the mechanism of injury and associated complications

Mechanisms of injury	Operative management (n=48)	Complications (n=13)	Non-operative management (n=70)	Complications (n=0)
Stab wounds (n=67)	23 (34.3%)	1	44 (65.7%)	0
Gunshot wounds (n=34)	22 (64.7%)	10	12 (35.3%)	0
Blunt trauma (n=17)	3 (17.6%)	2	14 (82.4%)	0

Seventy patients (59.3%) were managed conservatively. Forty-eight patients (40.7%) required surgery. Table 1 shows the management of abdominal trauma by the mechanism of injury.

Thirteen patients (27.1%) developed postoperative complications as listed in Table 2. Surgical site infection (SSI) and organ failure remained major postoperative complications.

The median hospital stay for all patients was 6 days (IQR 4-11). The median length of stay was significantly longer in patients who developed postoperative complications than in those who did not [16 (IQR 10-20) d vs. 5 (IQR 4-7) d, $p < 0.01$]. Only 1 patient (0.8%) died. The patient was a 17-year-old boy who was an unrestrained passenger involved in a motor vehicle accident. He was brought in by EMS and had sustained polytrauma including head injury, blunt abdominal trauma and pelvic fracture. On presentation to GSHTC, he was haemodynamically stable, and his Glasgow Coma Scale (GCS) was 8. His ISS was 34. His computed tomography (CT) scan of the brain and abdomen showed a sliver of left subdural and subarachnoid haemorrhage, pelvic fracture, grade 1-2 spleen fracture, and

perinephric haematoma around the left kidney with suspected hollow visceral injury. He had a non-therapeutic exploratory laparotomy with spleen and kidney preservation. Postoperatively, he was admitted to the intensive care unit (ICU). His head injury and pelvic fracture were managed conservatively. He died on day 15 post-admission due to severe sepsis and multiorgan failure. His ambulance RT, injury to arrival at GSHTC, booking to start surgery and injury to theatre time were 53 min, 105 min, 100 min and 487 min respectively.

Table 2. Types of complications according to Clavien-Dindo classification

Clavien-Dindo Grading	Postoperative Complications (n)
I	Wound sepsis (3), Ileus (1)
II	Pneumonia (2)
III a	Nil
III b	Empyema of chest (1)*
IV a	Acute kidney injury (1), Respiratory failure (1)
IV b	Multiorgan dysfunction (3)
V	Death (1)
Total	13

*related to diaphragm injury from thoracoabdominal gunshot wound

Analysis of delay vs. complications

The median RT of the EMS after being contacted was 53 min (IQR 46-78) for patients who developed postoperative complications, which was significantly more than those without complications, which was 21 min (IQR 10-75, $p < 0.01$). The median delay from injury to the theatre [with complications 10.3 hours (IQR 8.1-13.5), without complications 7.5 hours (IQR 5.1-11.5)] was a significant factor in the development of complications ($p = 0.02$). The median delay from the injury to arrival at GSHTC [with complications 3.9 hours (IQR 1.8-6.5), without complications 3 hours (IQR 1.9-4.7), $p = 0.27$] and from booking the case to start with surgery [with complications 2.3 hours (IQR 1.7-3.6), without complications 1.7 hours (IQR 0.9-3.8), $p = 0.27$] did not show a significant difference between both groups of patients (Table 3).

Subgroup analysis of gunshot abdomen patients

Out of thirty-four gunshot abdomen patients, 22 (64.7%) required surgery. In this group, 10 patients (45.5%) developed postoperative complications. The median response delay by EMS for gunshot abdomen patients with complications was 51 min (IQR 40-82), without complications 19 min (IQR 8-48), which was significant in the development of postoperative complications ($p < 0.01$). Also, the median delay from injury to the start of surgery for gunshot abdomen patients [with complications 10.7 hours (IQR 8.2-12.9), without complications 5.7 hours (IQR 3.4-10.8, $p = 0.03$) was also significant. The median ISS for gunshot patients with postoperative complication was 25 (IQR 16-25) and without complication was 16 (IQR 16-23). There was no association of severity of injury in the development of complications ($p = 0.22$).

Table 3. Analysis of delay vs. complications

	With complications (n=13)	Without Complications (n=35)	
	Delay in hours (IQR)		p-value
EMS response	0.9 (0.7-1.3)	0.3 (0.1-1.2)	<0.01
Injury to theatre	10.3 (8.1-13.5)	7.5 (5.1-11.5)	0.02
Injury to GSHTC	3.9 (1.8-6.5)	3 (1.9-4.7)	0.27
GSHTC to booking	2.8 (0.7-3.7)	1.3 (0.8-3)	0.09
Booking to theatre	2.3 (1.7-3.6)	1.7 (0.9-3.8)	0.27
GSHTC to theatre	5.6 (3.3-7.9)	3.9 (1.8-6)	0.03

Discussion

It is well known that the outcome improves when a trauma patient is transported to a designated trauma centre within an hour of injury - the “golden hour” [7].This “golden hour” is supported by two significant studies by Sampalis et al. in 1993 and 1999. Both studies showed reduced mortality associated with the reduction of pre-hospital time [8,9]. Shortened pre-hospital time was found to be associated with better outcomes in the case of trauma patients, such as patients with severe thoracic injuries, severe head injuries and intra-abdominal bleeding [7].

The concept of the golden hour is disputable in many countries. In 2010, a prospective cohort study in North America by Newgard et al. showed there is no relationship between in-hospital mortality and EMS transfer of severely injured patients [10]. More recently in Germany, Kleber et al. (2012) also found no significant survival benefit with shorter pre-hospital time [11]. The result is also supported by various studies done at other centres in America and Europe [7].

The reduction of pre-hospital time largely depends on the efficiency of the EMS system and especially on RT. In the event of a life-threatening condition, the rapid response of the EMS is an expectation, and it is used to measure the effectiveness of a pre-hospital system [4]. The history of RT can be traced back to a Seattle study in 1979 where the survival of cardiac arrest patients improved after basic life support (BLS) and advanced life support (ALS) initiated within four and eight minutes respectively. Several studies were done subsequently and showed similar timeframes. In 2002, Blackwell et al. showed EMS response times less than five minutes are associated with improving survival [12]. Later in 2005, Pons et al. found significant survival benefit, if the EMS response times were within four minutes [13]. Both trauma and non-trauma emergencies were included in these studies. Eight-minute response time was set as a standard for EMS operations by many authorities, but its validity was challenged by many subsequent studies [4].

It is wrong to have an arbitrary response time limit for all trauma and non-trauma emergencies. A cardiac arrest patient or one with penetrating trauma to the heart might need immediate attention of the EMS. On the other hand, a patient who sustained lower limb fracture following a motor vehicle accident might not need EMS response within eight minutes. So, EMS response time should be according to the merit of the case. According to Campbell MacFarlane, in South Africa, EMS system RT varies from 15 min in an urban area to 40 min or longer in some rural areas due to the disproportionate distribution of services; in addition, many rural areas are poorly resourced as a result of historical inequalities [14].

In the current study, it has been shown that the EMS response time is longer than the standard for abdominal trauma patients. It has also demonstrated that the patients who developed postoperative complications had longer EMS response time as well as a delay in access to surgery. After arrival to GSHTC, the group of patients who experienced complications took significantly longer time to go to

theatre than the group who did not experience complications. This was possibly due to various in-hospital factors like longer time for resuscitation, investigations, multi-system involvement, waiting for decisions from different specialties in stable patients and finally decision making for surgery. On the other hand, after arrival to GSHTC the time delay to booking and delay after booking to start the surgery did not show any statistically significant outcome difference in both groups due primarily to effective emergency surgical case triaging method by the surgeon and finally by the anaesthesiologist at GSH.

Developing postoperative complications depends on various factors including patient factors, the nature of the injuries, contamination, operative delay, operative techniques, local facilities, and postoperative care. Despite the conflicting evidence about RT and the "golden hour", it is not illogical to conclude that taking the patients to a definitive care facility as early as possible following an injury must play a role in decreasing complications and improving outcome.

Conclusions

Penetrating trauma continues to be a significant burden on the resources of a trauma centre. The response delay by EMSs and delay from injury to theatre increases complications. Delay in surgery for gunshot abdomen patients is associated with potentially graver complications. These patients should be rapidly transferred by EMS to a trauma centre. EMSs play a fundamental role in transporting patients worldwide. The EMS in South Africa has developed rapidly over the last decades. Available transport vehicles, both ground and aeromedical, should be placed strategically rather than based on facility and be used as a means to facilitate timely access and response, especially in the least accessible areas. Both government and private entrepreneurs should come forward to increase pre-hospital personnel as well as logistics to improve the current EMS system. Only an integrated modern EMS and first responders can help to provide faster access and more seamless patient transfer throughout the health care system.

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CHAPTER 6

Time since injury is the major factor in preventing tranexamic acid use in the trauma setting: An observational cohort study from a major trauma centre in a middle-income country

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Abstract

Background

Haemorrhage is responsible for about a third of in-hospital trauma deaths. The CRASH-2 trial demonstrated that early administration of tranexamic acid, ideally within 3 hours, can reduce mortality from trauma-associated bleeding by up to 32%.

Objective

To explore whether, in our trauma network in a middle-income country, patients arrived at hospital soon enough after injury for tranexamic acid administration to be effective and safe.

Methods

A prospective cohort study of 50 consecutive patients admitted to our trauma unit was undertaken. Inclusion criteria were as for the CRASH-2 study: systolic blood pressure <90 mmHg and/or heart rate >110 beats per minute, with injuries suggestive of a risk of haemorrhage. Patients with isolated head injuries were excluded. The mechanisms of injury, time since injury and any reasons for delay were recorded.

Results

Thirteen (26%) patients presented early enough for tranexamic acid administration. Of these, only three patients presented within the 1st hour. Eleven patients had a documented time of injury >3 hours prior to presentation. We were unsure of the time of injury for 26 patients, although for most of these it was likely to be >3 hours before presentation.

Conclusions

The majority (74%) of bleeding trauma patients did not present within the timeframe allowed for safe administration of tranexamic therapy. Of those who did, most would have benefited from even earlier commencement of therapy. This raises the possibility that tranexamic acid may be more effective on a population basis if incorporated into prehospital rather than in-hospital protocols; future studies should explore the benefits and risks of this approach.

Introduction

Trauma results in 5 million deaths each year worldwide, with 90% of these deaths occurring in lower-income countries [1]. Haemorrhage is responsible for up to a third of in-hospital trauma deaths; therefore, there is a need for an effective and inexpensive method of preventing the coagulopathy seen in bleeding trauma patients [2]. Tranexamic acid is an antifibrinolytic that competitively inhibits the activation of plasminogen to plasmin. At high concentrations, it is also a non-competitive inhibitor of plasmin. It has an established role in elective surgery, where it is used to address the coagulopathy associated with major operations such as complex cardiac surgery [3]. Recently, the CRASH-2 trial demonstrated a survival advantage when tranexamic acid was given to trauma patients with significant haemorrhage, although the mechanism of this effect was unclear [4]. Analysis of the CRASH-2 data has shown that for the best outcome, tranexamic acid needs to be administered within the 1st hour of trauma, and that after 3 hours it conversely results in an increase in mortality [5]. It has been suggested that tranexamic acid is unlikely to be used as a first-line treatment in hospitals in high-income countries where there is established and widespread use of blood products that can ameliorate the coagulopathy of trauma [6]. However, in low- and middle-income countries, where access to blood products is more difficult, tranexamic acid could be a practical, affordable and effective treatment for bleeding trauma patients.

Objective

We are based in a large trauma centre in South Africa, a middle-income country, where it has been suggested that tranexamic acid use may be incorporated into trauma protocols. Tranexamic acid is not currently a routine component of our care pathway nor is it at present readily available in our hospital. We explored whether patients arrived at our unit within a timeframe in which administering tranexamic acid on admission would be both safe and effective.

Methods

We undertook a prospective cohort study of 50 consecutive patients admitted to our trauma unit. We included any patient who had an injury that was suggestive of a risk of haemorrhage and who had a systolic blood pressure of <90 mmHg or a heart rate of >110 beats per minute (bpm) at any time from admission to 3 hours after injury. Any patient with an isolated head injury was excluded, as was any who, despite meeting the criteria based on vital signs, did not have injuries suggestive of haemorrhage as assessed by an experienced clinician. For each patient we recorded the time of injury, time with prehospital services, any reasons for delay in reaching our unit, the mechanism of injury, all significant injuries sustained, the blood pressure or heart rate that triggered inclusion into the study and whether the patient survived to discharge from our unit.

Results

Fifty patients were recruited into the study over a period of 3 months. Of these, 47 were male and 3 were female, with a mean age of 32 years (range 15 - 78). Three patients arrived within the 1st hour after injury, 10 patients between 1 and 3 hours, 11 patients after 3 hours and the remaining 26 patients had an unknown time of injury (Table 1). Regarding the 26 patients with unknown time of injury, these patients were often found in the road following a presumed community assault or hit-and-run pedestrian v. car accident (Fig. 1) and, given the networks in place for reporting and responding to these incidents, the time from injury to presentation was unlikely to be >3 hours.

Within our cohort there was a 22% mortality rate (n=11), with 5 patients dying in the emergency department and a further 6 not surviving to discharge. The data collected are summarised in Table 2.

For all patients for whom we did not have a documented time of injury from the paramedics, we recorded reasons for being unable to obtain this information from the patient; of the 26 patients, 14 were intoxicated, 8 had a Glasgow Coma Scale score of <15, and 4 were unable to remember with any certainty the time of their injury. We recorded the time from initial call to emergency services to arrival in

the emergency department. Owing to the tendency of prehospital staff to round to the nearest 5 minute mark on their timesheets, we took the same approach and rounded all timings to the nearest 5 minutes.

Table 1. Breakdown of results by injury and time to presentation

	Time since injury at presentation				
Mechanism of injury	**<1 h**	**1 - 3 h**	**>3 h**	**Unsure**	**Total**
Assault	0	1	2	11	14
Pedestrian v. vehicle	0	2	1	9	12
Motor vehicle accident	1	2	0	0	3
Gunshot	1	3	3	1	8
Stab	1	2	5	5	13
Total	3	10	11	26	50

There was one outlier in which 270 minutes elapsed between call and arrival - this case was an anomaly where normal prehospital protocols were not followed. With this anomaly excluded, there was no significant difference between time from call to emergency department arrival for those patients for whom we knew the time of injury compared with those where we were unsure (mean (SD) 65 (20.3) minutes v. 60 (20.5) minutes, respectively; $p<0.25$ using the unpaired two-tailed *t*-test). There was a significant difference in time from call to emergency department arrival between patients who presented <1 hour from injury and those who presented between 1 and 3 hours after injury, as could be expected (mean 35 (10.0) minutes v. 80 (9.7) minutes; $p<0.001$, unpaired two-tailed *t*-test).

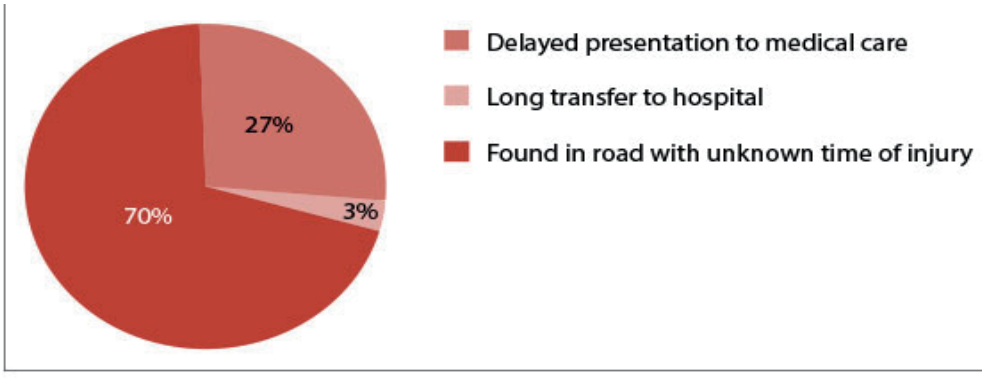

Fig. 1. Breakdown of reasons for delay if >3 hours or unsure.

Table 2. Summary of the patients included in the cohort with entry criteria and outcomes

Patient number	Age (y), gender	BP-sys (mmHg)	HR (bpm)	Mechanism of injury	Time since injury (h)	Time with ambulance crew (min)	Outcome
1	78, M	>90	125	Assault	>3	75	Survived to discharge
2	31, M	84	75	Stab buttock – vessel injury	2	95	Survived to discharge
3	31, M	76	88	Stab chest – praecordium	Unsure	30	Died in dept
4	20, M	>90	111	Stab chest and abdomen	Unsure	45	Survived to discharge
5	29, M	>90	140	PVA – multiple injuries	Unsure	40	Died in dept
6	21, M	<75	130	GSW abdomen	2	65	Died before discharge
7	21, M	>90	120	GSW abdomen	>3	40	Survived to discharge
8	44, M	<75	120	Stab back	Unsure	25	Died before discharge
9	28, M	>90	120	GSW abdomen	>3	55	Survived to discharge
10	21, M	88	140	Stab chest	Unsure	45	Survived to discharge
11	38, M	71	120	Stab neck	Unsure	60	Survived to discharge
12	20, M	>90	120	Stab chest	Unsure	45	Survived to discharge
13	34, F	>90	140	PVA – multiple injuries	2	80	Survived to discharge
14	18, M	80	145	GSW abdomen	Unsure	85	Survived to discharge
15	23, M	80	120	Community assault	Unsure	40	Survived to discharge
16	33, M	>90	135	PVA – multiple injuries	Unsure	70	Survived to discharge
17	35, F	85	95	PVA – multiple injuries	2	105	Survived to discharge
18	50, M	70	130	Stab chest	>3	70	Died before discharge
19	21, M	>90	120	Multiple stabs, chest and abdomen	>3	40	Survived to discharge
20	34, M	85	110	MVA	2	75	Survived to discharge
21	50, M	>90	120	Stab chest	2	80	Survived to discharge
22	15, M	88	100	Community assault	Unsure	45	Survived to discharge
23	24, M	90	120	Community assault	Unsure	50	Survived to discharge
24	51, M	80	130	PVA – multiple injuries	Unsure	70	Survived to discharge
25	43, M	70	130	Community assault	Unsure	55	Survived to discharge
26	21, F	>90	120	PVA – multiple injuries	Unsure	45	Survived to discharge
27	34, M	>90	130	Community assault	>3	45	Survived to discharge
28	20, M	>90	125	PVA – multiple injuries	Unsure	50	Survived to discharge
29	32, M	>90	115	Community assault	Unsure	65	Survived to discharge
30	57, M	>90	145	Multiple GSW chest and abdomen	2	70	Died before discharge
31	28, M	85	130	Community assault	Unsure	95	Survived to discharge
32	18, M	>90	125	GSW head and chest	1	35	Died before discharge
33	33, M	90	130	Community assault	Unsure	85	Survived to discharge
34	30, M	75	140	MVA – motorbike polytrauma	1	25	Died in dept
35	35, M	>90	120	Stab chest	>3	70	Survived to discharge
36	18, M	>90	120	Multiple stabs	1	45	Survived to discharge
37	26, M	>90	125	Community assault	>3	85	Survived to discharge
38	54, M	85	125	PVA – multiple injuries polytrauma	>3	270	Survived to discharge
39	43, M	>90	130	PVA – multiple injuries	Unsure	55	Survived to discharge
40	23, M	90	120	Stab abdomen	>3	70	Survived to discharge
41	16, M	85	118	Assault with panga	2	90	Survived to discharge
42	37, M	82	125	Community assault	Unsure	90	Survived to discharge
43	40, M	80	135	GSW face	Unsure	35	Died in dept
44	20, M	>90	125	PVA – multiple injuries	Unsure	60	Survived to discharge
45	48, M	85	130	PVA – multiple injuries	Unsure	80	Survived to discharge
46	33, M	80	120	PVA – multiple injuries	Unsure	95	Survived to discharge
47	43, M	85	135	MVA – ejected from vehicle	2	70	Died before discharge
48	35, M	90	120	Multiple GSW	2	75	Died in dept
49	20, M	85	125	PVA – multiple injuries	Unsure	80	Survived to discharge
50	25, M	>90	130	Assaulted	>3	60	Survived to discharge

BP-sys – systolic blood pressure; HR – heart rate; M – male; F – female; MVA – passenger or driver inside a motor vehicle accident; PVA – pedestrian hit by a vehicle; GSW = gunshot wound.

Interestingly, there was no significant difference in the time with prehospital services between patients who arrived <3 hours following injury and those who arrived >3 hours following injury (mean 70 (23.1) minutes v. 60 (15.6) minutes; p<0.300, unpaired two-tailed ĺ-test). The times with prehospital services prior to hospital arrival are summarised in Fig. 2.

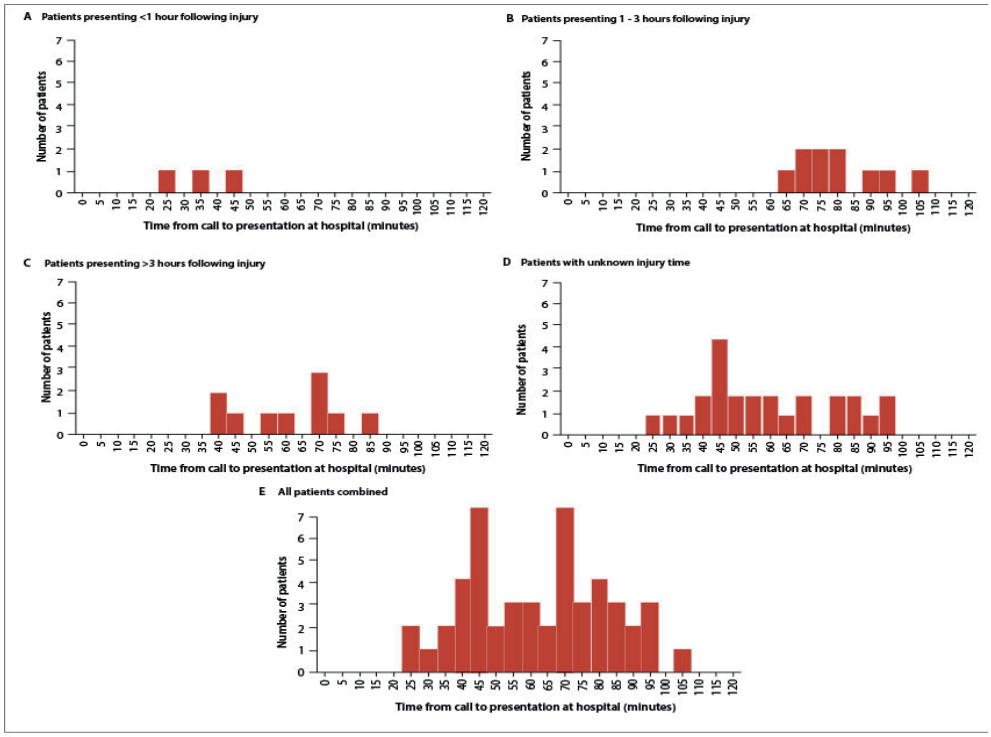

Fig. 2. Time from initial emergency call to presentation at hospital.

Discussion

Tranexamic acid is a cheap, effective and easily stored drug that has been shown to have a survival benefit when given to bleeding trauma patients. In lower- and middle-income countries where access to blood products is limited, tranexamic acid could have a considerable effect on reducing mortality from trauma. However, there is evidence that it needs to be used as soon as possible after injury - most benefit is seen in the 1st hour after injury; after 3 hours, administering tranexamic acid increases mortality.

In high-income countries with well-developed trauma networks and pre-hospital infrastructure, patients may often present to hospital within the 1st hour and almost certainly within 3 hours from injury. In lower- and middle-income countries, the presentation is often delayed. We explored whether bleeding trauma patients who met certain haemodynamic criteria reached our hospital early enough for administering tranexamic to be both safe and effective. Our results showed that only 6% of patients reached hospital within the ideal 1-hour period, and that in total only 26% arrived within a timeframe where it was safe to administer tranexamic acid. This suggests that the hospital environment would only serve a small minority of patients effectively, with 74% of patients unable to receive treatment and the subsequent survival benefit available from tranexamic acid.

The data from the paramedics regarding time from call to arrival at the emergency department suggests that emergency personnel are with the patient for a considerable proportion of the time from injury to hospital. Particularly for those patients arriving between 1 and 3 hours from injury, the delay would appear to be within the trauma system compared with those who arrive <1 hour from injury. This could be for a variety of reasons, including prolonged extrication time at the scene or the requirement to perform certain lifesaving procedures prior to departure (e.g. intubation or intercostal drain insertion). However, there is no statistical difference in the prehospital time between patients who presented <3 hours from injury and those who presented >3 hours from injury. The data therefore imply that the latter group presents later to medical care and that this delay in seeking care is the greatest factor in their ineligibility for tranexamic acid, rather than the time taken to reach hospital once the emergency services are aware of the incident.

The most common reason for patients not meeting the criteria for tranexamic therapy was an inability to pinpoint a time of injury. This made the administration of tranexamic acid potentially unsafe, as it increases mortality if given after 3 hours from time of injury. The proportion of patients for whom we could not establish a definite time of injury was surprising and in conflict with the CRASH-2 data, which had only 9 out of >20 000 patients for which injury time was unknown. There are some cultural differences in our population that could explain this, along with a limiting factor in our data collection (see below); however, the most likely explanation for this difference is that the CRASH-2 trial entry proforma only required an estimated time of injury rather than clear documentation or proof of injury time. It would be interesting to see whether estimating in this fashion correlates well with the actual time of injury.

The injury profiles of our cohort could explain the lack of data on precise injury time. A total of 22% of our patients arrived having suffered from community assault - a phenomenon not often seen in many other countries - where the community imposes its own retribution on members of that community who have committed crimes, often leaving that person for dead following physical assault. A further 24% of patients were victims of hit-and-run accidents that had no available witnesses. Apparent amnesia for events, either secondary to injuries sustained or due to intoxication, was also a complicating factor.

Unfortunately, we did not have access to the transcripts or recordings of the initial telephone calls to the emergency services, which may have enabled the time of injury to have been established in more cases. Our data relied on information provided from discussion with paramedics at handover and prehospital documentation (as would be available to our emergency physicians). There is an opportunity for a further multi-agency trial to explore whether the time of injury in our patients can be established more frequently and documented more accurately.

If tranexamic acid therapy were to be implemented in the prehospital setting, then it is likely that many of the 20% of patients who would have received treatment between 1 and 3 hours following injury may receive therapy within the 1st hour, potentially improving outcomes. Some of the patients who presented with a time from injury >3 hours previously may also become eligible for treatment.

This possibility has been raised before;[6] however, given the results of recent studies that have demonstrated an increased risk of thrombosis in patients given tranexamic acid, further work should be done on the safety of this approach before it is incorporated into routine practice [6,7]. Within our system, there would have to be considerable retraining of paramedics to ensure that indications for tranexamic acid use are correctly identified, along with appropriate awareness of relative contraindications. Subsequent to this, regulatory approval would need to be sought. These processes alone may present a significant barrier to implementation of protocol change even if the results of future studies suggest that tranexamic acid is safe to be used in this environment.

Conclusion

The use of tranexamic acid therapy in bleeding trauma patients has been shown by the CRASH-2 trial to decrease mortality by up to 32% if given in the 1st hour after injury. In low- and middle-income countries, there is a lack of other affordable and available agents to combat the coagulopathy associated with trauma; therefore, tranexamic acid has the potential to dramatically improve patient survival from trauma in these countries. However, as the CRASH-2 trial demonstrated an increased mortality if tranexamic acid was administered >3 hours after injury, it is paramount that the time of injury is ascertained, and therapy commenced as soon as possible. In our study, the majority of our patients did not meet the time criteria necessary to receive treatment.

The time-critical nature of tranexamic acid therapy unfortunately limits its utility in low- and middle-income countries. Within our population, only 6% of trauma patients received maximum benefit; however, this is largely due to community actions and cultural attitudes to trauma, with only a small percentage of patients for whom a delay within the trauma network itself was responsible for delayed presentation. This study therefore does not clearly support the use of tranexamic acid in the prehospital setting, although for those patients with a known time of injury, tranexamic acid therapy should be administered as soon as possible and prehospital administration would therefore be ideal. We suggest that routine incorporation of tranexamic acid into trauma protocols would have a far more modest effect overall than that proposed by CRASH-2.

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PART 3

In-Hospital Trauma System: Emergency Department

CHAPTER 7

Trauma Resuscitation Training: An Evaluation of Nurses' Knowledge

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Abstract

Background

Trauma resuscitation in the emergency department involves coordinated, well-equipped, and trained healthcare providers to make essential, prudent, and expedient management decisions. During this phase, healthcare providers' knowledge and skills are critical in minimizing the potential risks of mortality and morbidity.

Objective

This study aimed to evaluate the impact of training on nurses' knowledge and confidence regarding trauma resuscitation and whether there was any difference between participants with and without previous trauma training.

Methods

This study used pre-and posttraining test study design to evaluate the effects of an intensive 8-hr trauma resuscitation training program on nurses' knowledge from January 2018 to August 2021. The training program consisted of lectures and patient scenarios covering initial assessment, resuscitation, and management priorities for trauma patients in life-threatening situations, stressing the principles of the trauma team approach.

Results

A total of 128 nurses participated in 16 courses conducted during the study period. This study found significant improvement in nurses' knowledge after the training (pre-and posttraining median [interquartile range, IQR] test scores 5 [4–6] vs. 9 [8–9], $p < .001$). There was no significant difference in pretraining test scores between the participants with previous trauma training and those without training (median [IQR] test scores 5 [4–6] vs. 4 [4–5], $p = .751$).

Conclusion

Trauma resuscitation training affects the nurses' knowledge improvement, emphasizing the need for training trauma care professionals to provide adequate care.

Background

Trauma resuscitation is critical in managing patients with life-threatening injuries to achieve the best optimal outcomes (Arrowaili, 2018). The initial phase of inhospital management and trauma resuscitation requires critical, sensible, and urgent management decisions by coordinated, well-equipped, and trained healthcare professionals (McCullough et al., 2014). During this phase, the knowledge and skills of healthcare professionals are vital in reducing the potential risks of mortality or disability (Heidari & Shahbazi, 2016; Shakeri et al., 2018). As an integral part of the multidisciplinary team, nurses play a fundamental role in the initial management of trauma patients and, therefore, contribute significantly to patient care quality and safety (Schumaker et al., 2019). Hence, nurses need to be equipped with the essential knowledge and practical skills that are crucial to comprehensively assess and prioritize the patients' needs to optimize health outcomes (Cole, 2009; Gautreaux et al., 2019).

The introduction of dedicated trauma education and training programs disseminated worldwide, such as Advanced Trauma Life Support (ATLS) and Advanced Trauma Care for Nurses (ATCN), advocates systematic assessment and standardized approaches to decision-making for trauma resuscitation. These courses have been shown to increase the efficacy and quality of managing severely injured trauma patients during the early hospital management phase (Hussmann & Lendemans, 2014; Mohammad et al., 2014). In addition, advanced trauma training courses have been shown to enhance teamwork and collaboration positively, avoid potential delays in critical decisions or interventions, improve performance, and decrease resuscitation time and errors (Hughes et al., 2014; Tiel Groenestege-Kreb et al., 2014; Tsang et al., 2013).

Furthermore, a systematic literature review by Mohammad et al. (2014) demonstrated that ATLS significantly improves healthcare professionals' knowledge, clinical skills, organization, and priority approaches in the initial trauma management decisions. However, the high cost of these internationally recognized trauma courses makes them unfeasible to individuals and organizations as a training option (Armstrong et al., 2013; Gautreaux et al., 2019). Studies support the importance of high-capacity trauma-training at a low cost to achieve nursing resuscitation competence, specifically in the contexts of underdeveloped trauma

systems or in low-to middle-income countries (El-Shinawi et al., 2016; Livergant et al., 2021; Oussi et al., 2018; Petroze et al., 2014). Moreover, not all countries have accredited centers for conducting these courses. There is a need for sustainable trauma education programs that work within a cohesive system to demonstrate concrete benefits. Therefore, affordable and cost-effective continuing education and in-service training on trauma resuscitation and management are essential to maintain nurses' knowledge and skills.

Objective

This study aimed to evaluate the impact of training on nurses' knowledge and confidence regarding trauma resuscitation and whether there was any difference between participants with and without previous trauma training.

Methods

Setting: King Saud Medical City (KSMC) is a Level 1 trauma center, one of the largest tertiary care centers in Riyadh, Saudi Arabia, with 1,400 inpatient beds admitting over 2000 trauma patients annually (Chowdhury et al., 2019). In early 2017, the hospital collaborated with the Alfred Hospital, Australia, a recognized world leader in trauma and critical care, to establish a Level 1 trauma center and create a Ministry of Health trauma center network in the Kingdom. As part of this collaboration, a trauma resuscitation training program was developed to improve trauma care.

Training Course Description: Trauma resuscitation training is a structured learning trauma program aimed at medical and nursing staff, which focuses on the initial management of trauma patients. The training objectives are to identify patients who require immediate resuscitation, foster teamwork, discuss the proper sequence of priorities when assessing a trauma patient, demonstrate appropriate techniques, and appreciate the critical nature of performing essential management on a trauma patient. The training is a full-day 8-hr program consisting of lectures, discussions, and interactive sessions. The didactic sessions focused on the initial assessment, resuscitation, and management priorities for trauma patients in life-threatening situations, emphasizing the ATLS protocol's

primary survey of airway, breathing, circulation, and disability management, as well as the trauma team approach's principles. Three case scenarios were used to demonstrate the skills, including a moulage demonstration and a hands-on return demonstration.

Time	Activity
7:30 am	Registration
7:45 am	Welcome message and course orientation
8:00 am	Pre-training test
8:20 am	Introduction of the trauma team
8:50 am	Initial assessment of a trauma patient: a review
9:50 am	Dealing with an unconscious trauma patient (airway and spine management) following hemorrhage control
10:30 am	Morning tea
10:50 am	Case scenario 1: moulage demonstration and hands-on return demonstration
11:30 am	Dealing with a trauma patient in respiratory distress (Tension pneumothorax, open pneumothorax, and haemothorax)
12:10 pm	Lunch break
12:50 pm	Case scenario 2: moulage demonstration and hands-on return demonstration
1:30 pm	Dealing with a trauma patient in shock (recognition of shock and intravenous fluid resuscitation)
2:10 pm	Case scenario 3: moulage demonstration and hands-on return demonstration
2:50 pm	Afternoon tea
3:10 pm	Post-training test
3:30 pm	Course evaluation by the participants
3:40 pm	Presentation of certificates
3:50 pm	Meeting with the mentors
4:00 pm	End of formal trauma resuscitation training program

Figure 1: Trauma resuscitation training course description.

Scenario training allows targeting topics considered critical for trauma patient resuscitation while tailoring to the learners' needs. Details on the trauma resuscitation training course schedule are provided in **Figure 1**.

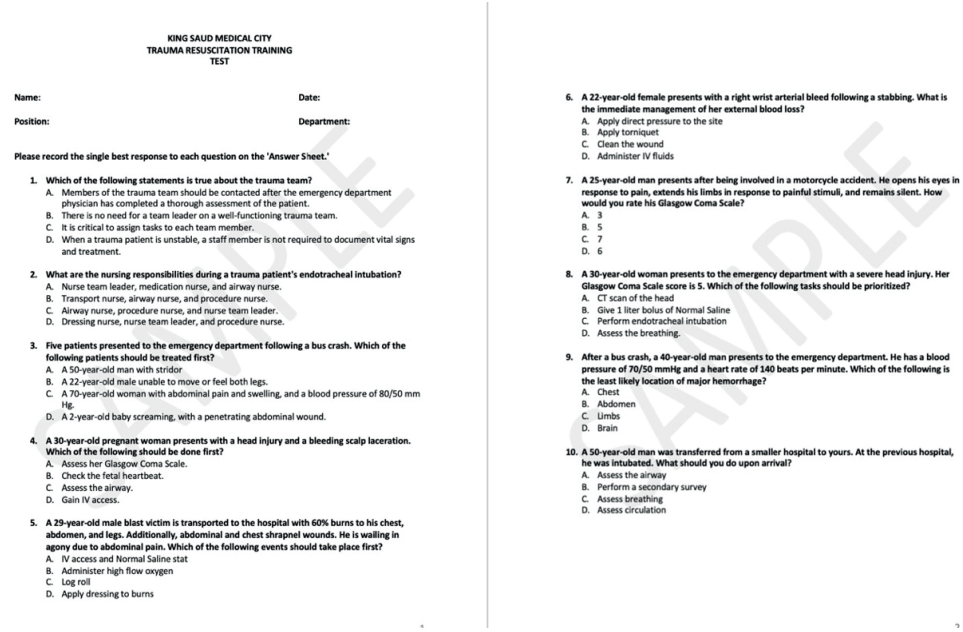
Design: This study used pre-and posttraining tests to evaluate the effects of a designed trauma resuscitation training program on the participants' knowledge. The questionnaire consists of 10 questions developed from a validated ATLS pretest. It is distributed evenly throughout the curriculum and assesses both simple recall or application and clinical judgment. The pre- and posttest sessions were scheduled for 15 min each, with an additional 5 min allocated for distribution and collection of the questionnaire and answer sheet, totaling 20 min for this session (see **Figure 1**). The same questionnaire was used to assess knowledge acquisition following training. The items assessed the didactic content of the course primarily, while the skills station section included a hands-on return demonstration to assess competency. The questionnaire items were analyzed and revised on a regularly during the administration of this program. The sample 10-question knowledge questionnaire is shown in **Figure 2**.

Sample: The sample is taken from the trauma resuscitation training was conducted from January 2018 through August 2021. Preregistrations was mandatory, and the number of participants was restricted to a maximum of eight per course. All nursing professionals associated with trauma care were encouraged to join.

Data Collection: Data were collected using three tools. First was the nurses' demographics questionnaire, which included gender, age, nationality, current workplace, position, qualification, current working area, years of experience, and previous trauma training. The second tool (pre-and posttraining) was the nurses' knowledge questionnaire consisting of 10 questions covering the trauma resuscitation topics (see **Figure 2**). The third tool was the course evaluation form provided after the training program to obtain the participants' evaluation and feedback regarding the program's perceived value.

Data Analysis: Data analysis was performed using SPSS, version 25 (IBM, Armonk, NY), and R, Version 2021.09.0, (R Studio Team, Vienna, Austria). Demographics data were analyzed and presented using descriptive statistics in the form of frequencies and percentages. Participants were divided into two groups based

on whether they had previous trauma training (e.g., ATLS and ATCN) or not. Data were then compared to determine the equivalence of the two subgroups. The nonparametric χ^2 test was used to compare count data summarized using



KING SAUD MEDICAL CITY
TRAUMA RESUSCITATION TRAINING
TEST

Name: Date:

Position: Department:

Please record the single best response to each question on the 'Answer Sheet.'

1. Which of the following statements is true about the trauma team?
   A. Members of the trauma team should be contacted after the emergency department physician has completed a thorough assessment of the patient.
   B. There is no need for a team leader on a well-functioning trauma team.
   C. It is critical to assign tasks to each team member.
   D. When a trauma patient is unstable, a staff member is not required to document vital signs and treatment.

2. What are the nursing responsibilities during a trauma patient's endotracheal intubation?
   A. Nurse team leader, medication nurse, and airway nurse.
   B. Transport nurse, airway nurse, and procedure nurse.
   C. Airway nurse, procedure nurse, and nurse team leader.
   D. Dressing nurse, nurse team leader, and procedure nurse.

3. Five patients presented to the emergency department following a bus crash. Which of the following patients should be treated first?
   A. A 50-year-old man with stridor
   B. A 22-year-old male unable to move or feel both legs.
   C. A 70-year-old woman with abdominal pain and swelling, and a blood pressure of 80/50 mm Hg.
   D. A 2-year-old baby screaming, with a penetrating abdominal wound.

4. A 30-year-old pregnant woman presents with a head injury and a bleeding scalp laceration. Which of the following should be done first?
   A. Assess her Glasgow Coma Scale.
   B. Check the fetal heartbeat.
   C. Assess the airway.
   D. Gain IV access.

5. A 29-year-old male blast victim is transported to the hospital with 60% burns to his chest, abdomen, and legs. Additionally, abdominal and chest shrapnel wounds. He is wailing in agony due to abdominal pain. Which of the following events should take place first?
   A. IV access and Normal Saline stat
   B. Administer high flow oxygen
   C. Log roll
   D. Apply dressing to burns

6. A 22-year-old female presents with a right wrist arterial bleed following a stabbing. What is the immediate management of her external blood loss?
   A. Apply direct pressure to the site
   B. Apply torniquet
   C. Clean the wound
   D. Administer IV fluids

7. A 25-year-old man presents after being involved in a motorcycle accident. He opens his eyes in response to pain, extends his limbs in response to painful stimuli, and remains silent. How would you rate his Glasgow Coma Scale?
   A. 3
   B. 5
   C. 7
   D. 6

8. A 30-year-old woman presents to the emergency department with a severe head injury. Her Glasgow Coma Scale score is 5. Which of the following tasks should be prioritized?
   A. CT scan of the head
   B. Give 1 liter bolus of Normal Saline
   C. Perform endotracheal intubation
   D. Assess the breathing.

9. After a bus crash, a 40-year-old man presents to the emergency department. He has a blood pressure of 70/50 mmHg and a heart rate of 140 beats per minute. Which of the following is the least likely location of major hemorrhage?
   A. Chest
   B. Abdomen
   C. Limbs
   D. Brain

10. A 50-year-old man was transferred from a smaller hospital to yours. At the previous hospital, he was intubated. What should you do upon arrival?
    A. Assess the airway
    B. Perform a secondary survey
    C. Assess breathing
    D. Assess circulation

Figure 2: Pre-and posttest questionnaire

proportions. Test score data were summarized using median (interquartile range, IQR) and compared using the nonparametric Mann–Whitney *U* test as a two-tailed test. A *p* value of .05 was regarded as statistically significant. This study was approved by the Institutional Review Board at KSMC (Reference No. H1RI-31-May21-01), and informed consent was obtained prior to participation.

Results

Descriptive Findings: A total of 128 nurses participated in 16 courses conducted during the study period. The majority of the participants were from KSMC (86.7%), followed by three other hospitals in the region- Al Iman General Hospital (5.5%), King Salman Hospital (3.9%), and Imam Abdulrahman Hospital (3.9%). Most participants were female (85.9%), ages between 30 and 34 years (42.2%), and non-

Saudi nationals (67.2%). Half of the nurses were staff nurses (51.6%), followed by charge (28.1%) and head nurses (7.8%). Regarding educational qualifications, 28 (21.9%) nurses were diploma, 93 (72.7%) were bachelor's, and only seven (5.4%) were master's degree holders. Ninety-three (72.6%) nurses were working in the emergency department. The majority of the participants (49 [38.3%]) had work experience ranging between 6 and 10 years. Thirty-nine (30.5%) nurses had more than 10 years of work experience. Furthermore, 55 (43%) had previous work experience in the emergency department. Most of the participants (n = 102) had no previous trauma training. **Table 1** compares participants' demographics (with and without training), including gender, age distribution, nationality, current workplace, position, qualification, current working area, and years of experience.

Outcome Measurement: The median pretraining test score for all participants was 5 (IQR 4–6), which then improved to a median score of 9 (IQR 8–9) after the training (**Figure 3**). The study's findings demonstrate a significant improvement in nurses' knowledge after the trauma resuscitation training ($p < .001$). The participants with previous trauma training had a median pretraining score of 5 (IQR 4–6), whereas those without previous trauma training had a median pretraining score of 4 (IQR 4–5). There was no significant difference in pretraining test scores between the participants with previous trauma training and those without training ($p = .751$). In addition, posttraining test scores improvement was similar for both groups (with training 9 [IQR 0] and without previous training 9 [IQR 8–9]), as well as statistically not significant ($p = .051$).

Table 1: Comparison Between Previously Trained and Not Trained Participants (*N* = 128).

Variables	n (%)	Previous Trauma Training (Yes= 26) n (%)	Previous Trauma Training (No=102) n (%)	*p*
Gender				.006
Male	18 (14.1)	8 (30.8)	10 (9.8)	
Female	110 (85.9)	18 (69.2)	92 (90.2)	
Age (years)				.207
25-29	35 (27.3)	4 (15.4)	31 (30.4)	
30-34	54 (42.2)	15 (57.7)	39 (38.2)	
35-39	23 (18)	4 (15.4)	19 (18.6)	
40-44	8 (6.3)	3 (11.5)	5 (4.9)	
45-49	3 (2.3)	0 (0)	3 (3.0)	
50+	5 (3.9)	0 (0)	5 (4.9)	
Nationality				.005
Saudi	42 (32.8)	9 (34.6)	33 (32.4)	
Non-Saudi	86 (67.2)	17 (65.4)	69 (67.6)	
Filipino	44 (34.4)	9 (34.6)	35 (34.3)	
Indian	37 (28.9)	4 (15.4)	33 (32.4)	
Jordanian	3 (2.3)	3 (11.5)	0 (0)	
Egyptian	2 (1.6)	1 (3.9)	1 (0.9)	
Current Workplace				.712
King Saud Medical City	111 (86.7)	22 (84.7)	89 (87.3)	
King Salman Hospital	5 (3.9)	1 (3.8)	4 (3.9)	
Al-Iman General Hospital	7 (5.5)	1 (3.8)	6 (5.9)	
Imam Abdulrahman Hospital	5 (3.9)	2 (7.7)	3 (2.9)	
Position				.002
Staff Nurse	66 (51.6)	7 (26.9)	59 (57.8)	
Charge Nurse	36 (28.1)	9 (34.7)	27 (26.5)	
Head Nurse	10 (7.8)	5 (19.2)	5 (4.9)	
Nursing Supervisor	9 (7)	5 (19.2)	4 (3.9)	
Clinical Instructor	5 (4)	0 (0)	5 (4.9)	
Trauma Data Collector	2 (1.5)	0 (0)	2 (2)	
Qualification				< .001
Diploma	28 (21.9)	1 (3.9)	27 (26.5)	
Bachelor	93 (72.7)	20 (76.9)	73 (71.6)	
Master	7 (5.4)	5 (19.2)	2 (1.9)	

Current working area				.545
Emergency department	93 (72.6)	17 (65.4)	76 (74.6)	
Adult Emergency Depart.	51 (39.8)	9 (34.6)	42 (41.3)	
Pediatric Emergency Depart.	42 (32.8)	8 (30.8)	34 (33.3)	
Intensive Care Unit (ICU)	8 (6.2)	0 (0)	8 (7.8)	
Adult ICU	4 (3.1)	0 (0)	4 (3.9)	
Pediatric ICU	4 (3.1)	0 (0)	4 (3.9)	
General Wards	16 (12.5)	5 (19.3)	11 (10.8)	
Adult General Wards	15 (11.7)	5 (19.3)	10 (9.8)	
Pediatric General Wards	1 (0.8)	0 (0)	1 (1)	
Others	11 (8.7)	4 (15.3)	7 (6.8)	
Trauma coordination	6 (4.8)	2 (7.7)	4 (3.9)	
Administration	5 (3.9)	2 (7.6)	3 (2.9)	
Nursing Experience (years)				.249
<2	2 (1.6)	0 (0)	2 (2)	
2-5	38 (29.6)	4 (15.4)	34 (33.3)	
6-10	49 (38.3)	13 (50)	36 (35.3)	
>10	39 (30.5)	9 (34.6)	30 (29.4)	
ED Experience (years)				.197
No	9 (7)	2 (7.7)	7 (6.8)	
<2	19 (14.8)	4 (15.4)	15 (14.7)	
2-5	55 (43)	8 (30.7)	47 (46.1)	
6-10	28 (21.9)	10 (38.5)	18 (17.7)	
>10	17 (13.3)	2 (7.7)	15 (14.7)	

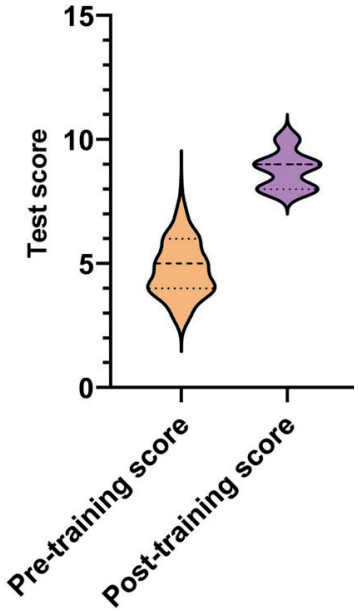


Figure 3: Comparison between pre- and posttraining test scores.

Course Evaluation: The scores obtained from the courses' evaluation analysis indicated the nurses' highly perceived value of the trauma resuscitation training program. The evaluation was divided into three main questions. First was the nurses' confidence in trauma care after the course, wherein a total of 115 (89.8%) participants (33 [25.8%] strongly agreed and 82 [64.1%] agreed) believed that the training would increase their confidence in trauma patient care. The second question was regarding recommending the course to a colleague, wherein 119 (92.9%) participants were in favor. The final question was regarding the adequacy of the course content. Most of the participants (68 [53.1%]) indicated that the course was adequate, 34 (26.6%) had neutral responses, and 26 (20.3%) disagreed and believed that more content should be included in the program (**Table 2**).

Table 2: Course Evaluation by the Participants (*N* = 128).

Questions	Response n (%)	Previous Trauma Training (Yes= 26) n (%)	Previous Trauma Training (No=102) n (%)	*p*
Are you more confident in Trauma patient care after the course?				.655
Strongly agree	33 (25.8)	9 (34.6)	24 (23.5)	
Agree	82 (64.1)	16 (61.5)	66 (64.7)	
Neutral	10 (7.8)	1 (3.9)	9 (8.8)	
Disagree	1 (0.8)	0 (0)	1 (1)	
Strongly disagree	2 (1.5)	0 (0)	2 (2)	.241
Will you recommend the course to your colleague?				
Strongly	65 (50.8)	17 (65.4)	48 (47.1)	
Likely	54 (42.2)	8 (30.7)	46 (45.1)	
Neutral	9 (7)	1 (3.9)	8 (7.8)	
Less likely	0 (0)	0 (0)	0 (0)	
Least likely	0 (0)	0 (0)	0 (0)	
Was the course curriculum adequate?				.263
Strongly agree	12 (9.4)	4 (15.4)	8 (7.8)	
Agree	56 (43.7)	14 (53.8)	42 (41.2)	
Neutral	34 (26.6)	4 (15.4)	30 (29.4)	
Disagree	20 (15.6)	2 (7.7)	18 (17.7)	
Strongly disagree	6 (4.7)	2 (7.7)	4 (3.9)	

Discussion

The findings of this study indicated a significant improvement in the nurses' knowledge after the trauma resuscitation training program. These results align with several studies that demonstrated the positive effects of different trauma educational approaches on the professionals' knowledge and skills, thus emphasizing the need for continued trauma training (Abu-Zidan, 2016). Garvey et al. (2016) reported the benefits a 2-day trauma tactics course that used high-fidelity human patient simulation that focused on nurses' knowledge, performance, confidence, and educational experience. Furthermore, Kapucu (2017) discussed the benefits of trauma education through simulation on nursing trainees' confidence and preparedness for real-world clinical settings. More recently, Peters et al. (2018) also noted the growing evidence that trauma nursing training, including didactic education and simulation, incorporated teamwork collaboration, and training are linked to increased knowledge, self-confidence in clinical judgment and performance, and therefore good patient outcomes.

Finstad et al. (2018) assessed the effect of a 2-day trauma nursing course on trauma management and treatment in Norway. This course was modeled after ATLS and ATCN and taught standardized assessment and management of trauma patients. Furthermore, this study showed improvement in the nurses' self-perceived competence concerning trauma management and treatment (Finstad et al., 2018).

The pretraining scores did not significantly differ between participants with and without previous training, suggesting that all participants started the course with similar trauma resuscitation knowledge, irrespective of any previous trauma course. This results could be attributed to the poor retention of knowledge among the previously trained participants over the long term. Hence, this further emphasizes the need for continuous and periodical trauma training and education (Pemberton et al., 2013). This interpretation is consistent with studies that found a decline in trauma knowledge and skills after 3–6 months and poor retention for long-term gains (Ansquer et al., 2019; Mohammad et al., 2014). On the other hand, posttraining scores improvement was identical in both groups, indicating equal effectiveness. Such findings should encourage all nurses to enroll in these courses.

Nevertheless, this study did not follow up on the nurses' knowledge retention and only evaluated nurses' knowledge immediately after course completion. Participants would usually report low scores that may not appear statistically significantly different from precourse scores based on literature evidence. Therefore, to maximize the benefits of trauma education, identifying such a curriculum framework for ongoing trauma training initiatives is required to sustain the nurses' knowledge and skills (Mador et al., 2020). In addition, further research investigation is necessary to identify potential educational methods that could maintain a sustainable and long-term impact of trauma education.

More than half of the participants were satisfied with the course curriculum in the current study, although some participants reported the need for more content. After the course completion, the evaluation received from the participants signifies a meaningful effect of the trauma resuscitation course on nurses' knowledge and confidence, which underscores the need for standardizing an affordable continuing trauma education and in-service training within hospitals (Haley et al., 2017).

Limitations

Although this study has contributed to trauma nursing education by identifying trauma resuscitation training benefits as an approach that can be customized to be more comprehensive for the nurses and implemented with a minimal financial cost, it has several limitations. First is the inability to assess nurses' clinical skills after completing skill stations in this the trauma resuscitation training program, which could identify the potential effects of the trauma resuscitation course on their trauma practice besides knowledge. Despite the program assessed skills through hands-on return demonstrations, additional predetermined criteria could be more beneficial in this regard and help to further strengthen the study objectives. Second is the inability to evaluate the long-term retention of knowledge acquired after the course, which can help determine the factors influencing the employed educational methods and identify suitable pedagogical approaches. In addition, the study did not consider comparing other variables such as years of experience and working units to influence the knowledge score. Finally, because both trained and untrained nurses scored similarly, the size disparity between the

two groups may limit the study's conclusion. The hypotheses can be tested more rigorously using different designs, such as randomized controlled trials or cohort studies, which would increase the robustness of the obtained conclusion.

Future perspectives

As nurses expressed a desire for additional content in the course through their course evaluations, we are considering revising the curriculum in the future and possibly expanding it to 2 days. Additionally, the study evaluates the effects of a designed training program through nurses' self-assessment. However, other objective variables such as time to computed tomography for head-injured patients, resuscitation endpoints, restoration of vital signs following hemorrhagic shock, emergency department length of stay, and mortality, among others, are critical for determining the true effectiveness of the provided training and warrant future research investigations.

Conclusions

Trauma or physical injuries remain the most significant cause of death and disability worldwide, substantially impact people's lives and straining healthcare systems (World Health Organization, 2018). Trauma training is critical for healthcare professionals to improve patient outcomes. The study's findings highlighted the importance of nursing personnel receiving ongoing and periodic trauma training. Additional research is necessary to determine the long-term effect of trauma resuscitation training on nurses' knowledge and practice abilities and the influence of hands-on experience in retaining knowledge. More significantly, organizations must identify cost-effective alternatives, implement trauma nurse education methods that are inclusive and accessible to a broader nursing audience across all units, and optimize the advantages of such training while increasing the quality of trauma treatment.

The authors recommend adopting comprehensive trauma resuscitation training for the hospitals managing trauma patients. These practices entail organizational and clinical changes within the hospital, emphasizing policy and educational

opportunities to recognize the impact of trauma. Trauma center adminstrators must be involved in building a team with the necessary expertise and a framework for organizational and clinical changes that can be implemented practically across the health care sector.

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CHAPTER 8

Outcomes of trauma patients present to the emergency department with a shock index of ≥1.0

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Abstract

Introduction

The study aimed primarily to evaluate the association between the initial shock index SI ≥1.0 with blood transfusion requirement in the emergency department (ED) after acute trauma. The study's secondary aim was to look at the outcomes regarding patients' disposition from ED, ICU & Hospital length of stay, and deaths.

Methods

It was a retrospective, cross-sectional study and utilized secondary data from the Saudi Trauma Registry (STAR) between September 2017 to August 2020. We extracted the data related to patient demographics, mechanism of injuries, the intent of injuries, mode of arrival at the hospital, characteristics on presentation to ED, length of stay, and deaths from the database and compared between two groups of SI<1.0 and SI≥1.0. A p-value of < 0.05 was considered significant.

Results

Of 6667 patients in STAR, 908 (13.6%) had SI≥1.0. With SI ≥1.0, there was a significantly higher incidence of blood transfusion in ED compared to SI <1.0 (8.9% vs. 2.4%, p <0.001). Also, SI ≥1.0 was associated with significant ICU admission (26.4% vs. 12.3%, p <0.001), emergency surgical intervention (8.5% vs. 2.8%, p <0.001), longer ICU stay (5.0±0.36 vs. 2.2±0.11 days, p <0.001), longer hospital stays (14.8±0.61 vs. 13.3±0.24 days, p <0.001), and higher deaths (8.4% vs.2.8%, p <0.001) compared to the patient with SI <1.0.

Conclusions

In our cohort, a SI≥1.0 on the presentation at the ED carried significantly worse outcomes. This simple calculation based on initial vital signs may be used as a screening tool and therefore incorporated into initial assessment protocols to manage trauma patients.

Introduction

Trauma or physical injury is a significant cause of mortality and disability worldwide [1]. Road Traffic Accidents (RTAs) are one of the most common reasons for major trauma [2,3]. The RTAs are responsible for approximately 50 million injuries each year – including the deaths of over 1.25 million people [4]. It is estimated that injuries from RTAs rank as the ninth cause of death globally and are assumed to be the seventh leading cause of death by 2030. In Saudi Arabia, nearly 80% of all trauma admissions are due to RTAs and cost the economy around 21 billion US dollars every year [5,6]. Moreover, 4.7% of all deaths are caused by RTAs, representing nearly 11% of total deaths in 2010 [6-8]. RTAs rank as the leading cause of disability also [4,6]. In 2013, there were 526,400 accidents, resulting in 7,661 deaths, and every day there are approximately 25 deaths as a result of RTAs [6,9]. It is estimated that between 35 and 38 per 100,000 people die or are disabled due to RTAs each year [10].

Massive haemorrhage accounts for 50% of deaths during the first 24 hours after hospital admission following major trauma [11]. Studies demonstrate an association with improved outcomes when massive transfusion is started in the ED. The failure to do so is an independent predictor of mortality [12].

The emergency evaluation of trauma victims can be challenging when vital signs and physical examination findings do not reflect severe injuries. The use of the shock index (SI), defined as the ratio of Heart Rate (HR) to Systolic Blood Pressure (SBP), has been correlated with the degree of shock, decreased tissue oxygenation, and Left Ventricular (LV) performance [13]. A SI value >0.9 has helped identify the ED patients requiring immediate therapy, admission, and Intensive Care Unit (ICU) admission [14]. Massive transfusion initiation is inconsistent amongst providers, and up to 25% of "potentially preventable" trauma deaths did not receive a massive transfusion because of failure to identify the need [15].

This study aimed primarily to evaluate the association between initial SI≥1.0 with blood transfusion in the ED after acute trauma. The study's secondary aim was to look at the outcomes regarding patients' disposition from ED, ICU & Hospital length of stay, and deaths.

Materials and Methods

Setting: The King Saud Medical City (KSMC) is one of the largest hospitals in Saudi Arabia, with 1400 inpatient beds. The KSMC emergency department (ED) is the busiest in the Kingdom [16]. The annual patient visit at the ED of KSMC is more than 246,000, of which more than 23,000 are trauma patients, which makes KSMC the largest in the country [17]. **S**audi **T**raum**A R**egistry (STAR) became operational at KSMC in September 2017. It is a comprehensive trauma management software system to document patient injuries, the care provided, patient outcomes, and system performance, which will link to all MOH trauma centers' registry system. All trauma patients with a principal diagnosis of injury and one of the following were included in the registry: death in the ED due to injury, inpatient admission, or transfer to KSMC, inpatient death following injury, and admission to the intensive care unit (ICU). On the other hand, superficial injury and/or amputation of single fingers and toes only, length of stay <3 calendar days apart from death and/or admission to the ICU, burns <10% total body surface area, and injury date more than three calendar days before admission to the first hospital were excluded in the registry [18].

Design: It was a retrospective, cross-sectional study and utilized the secondary data from the STAR between September 2017 to August 2020. The data related to patient demographics, mechanism of injuries, the intent of injuries, mode of arrival at the hospital, baseline (on presentation to ED) characteristics, length of stay, and deaths were extracted from the STAR database. The data were compared between two groups of SI<1.0 and SI≥1.0. Blood transfusion requirement at ED with SI≥1.0 was the primary outcome variable. The secondary outcome variables were patients' disposition from ED, ICU & Hospital length of stay, and deaths.

Ethics: The experiment protocol for involving human data was following the guidelines of national/international/institutional or Declaration of Helsinki in the manuscript. The KSMC Institutional Review Board (IRB) approved the study with the reference number H1RI-22-Dec20-07. A waiver of the obligation to obtain informed consent from participants for a retrospective review of their data was approved by the IRB committee.

Statistical Analysis: The data were analyzed using SPSS 25.0 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). The patients were classified based on presenting shock index SI≥1.0 vs <1.0. in the ED. The nominal variables were presented in frequency and percentage. The association between the demographic and risk factors was tested by the Mann Whitney test, Chi-Square test, Wilcoxon signed-rank test based on the number of categories. The diagnostic tools sensitivity, specificity with Receiver Operating Characteristic (ROC) curves, and the Odds Ratio (OR) with 95% confidence interval (CI) were provided. The Kaplan Meier survival curves were used to predict the probability of survival among the patients with SI≥1.0 vs <1.0. All the tests were performed at a 5% level of significance.

Results

In total, 6667 patients were included for analysis from the STAR database during the study period. Of these, 908 (13.6%) patients had SI≥1.0 (Figure 1).

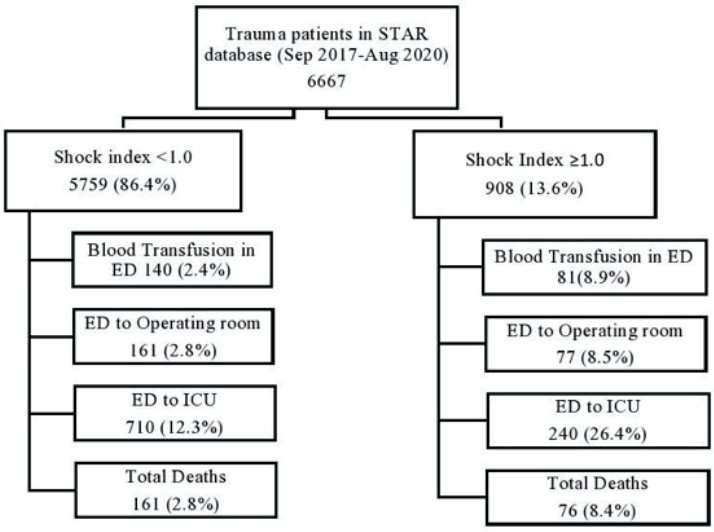

Figure 1: Sample

The overall mean age was 32.8 (SD 0.22) years and the majority [5574 (83.6%)] were men. The commonest mechanism of injury was blunt [6096 (91.4%)] trauma. Of these, 3909 (58.6%) patients sustained motor vehicle collisions, and 2187 (32.8%) fell. A trauma team was activated in 680 (10.2%; 95% CI: 9.5%-10.9%) cases. The majority of patients [5358 (80.8%)] ISS was <15 (Table 1).

Table 1. The comparison between demographics, mechanisms, intent of the injuries, and baseline (on presentation to ED) characteristics

Variable	Total (n=6667), N (%)	Shock Index <1.0 (n=5759; 86.4%), n (%)	Shock Index ≥1.0 (n=908; 13.6%), n (%)	p-value
Age in years (mean [SD])	32.8 (0.22)	32.8 (0.23)	33.2 (0.61)	<0.001*
Male sex (%)	5574 (83.6)	4865 (84.5)	709 (78.1)	<0.001*
Injury mechanism				
Blunt	6096 (91.4)	5325 (92.5)	771 (84.9)	<0.001*
- MVC†	3909 (58.6)	3428 (59.5)	481 (53.0)	0.243
- Fall	2187 (32.8)	1897 (33.0)	290 (31.9)	0.030*
Penetrating	261 (3.9)	223 (3.9)	38 (4.2)	0.666
- Stab	217 (3.2)	190 (3.3)	27 (3.0)	<0.001*
- Firearm	44 (0.7)	33 (0.6)	11 (1.2)	<0.001*
Burn	299 (4.5)	204 (3.5)	95 (10.5)	<0.001*
Others/Unknown	11 (0.2)	7 (0.1)	4 (0.4)	0.025*
Injury intent				
- Non-intentional	6367 (95.5)	5501 (95.5)	866 (95.4)	0.893
- Intentional	32 (0.5)	26 (0.5)	6 (0.7)	0.439
- Assault	240 (3.6)	209 (3.6)	31 (3.4)	0.763
- By police & military	5 (0.1)	4 (0.1)	1 (0.1)	1.000
- Unknown	23 (0.3)	19 (0.3)	4 (0.4)	0.617
Mode of arrival				
- Government	1707 (25.6)	1452 (25.2)	255 (28.0)	0.072
- Red Crescent	2049 (30.7)	1875 (32.6)	174 (19.2)	<0.001*
- Private	1879 (28.2)	1635 (28.4)	244 (26.9)	0.351
- Others	1032 (15.5)	797 (13.8)	235 (25.9)	<0.001*
Trauma Team Activation	680 (10.2)	511 (8.9)	169 (18.6)	<0.001*
Systolic Blood Pressure (mmHg), mean ± SD	126.5 ± 0.28	130.5 ± 0.27	101.1 ± 0.57	<0.001*

Heart Rate (beats/min), mean ± SD	93.7 ± 0.23	89.2 ± 0.19	122.3 ± 0.61	<0.001*
GCS, mean ± SD	14.3 ± 0.03	14.4 ± 0.03	13.5 ± 0.11	<0.001*
PH, mean ± SD	7.3 ± 0.00	7.4 ± 0.00	7.3 ± 0.00	<0.001*
Base deficit, mean ± SD	1.1 ± 0.03	0.90 ± 0.03	2.6 ± 0.12	<0.001*
INR‡, mean ± SD	1.1 ± 0.00	1.1 ± 0.00	1.1 ± 0.01	1.000
Mechanical Ventilation	950 (14.2)	689 (12.0)	261 (28.7)	<0.001*
Injury Severity Score (ISS)				
-<15	5385 (80.8)	4736 (82.2)	649 (71.5)	<0.001*
-15-25	923 (13.8)	738 (12.8)	185 (20.4)	<0.001*
->25	359 (5.4)	285 (5.0)	74 (8.1)	<0.001*

* Statistically significant at 5% level, †Motor vehicle collision, ‡International normalized ratio

A total of 221 (3.3%; 95% CI: 2.8%-3.7%) received a blood transfusion in the ED. Overall, 238 (3.6%; 95% CI: 3.1%-4.0%) patients required emergency surgical intervention and were transferred to the operating room directly from the ED. A total of 950 (14.2%; 95% CI: 13.4%-15.1%) patients were admitted to ICU from ED, and overall mortality was 237 (3.6%; 95% CI: 3.1%-4.0%) among the cohort (Table 2). The comparison between demographics, injury mechanisms, the intent of injuries, and baseline (on presentation to ED) characteristics between two groups of SI <1.0 and ≥1.0 are described in Table 1. The GCS (14.4 vs. 13.5; p-value <0.001), and PH (7.4 vs. 7.3; p-value <0.001) were significantly lower, and the base deficit was significantly higher (0.90 vs. 2.6; p-value <0.001) in SI ≥1.0 group. Also, there was a significantly higher proportion (12% vs. 28.7% p-value <0.001) of mechanically ventilated patients in the SI ≥1.0 group (Table 1).

The performance of SI to predict blood transfusion in ED is illustrated in Figure 2.

Overall AUROC for the entire cohort was 0.712 (p =0.000, 95% CI: 0.676 - 0.748). The patients sustained blunt trauma with AUC=0.712 (p = 0.000, 95% CI: 0.674 – 0.750) performed better than the patients sustained penetrating trauma with AUC= 0.693 (p=0.002, 95% CI:0.571 - 0.816) (Figure 2).

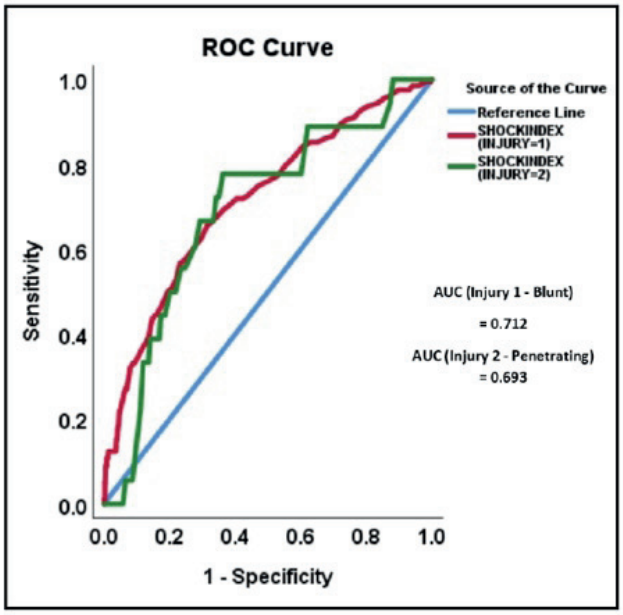

Figure 2. Receiver Operator Characteristics curve for Penetrating and Blunt Injury (n=6667)

With SI ≥1.0, a significantly higher incidence of blood transfusion in ED was observed compared to SI <1.0 (8.9% vs. 2.4%, p-value <0.001, OR 3.9, and 95% CI: 3.0-5.2) in our cohort. Also, SI ≥1.0 on presentation was associated with significant ICU admission (26.4% vs. 12.3%, p-value <0.001, OR 2.6, 95% CI: 2.2-3.0), emergency surgical intervention (8.5% vs. 2.8%, p-value <0.001, OR 3.2, 95% CI: 2.4-4.3), longer ICU stay (5.0±0.36 days, p-value <0.001), longer hospital stay (14.8±0.61 days, p-value <0.001), and higher deaths (8.4% vs.2.8%, p-value <0.001, OR 3.2, 95% CI: 2.4-4.2) compared to the patient with SI <1.0 (Table 2).

Table 2. Outcome analysis

Variable	Total (*n*=6667), *n* (%)	Shock index <1.0 (*n*=5759; 86.4%), *n* (%)	Shock index ≥1.0 (*n*=908; 13.6%), *n* (%)	*P*	OR (95% CI)
Blood transfusion in ED	221 (3.3)	140 (2.4)	81 (8.9)	<0.001*	3.9 (3.0-5.2)
Disposition from ED					
Ward	5291 (79.4)	4853 (84.3)	438 (48.2)	<0.001*	10.1 (8.6-11.9)
ICU	950 (14.2)	710 (12.3)	240 (26.4)	<0.001*	2.6 (2.2-3.0)
Operating room	238 (3.6)	161 (2.8)	77 (8.5)	<0.001*	3.2 (2.4-4.3)
Others	188 (2.8)	35 (0.6)	153 (16.9)	<0.001*	33.1 (22.7-48.2)
ICU length of stay (days), mean±SD	2.6±0.11	2.2±0.11	5.0±0.36	<0.001*	-
Hospital length of stay (days), mean±SD	13.6±0.22	13.3±0.24	14.8±0.61	0.023*	-
Death	237 (3.6)	161 (2.8)	76 (8.4)	<0.001*	3.2 (2.4-4.2)

*Statistically significant at 5% level. SD: Standard deviation, ED: Emergency department, ICU: Intensive care unit, OR: Odds ratio, CI: Confidence interval

The mean survival time of patients with SI≥1.0 was 94±8 days compared to those with SI<1.0 was 200±10days (Mantel Hazel log-rank p=0.000). The probability of survival among the patients with SI≥1.0 vs. SI<1.0 is shown in Figure 3.

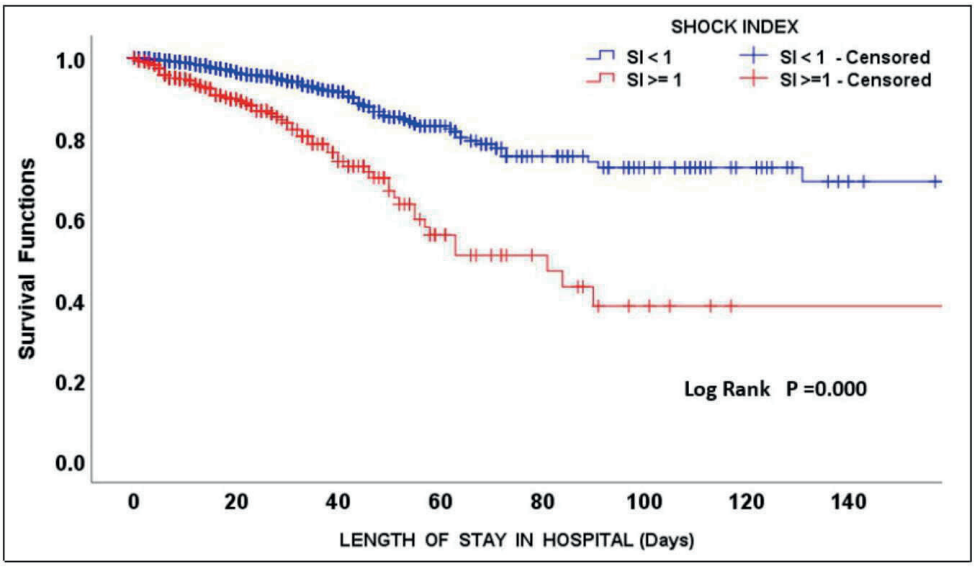

Figure 3. Survival Probability Functions of the Shock Index (n=6667)

Discussion

Trauma leads to bleeding and can cause deaths if not controlled [19,20]. Traditionally, hypovolemic shock is classified based on the percentage of circulatory blood loss [21]. Practically, accurate quantification of blood loss is not possible. So, physiological signs like heart rate, systolic blood pressure, pulse pressure, respiratory rate, urine output, and mental status have been correlated to the class of shock by the ATLS®. The clinical validity of shock classification by ATLS was recently questioned by data from the TARN registry and TraumaRegister DGU®, and physiological parameter base deficit was recommended as more appropriate to recognize the hypovolemic shock in trauma patients [22-24]. The point of care testing (POCT) of base deficit may not be readily available everywhere. The SI calculation to recognize hypovolemia due to bleeding in trauma patients is more practical and can quickly be done when the vitals are available.

The SI of ≥1.0 has been correlated with moderate (class III) to severe (class IV, SI ≥1.4) shock and blood and blood products transfusion needs [21,25]. In our cohort, the patients with SI of ≥1.0 showed significantly higher blood transfusion requirements in the ED. This group of patients was also considerably acidotic and had a higher base deficit on our ED presentation. Vandromme, M.J. et al. demonstrated on 8,111 patients that a SI of more than 0.9 had increased the risk of massive blood transfusion by 1.5-fold. A further increase of SI more than 1.3 was associated with an eightfold risk of blood transfusion [26]. Zarzaur, B.L. showed overall trauma population, SI was most closely associated with a transfusion of four blood units or more within the first 48 hours after admission to the hospital [27].

There was a significantly higher patients' proportion of ISS (15-25 and >25) in the SI of ≥1.0 group in our series. Mutschler, M. et al. on a retrospective analysis of 21,853 trauma patients from TraumaRegister DGU® showed worsening of SI category was associated with increments in ISS, new injury severity scores (NISS), and revised injury severity classification (RISC) scores as well as higher percentages of chest, abdomen and pelvic injuries [25].

We found that the mortality was significantly higher, with an SI of ≥1.0, corresponding with the previously published research in the literature [25,28,29]. Cannon, C.M. et al. demonstrated increased mortality with SI >0.9 in 2,445 trauma

patients treated in an urban level I center [28]. They also concluded that a five-fold increase in mortality between the accident scene and the arrival at ED in patients increased SI by ≥0.3 [28]. According to Zarzaur, B.L., the SI was also a significantly better mortality predictor for 48-hour than systolic blood pressure or heart rate alone [29]. In another study, Kim, M.J. et al. on 628 patients showed SI is a good predictor of mortality in polytrauma patients [30]. Although they emphasized 'delta SI' defined as the difference between SI of at scene and arrival in ED is the best predictor, which was also supported by Schellenberg, M. et al. in their study on 2591 patients [31]. Schellenberg, M. et al. also showed delta SI >0.1 is associated with an increased need for blood transfusion and ICU length of stay 31]. In our study, SI of ≥1.0 was associated with a significantly higher portion of mechanically ventilated patients and required ICU admissions. Zampieri, F.G. et a support these findings in their study on 3,140 patients [32]. Liu et al. argued that diastolic blood pressure falls earlier than systolic pressure, hence modified SI, calculated by dividing HR by mean arterial pressure, may be a more accurate marker for assessing shock state and mortality [33]. Few studies supported age-SI as superior to SI and modified SI in predicting mortality [34,35].

Our study has several limitations. Being a retrospective registry-based study, it did not evaluate at scene SI, the number of units of blood transfusion, any other blood products transfusions in ED, reasons for surgical interventions, etc. Moreover, additional calculation of delta-SI, modified-SI, or age SI would have given our study more strength in outcome analysis. However, as the first report on approximately 7,000 trauma patients over three years from a newly developed trauma registry- the STAR, would help the emergency health professional recognize the importance of SI in managing trauma patients. Carefully selecting and adding more variables in our trauma registry with a systematic collection of data on patients' presentation and outcomes would be invaluable in the future.

Conclusion

Early recognition of shock is essential for early initiation of blood transfusion and lethal triad - hypothermia, acidosis, and coagulopathy arrest and improve outcomes. This study indicates that an easily calculated physiological variable, the SI, may identify blood transfusion prediction among adult trauma patients at

high risk. In our cohort, a SI≥1.0 on the ED presentation carried significantly worse outcomes, including increased emergency surgeries, ICU admissions, length of stay, and deaths among trauma patients. This simple calculation based on initial vital signs may be used as a screening tool and therefore incorporated into initial assessment protocols to manage trauma patients.

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PART 4

In-Hospital Trauma System: Treatment Strategies

CHAPTER 9

Selective nonoperative management of liver gunshot injuries

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Abstract

Purpose

Nonoperative management (NOM) of gunshot liver injuries (GLI) is infrequently practiced. The aim of this study was to assess the safety of selective NOM of GLI.

Methods

A prospective, protocol-driven study, which included patients with GLI admitted to a level 1 trauma center, was conducted over a 52-month period. Stable patients without peritonism or sustained hypotension with right-sided thoracoabdominal (RTA) and right upper quadrant (RUQ), penetrating wounds with or without localized RUQ tenderness, underwent contrasted abdominal CT scan to determine the trajectory and organ injury. Patients with established liver and/or kidney injuries, without the evidence of hollow viscus injury, were observed with serial clinical examinations. Outcome parameters included the need for delayed laparotomy, complications, the length of hospital stay and survival.

Results

During the study period, 54 (28.3%) patients of a cohort of 191 patients with GLI were selected for NOM of hemodynamic stability, the absence of peritonism and CT imaging. The average Revised Trauma Score (RTS) and Injury Severity Score (ISS) were 7.841 and 25 (range 4–50), respectively. 21 (39%) patients had simple (Grades I and II) and 33 (61%) patients sustained complex (Grades III to V) liver injuries. Accompanying injuries included 12 (22.2%) kidney, 43 (79.6%) diaphragm, 20 (37.0%) pulmonary contusion, 38 (70.4%) hemothoraces, and 24 (44.4%) rib fractures. Three patients required delayed laparotomy resulting in an overall success of NOM of 94.4%. Complications included: liver abscess (1), biliary fistula (5), intrahepatic A-V fistula (1) and hospital-acquired pneumonia (3). The overall median hospital stay was 6 (IQR 4–11) days, with no deaths.

Conclusion

The NOM of carefully selected patients with GLI is safe and associated with minimal morbidity.

Introduction

The trauma fraternity is gradually embracing the selective nonoperative management (NOM) of penetrating abdominal trauma. The NOM of abdominal stab wounds (SW) is widely accepted and considered the standard of care. Conversely, the NOM of gunshot wounds to the abdomen is slowly gaining momentum in the context of concurrent use of computerized tomographic (CT) scanning in patients without peritonism or sustained hypotension. Patients who sustained a gunshot wound to the abdomen, not having an indication for emergency laparotomy, and undergoes CT imaging that shows liver injuries with or without other solid organ injuries and the absence of any evidence of hollow viscus injuries, are selected for NOM. This study sought to validate the feasibility and safety of the NOM of gunshot liver injuries (GLI).

Patients and methods

This study is a retrospective analysis of prospectively collected data of a University of Cape Town Human Research Ethics Committee approved protocol-driven study that was conducted over a 52-month period (September 2008–December 2012) at Groote Schuur Hospital Trauma Center (GSHTC) in Cape Town, South Africa. All patients with penetrating abdominal trauma presenting to the GSHTC were initially assessed and resuscitated according to the standard guidelines. The patients with hemodynamic instability, signs of peritonism (diffuse abdominal tenderness, rebound tenderness, guarding, or rigidity), and unreliable physical examination due to the associated brain and spinal cord injuries were taken to the theater for emergency laparotomy. Stable patients with intact sensorium and without signs of peritonism were selected for a trial of NOM.

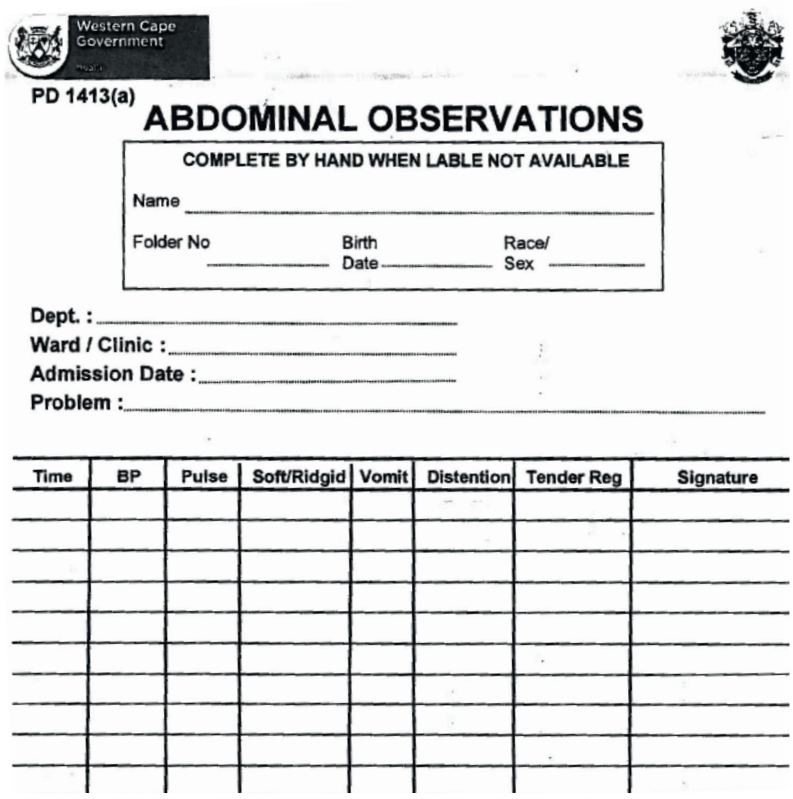
An abdominal CT scan was performed using a 16-channel scanner with a high-power injection of 100 mL of intravenous contrast at 5 mL/s on all patients with right upper quadrant (RUQ) and right-sided thoracoabdominal (RTA) penetrating injuries, with or without localized RUQ tenderness, to identify or exclude a liver injury. During CT imaging, arterial, porto-venous, and delayed phases were routinely acquired. The patients with CT confirmed liver injuries, without CT evidence of hollow-viscus injury (free air-related to hollow viscera, bowel wall

thickening, mesentery stranding, close proximity of missile trajectory to hollow viscus) were admitted to a high-care observation area in the general trauma ward for continuous hemodynamic monitoring including blood-pressure, pulse rate, saturation, respiratory rate, 4-hourly hemoglobin, and physical examination at regular intervals. Intrahepatic pseudo-aneurysms or arteriovenous fistulae detected on the initial CT underwent peripheral percutaneous angiography and embolization.

The patient is regularly reviewed on ward rounds with the on-call trauma operative team which includes a senior and junior trauma consultant (both board-certified surgeons) and general surgical trainees (3–4th year of training) at 08H00 and 16H00 daily. The surgical trainee on call will review the patient at least once between 08H00 and 16H00, and at least twice after 16H00 till the next morning at 08H00. On-call consultants are available to review the patient at the request of the on-call surgical trainee. Re-examination consists of documenting the BP, pulse, temperature, respiratory rate, hemoglobin check, enquiring about GIT symptoms (nausea, vomiting, and diarrhea) and abdominal examination focusing on any distension, increasing tenderness or frank peritonitis. A data sheet with standardized documentation of the abdominal exam is completed after each examination (Fig. 1). An immediate laparotomy was performed if there was development of peritonitis, increasing local tenderness, hemodynamic instability or significant hemoglobin drop needing more than four units of blood transfusion in 24 h at any time during admission. During the first 24 h, the patient is administered intravenous fluids and thereafter, an oral diet is introduced. The patient was transferred to the general ward section after 48 h of close observation once tolerating an oral diet. CT scan is repeated only for clinically suspected liver-related septic complications (infected biloma, liver abscess, subphrenic or perihepatic collections, thoracobiliary fistula) and haemobilia.

On discharge from hospital, all patients were entered into a 3-month follow-up programe (2 weeks then monthly thereafter), and issued with a summary note detailing diagnosis and management, and a list of instructions: no contact sport for 8 weeks, and to return to the unit in the event of jaundice, abdominal pain or distension, vomiting, loss of appetite, fever and upper or lower gastrointestinal bleeding. The severity of the injury was characterized using the Revised Trauma Score (RTS), Injury Severity Score (ISS) and American Association of Surgery for

Trauma (AAST) grading for solid organ injury. The outcome was measured by the need for delayed laparotomy, liver-related complications, the duration of hospital stay and survival.



Western Cape Government

PD 1413(a)

ABDOMINAL OBSERVATIONS

COMPLETE BY HAND WHEN LABLE NOT AVAILABLE

Name _____

Folder No _____ Birth Date _____ Race/ Sex _____

Dept. : _____

Ward / Clinic : _____

Admission Date : _____

Problem : _____

Time	BP	Pulse	Soft/Ridgid	Vomit	Distention	Tender Reg	Signature

Fig. 1 Abdominal observation record chart

Ethical approval

The study has been approved by the institutional ethics committee and has been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards: University of Cape Town Human Research Ethics Committee approved study: 048/2007.

Results

A total of 278 patients were admitted with penetrating liver injuries during the study period. Of these, 87 (31.3%) liver stab wounds and 191 (68.7%) patients sustained GLI. Of 191 GLI patients, 137 (71.7%) required an emergency laparotomy. At laparotomy 65 (47.4%) patients did not have any surgical intervention related to the liver (Table 1).

Table 1. Management of liver injuries in 137 patients who underwent emergency laparotomy

Liver-related procedure (N=72)	
Definitive packing (damage control)	40
Temporary packing	16
Suture	16
Non liver related procedure (N=65)	
Drain	39
Nil	26
Total	137

By hemodynamic stability, the absence of peritonism and CT findings, 54 (28.3%) GLI patients were admitted for NOM. Of these, 51 were male, and 3 were female with a mean age of 27 (range 14–88) years. The average RTS and ISS was 7.841 and 25 (range 4–50), respectively. Although 18 patients had associated haematuria, CT revealed 12 patients with both liver and kidney injuries, and 42 patients with isolated liver injuries. 21 (39%) patients had simple (Grades I and II) and 33 (61%) patients sustained complex (Grades III–V) liver injuries (Table 2).

Table 2. Liver and Kidney injury according to AAST-OIS

	GI	GII	GIII	GIV	GV
Liver (54)	6	15	19	13	1
Kidney (12)	1	3	6	2	0

AAST-OIS, American Association of Surgery for Trauma organ injury scale

Associated right sided diaphragm injuries were recognized in the presence of right-sided hemo/pneumothoraces or lung contusion from the same missile trajectory (Table 3).

Table 3. Associated injuries (same gunshot trajectory causing liver injury)

Viscera	N
Diaphragm	43
Lung contusion	20
Hemothorax/Pneumothorax	38
Rib fracture	24
Kidney	12

Of the 54 GLI, three (5.6%) patients failed abdominal observation and underwent delayed laparotomy; one with a grade 2 liver injury and two with Grade 4 liver injuries. This translates to a 95 and 93.9% NOM success rate for simple and complex liver injuries, respectively. No hollow viscus injuries were detected at laparotomy (Table 4).

Table 4. Patients undergoing delayed laparotomy (N=3)

No.	CT findings	Indication for laparotomy	Delay	Findings/Procedures
1	G-II liver	Peritonism and fever	18 h	300 ml hemoperitoneum Diaphragm repair Liver drained
2	G-IV liver G-I kidney	Peritonism and fever	12 h	300 ml hemoperitoneum Diaphragm repair Liver drained
3	G-IV liver	Bile peritonitis	15 days	400 ml bilious fluid Liver drained

Complications related to liver injury were seen in seven (13%) patients, and all occurred during the acute index admission. One patient developed a liver abscess, confirmed with repeat CT scan based on increased septic markers (fever and neutrophilic leucocytosis) that was treated by ultrasound guided percutaneous

drainage. Cultures grew a cloxacillin sensitive Staphylococcus aureus. In one patient, admission CT revealed an arteriovenous fistula that underwent immediate successful angioembolization (AE).

There were five biliary cutaneous fistulas of which, three fistulas developed through the drains placed at the time of laparotomy for failed conservative management and two in the NOM group. All three patients in the failed conservative management group who developed postoperative biliary cutaneous fistulas, required further intervention with an endoscopic retrograde cholangiogram (ERC) for persistent peripheral bile leaks (> 50 mL for > 14days). Biliary sphincterotomy and a 10 Fr stent were placed to manage these patients. The outcome of these patients was further uneventful except an extended hospital stay (mean 22 days). The two patients with the biliary fistulas in the NOM group, both underwent repeat CT scans to exclude intrahepatic/perihepatic septic collections. One intrahepatic culture-negative biloma was managed successfully by percutaneous drainage and the other fistula that developed through the GSW site, resolved spontaneously. Non-liver-related complications included nosocomial pneumonia or infected lung contusions established in three patients, treated successfully with intravenous antibiotics. The overall median hospital stay was 6 (IQR 4–11) days. There were no deaths and also, no new complications requiring readmission of any patients in the 2-week clinical follow-up of 100%. The follow-up at one-month and two months was 40% and 10%, respectively, with no new complications encountered. The three patients with biliary fistulas who had a stent placed had a repeat ERC at 6 weeks. All biliary leaks had resolved, and the stents were removed without any complications.

Discussion

Liver injuries commonly occur in both blunt and penetrating abdominal trauma. Management of liver trauma has radically changed over the last three decades. For blunt trauma to the liver, NOM has now become the standard of care in stable patients, irrespective of grades of injury. For penetrating liver injuries, selective NOM is also gaining popularity. Selective NOM for a stab wound to the liver is practical and safe in the absence of hemodynamic instability or without the evidence of concomitant hollow visceral injury. Although different authors

described selective NOM for low-velocity GLI, it has not yet been widely practiced [1–4]. Demetriades et al. first described NOM in penetrating liver trauma in 1986. The authors assumed liver injuries based on the trajectories with penetrating trauma in the RUQ of the abdomen. In their prospective study, all 21(33%) patients selected for non-surgical treatment were managed successfully with serial physical examinations and blood transfusions when needed without any complications [5]. Since then, selective NOM has become a preferred strategy for penetrating liver trauma. Later, several reports were published in the literature, but most had a relatively small cohort of patients [6]. The reports of NOM related to GLI appeared more frequently since the nineties [4, 7–14].

Renz et al. [7] are attributed to reporting first successful NOM of GLI. In their small series of 13 patients with an RTA gunshot, 7 had CT confirmed liver injuries who were successfully managed nonsurgically without any liver-related complications [7]. In the following year, Chmielewski et al. described successful NOM in 12 patients with RUQ gunshot wound, of which eight sustained grade II–III liver injuries [8]. Demetriades et al. reported lower success rate (69%) for selective NOM in GLI. They managed to treat 11 of 16 patients nonsurgically successfully, and concluded that particular patients with simple (grade I/II) liver injuries can be managed nonoperatively [10]. Later in 2005, in a relatively larger series of patients by Omoshoro-Jones et al. described 97% success rate of NOM for GLI. In their series of 33 patients, 8, 14 and 11 patients had grade I/II, grade III and grade IV/V liver injuries, respectively. Only two patients failed conservative management and required delayed laparotomy unrelated to liver trauma [11]. More recently, in 2009, Navsaria et al. described 92% success of NOM for both simple and complex GLI. They treated 58 of 63 patients nonoperatively, the largest series in the literature so far, with overall liver-related complications seen in only 9.5% (three liver abscesses, and three biliary fistulas) of patients [4]. The overall success rate of NOM for GLI, identified in the English literature, is 93% (Table 5) that is similar to our current series (94.4%). The constant high success rate could be ascribed to the fact that most isolated GLI requires no treatment [15]. A ‘blush’ of contrast on CT scan, seen only once in this study, signifies a false aneurysm, arteriovenous fistula or intrahepatic bleeding. Hemodynamically stable patients should be immediately transferred for angioembolization (AE), which is essential for the success of NOM [16, 17].

Table 5. Reported results of nonoperative management of gunshot liver injuries (GLI).

References	Study design	N	Success rate (%)
Renz et al. [7]	Prospective	7	100
Chmielewski et al. [8]	Prospective	8	88
Ginzburg et al. [9]	Prospective	4	100
Demetriades et al. [10]	Retrospective	16	69
Omoshoro-Jones et al. [11]	Prospective	33	97
Pal et al. [12]	Case reports	2	100
Shanmuganathan et al. [13]	Prospective	9	100
DuBose et al. [14]	Retrospective	10	90
Navsaria et al. [4]	Prospective	63	92
Current series	Prospective	54	94
Total		206	93

The main complication after AE is hepatic necrosis [18]. Recently, Michailidou et al. [19] described a small pseudoaneurysm following blunt trauma that was successfully observed without intervention. As the risk of hepatic necrosis is high, Scalea in a recent review suggested avoiding AE for small pseudoaneurysm in asymptomatic patients and selective embolization for a large aneurysm with coils rather than the use of gel foam [6]. Hepatic necrosis can be managed better by early hepatic lobectomy than repeated attempts of debridement or interventional drain placement [20].

Missing a hollow visceral injury is the downside of the success of NOM following a gunshot wound to the abdomen in the absence of peritonism. The sensitivity and accuracy for diagnosing hollow visceral injury characterized by free intraperitoneal or retroperitoneal air, free fluid in the absence of a solid organ injury, hematoma adjacent to hollow viscera, thickening of the wall of the injured bowel, mesenteric stranding following penetrating abdominal trauma remain an apprehension even with modern, and sophisticated CT scanners [17, 21, 22]. Patients who are considered for NOM should undergo serial physical examination, and any signs of deterioration, warrants a laparotomy [4].

The number of right-sided diaphragm injuries may have been underestimated in this study; since CT scan is not a reliable method in diagnosing penetrating diaphragm injuries. Low-velocity gunshot injuries to the diaphragm tend to be

minor Grade 1 injuries, and with the liver providing a protective covering of the entire diaphragm, herniation is very unlikely. In our experience, we have not seen a single right-sided hollow-visceral diaphragm herniation to date following low-velocity penetrating trauma. Ongoing bile leak, perihepatic biliary collection, biliary fistula, infected biloma, liver abscess or bleeding from false aneurysms or AVF are the common liver-related complications. In symptomatic patient follow-up, ultrasound or CT scan can be used to diagnose these complications. Ongoing bile leak can be managed by ERC and stenting and/or biliary sphincterotomy. Biliary abscess and infected biloma can be drained percutaneously under cover of intravenous broad spectrum antibiotics [23]. Only one liver-related septic complication occurred in our study. The three patients treated with intravenous antibiotics for hospital-acquired pneumonia, or infected pulmonary contusions may have masked or inadvertently treated liver-related septic complications [4]. While beyond the scope of this report, all associated 12 renal injuries were successfully managed nonsurgically. The reports of conservative treatment of gunshot kidney injuries are few, and this study provides further evidence that NOM is also highly practical, and when associated with liver injuries, does not preclude the NOM of either solid organ [14, 24–27].

A major limitation of this study is the patients lost to follow-up. According to Leukhardt et al. [28], lower income, higher poverty rates, and lower education are significantly associated with failure to follow-up. The patient cohort in this study met the above criteria and that would possibly account for the high rate in the failure to follow-up. Second, in keeping with the theme of NOM, the patients who failed abdominal observation could have possibly been manged successfully, laparoscopically, an option we will consider including in our protocol. Finally, considering the small numbers of patients treated, it begs the question of whether one can maintain the consistency in the use of this protocol. In a center with a high incidence of penetrating trauma like ours, this management protocol was successful in avoiding a significant number of nontherapeutic laparotomies in 51 (94%) of the 54 patients reviewed in this study. In our center, it certainly appears to be a viable and successful management option.

In conclusion, our study validates the efficacy of NOM for GLI using serial clinical examination in a particular group of hemodynamically stable and clinically assessable patients. The candidates qualifying for NOM are selected by CT

imaging that identifies liver injury following a RTA and RUQ gunshot wounds with or without a localized tenderness. In our current series, 26.7% (51/191) of GLI were managed without laparotomy with a 94.4% success rate, irrespective of the severity of the injury. An associated liver-related complication rate of 13% is acceptable but requires ongoing vigilance and intermittent minimally invasive therapies including AE, percutaneous interventional drainage techniques, ERC, and stenting. However, NOM of penetrating abdominal trauma is still mainly based on the findings of serial clinical examinations, irrespective of solid organ injury and cutting-edge CT technology.

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CHAPTER 10

Laparoscopy or clinical follow-up to detect occult diaphragm injuries following left-sided thoracoabdominal stab wounds: A pilot randomized controlled trial

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Abstract

Background

The purpose of this study was to determine whether patients with left-sided thoracoabdominal (TA) stab wounds can be safely treated with clinical and chest X-ray follow up.

Method

A prospective, randomized control study was conducted at Groote Schuur Hospital from September 2009 through to November 2014. Patients with asymptomatic left TA stab wounds included in the trial were randomized into two groups. Group A underwent diagnostic laparoscopy and Group B underwent clinical and radiological follow-up.

Results

Twenty-seven patients were randomized to Group A (N=27) and thirty-one to Group B (N=31). All patients were young males with a median age of 26 years (range 18 to 48). The incidence of occult diaphragm injury in Group A was 29%. All diaphragm injuries found at laparoscopy were repaired. The mean hospital stay for the patients in Group A was 5 days (SD 1.3), compared to a mean hospital stay of 2.9 days (SD, 1.5), in Group B ($p < 0.001$). All patients in Group B had normal chest X-rays at their last visit. The mean follow-up time was 24 months (median: 24; interquartile range: 1-40). There was no morbidity or mortality in Group B.

Conclusion

Clinical and radiological follow-up are feasible and appear to be safe, in the short term, in patients who harbour occult diaphragm injuries after left TA stab wounds. Until studies showing the natural history of diaphragm injury in humans are available, laparoscopy should remain the gold standard in treatment.

Introduction

Selective non-operative management (NOM) of abdominalstab wounds has become the standard of care around the world [1]. The problem with the NOM of patients with thoracoabdominal (TA) stab wounds without peritoneal signs is that these asymptomatic patients may harbor isolated diaphragm injuries that may go undetected, and later develop a diaphragm hernia. To overcome this, it was initially proposed by Stylianos et al. that all left side TA stab wounds should undergo a laparotomy to rule out a diaphragm injury [2]. During the mid 1990s, when videoscopy was introduced and popularized in other areas of surgery, numerous studies confirmed that both laparoscopy and thoracoscopy are very sensitive and specific in detecting a diaphragm injury [3-7]. Even today with the modern multidetector CT (MDCT) imaging, direct vision of the diaphragm with laparoscopy and thoracoscopy remains the gold standard of diagnosing an occult diaphragm injury [8]. Current international guidelines, including those of the Eastern Association for the Surgery of Trauma (EAST), recommend that all patients with left-sided penetrating thoracoabdominal trauma undergo routine diagnostic laparoscopy under general anesthesia to exclude a diaphragm injury [9]. The purpose of this study was to establish the incidence of occult diaphragm injury in our local trauma population and to establish if close initial observation and subsequent follow up is a safe and feasible practice for this group of patients.

Patients and methods

Study design

The study was a single center, parallel-group trial with equal randomization conducted at the Trauma Centre at the Groote Schuur Hospital from 01 September 2009 through to 01 November 2014. Study inclusion criteria were age between 18 and 60 years, asymptomatic left TA stab wounds (bounded by the nipple line over the anterior and posterior chest, superiorly, the left costal margin inferiorly and, the tip of the scapula and the sternum, medially), passed 24-hour period of abdominal observations and signed informed consent. Study exclusion criteria were signs of diaphragm injury, either radiological or clinical, hemodynamically unstable patients, previous penetrating injury to the left TA area, patients requiring early surgical exploration for injuries other than diaphragm injuries,

and a positive pregnancy test. The study was approved by the Faculty of Health Sciences Research Ethics Committee of the University of Cape Town and registered at ClinicalTrials.gov NCT01044550.

Management protocol

All patients with left TA stab wounds and suspected occult diaphragm injury were subjected to a 24-hour period of serial abdominal observations to identify patients who required laparotomy for associated intra-abdominal injury. The site of injury was recorded on a visual torso map and divided into lateral, anterior and posterior stab wounds. The lateral region is between the anterior and posterior axillary lines, the anterior territory is anterior to the anterior axillary line and the posterior territory is posterior to the posterior axillary line. Patients with a pneumo- and/or hemothorax were managed with a tube thoracostomy. During the observation period, patients were kept nil per os and maintained on intravenous fluids. Analgesia alone with no antibiotics was administered. The patients were clinically reassessed every 6 hours. Patients who did not develop foregut symptoms (nausea and vomiting) or signs of peritonism after 24 hours were considered eligible for the trial. After informed consent was taken, the patients were randomized into a treatment Group A and follow-up Group B.

Group A underwent a diagnostic laparoscopy, with repair to an injured diaphragm when detected. The local incidence of diaphragm injury in this subset of trauma patients was thus determined. Group B underwent no treatment except suturing of wounds and drainage of a hemo- / pneumothorax when present. Participants in Group A were requested to attend a follow-up clinic in 2 weeks. Participants in Group B were requested to attend a follow-up clinic at 2 weeks, 4 weeks, 3 months, 6 months, 12 months and yearly intervals. During follow up a detailed history was taken and a chest X-ray performed.

Randomization process

A computerized number generator was used to create a random number table with the numbers 1 (laparoscopy) and 2 (clinical follow-up). These numbers were placed in a sealed envelope. If a patient was considered eligible to participate in the trial, informed consent was taken and the envelope was opened to reveal the group into which the patient fell.

Endpoints of study

The primary endpoints were the demonstration of a diaphragmatic laceration at laparoscopy or any evidence of a diaphragmatic hernia during follow-up. Secondary end points were the duration of hospital stay and complications.

Statistical methods

Using a two-sided binomial test, a sample size of 100 achieves 83% power to detect a difference of 0.15 with a significance level of 0.035 [10-13]. Continuous variables were compared with the use of the t-test. Chi-square analysis and the Fisher exact test were used for the analysis of the categorical variables where appropriate. Confidence intervals were based on the normal approximation to the binomial distribution. P values of less than 0.05 were considered to be significant.

Results

We identified 64 potentially eligible patients of which 62 met inclusion criteria. Five patients were excluded, two did not meet the inclusion criteria and three declined to participate by refusing consent. The final sample group, therefore, consisted of 59 patients. After providing informed consent, they were subsequently randomized to 28 in Group A and 31 in Group B. We discontinued enrollment before reaching our sample size goal of 100 patients due to slow patient accrual. There were no protocol violations and one patient was excluded after randomization in Group A due to failed laparoscopy and laparotomy because of extensive adhesions (frozen abdomen) after a previous laparotomy. Therefore, 27 patients were analyzed in Group A and 31 in Group B. The enrollment and outcomes are presented in Figure 1 according to the Consort 2010 flow diagram [14].

Patient characteristics

The 59 patients selected for the study were all hemodynamically stable on arrival. The baseline characteristics of the 2 groups were comparable in respect of age, mean arterial pressure, respiratory rate, hemoglobin level, and revised trauma score (Table 1).

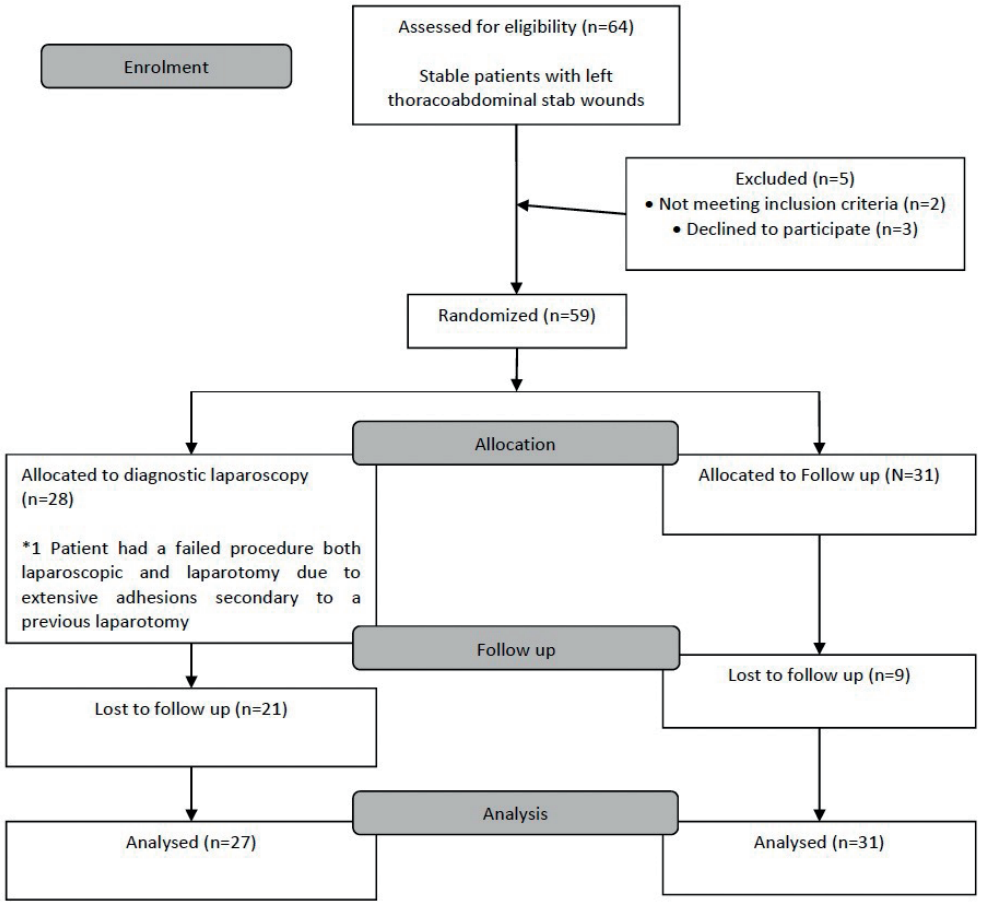

Figure 1: Enrolment and outcomes

Area of injury

The site of injury was recorded on a visual torso map and divided into lateral, anterior and posterior stab wounds. The lateral region is between the anterior and posterior axillary lines, the anterior territory is anterior to the anterior axillary line and the posterior territory is posterior to the posterior axillary line. Some patients presented with multiple stabs. The findings are represented in Figure 2a and Figure 2b.

Table 1. Patient characteristics

Variable	Laparoscopy Mean (SD*) (n=27)	Follow up Mean (SD*) (n=31)	*P*
Age	27.1 (6.2)	27.7 (6.8)	0.73
Mean Arterial Pressure	94.7 (14.9)	91.4 (13.4)	0.50
Hemoglobin	12 (2)	12.7 (2.2)	0.25
Respiratory rate	17.8 (3.0)	18.4 (4.0)	0.60
Revised trauma score	7.84	7.84	1.00

* SD indicates standard deviation

Laparoscopy group (n = 27)

The stab wounds penetrated the chest at various TA locations with no specific level associated with an increased likelihood of diaphragm injury. All the patients were subjected to initial laparoscopy under general anesthesia, two patients were converted to laparotomy and one patient to thoracotomy. The decision to convert was left to the discretion of the operating surgeon and was done more often because of difficulty in visualizing or repairing the diaphragm. Three patients were converted to an open procedure, all of whom had a diaphragm injury. Eight (29%) of 27 patients in Group A had a diaphragm laceration. All the lacerations were smaller than 2 cm in length. One patient had omentum herniating through the diaphragm injury. Seventeen (62%) patients had an associated hemo/pneumothorax managed with pleural drainage.

Follow up group (n = 31)

The mean follow-up of patients allocated to Group B was 24 months (median: 24; interquartile range: 1–40). Twenty-three (74%) patients had a pleural drain inserted for a hemo/pneumothorax. At the last follow-up, all chest X-rays were normal and all patients had a normal clinical examination with no abdominal or thoracic symptoms. The X-rays were reviewed by a single, senior consultant (author two) in the trauma center. Five patients (16%) had no followup and four (12%) patients had limited follow-up ranging from 1–9 months before they were lost to follow-up.

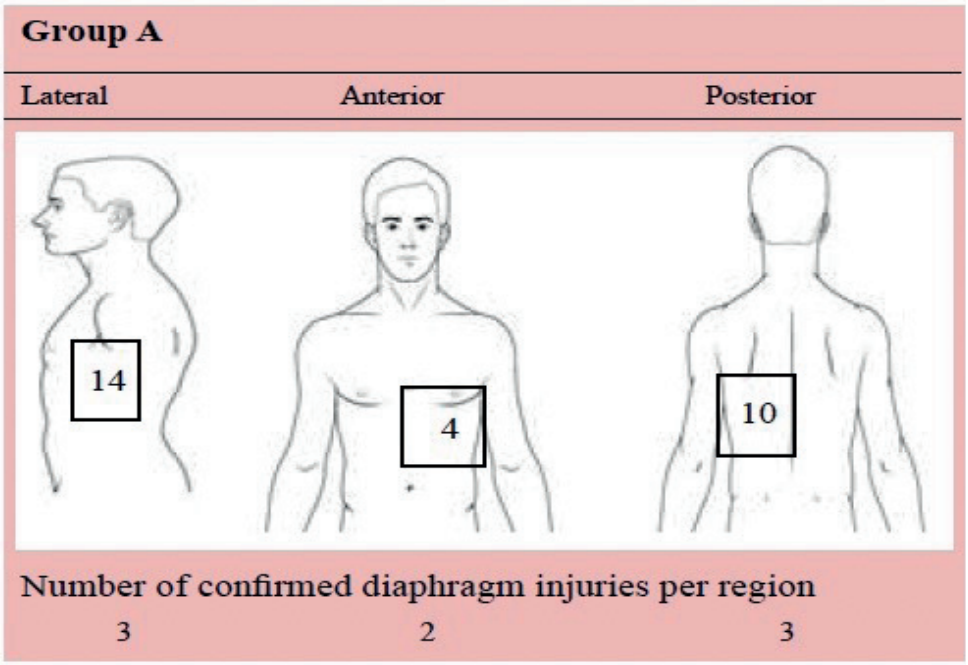

Figure 2a. Site of stab wounds for Group A

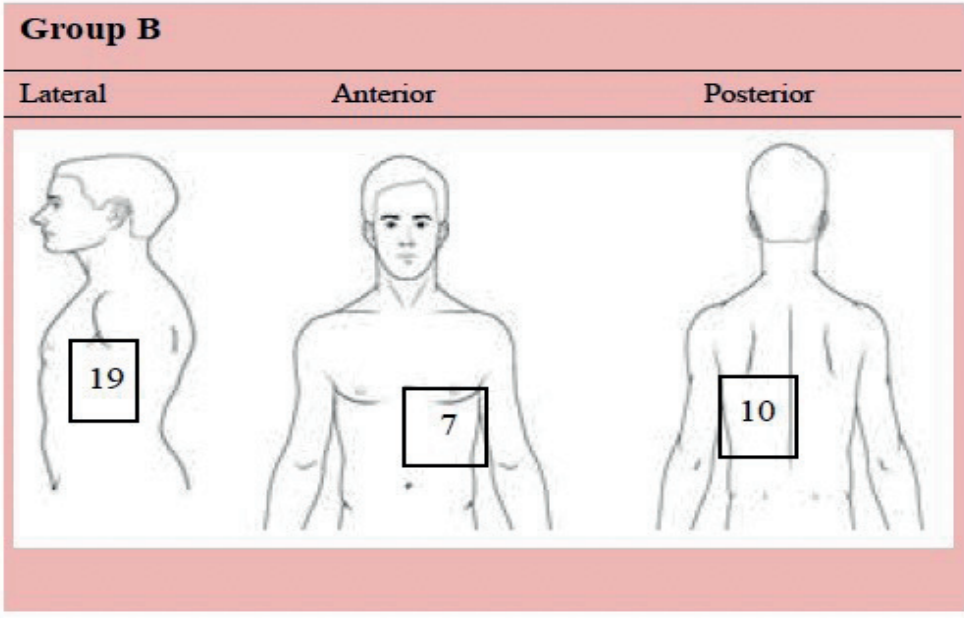

Figure 2b. Site of stab wounds for Group B

Morbidity and Mortality

No patients died as a result of injuries sustained during the initial hospitalization. Three patients had postoperative complications in Group A. The complications were superficial surgical site sepsis, pneumonia and prolonged postoperative paralytic ileus. The patient with surgical site sepsis was managed with suture removal and antibiotics. The patient who developed pneumonia was a patient converted to laparotomy and was managed with antibiotics, physiotherapy and mobilization. The patient with the prolonged ileus was managed conservatively, and the ileus resolved four days post-operatively. These complications were classified as grade II complications, according to the Clavien-Dindo classification of surgical complications [15]. There was no morbidity in Group B.

Hospital Stay

The mean hospital stay in the patients who underwent laparoscopy was 5 days (SD 1.3), compared to a mean hospital stay of 2.9 days (SD 1.5), resulting in a statistically significant difference of $p < 0.001$. In the authors opinion the laparoscopy group had a longer hospital stay because of reasons related to theatre access. They were a stable group of patients and often had to wait for theatre access after more urgent cases.

Discussion

Current EAST guidelines strongly recommend diagnostic laparoscopy in all patients with penetrating trauma to the left TA area who have no other indications for laparotomy to diagnose and repair diaphragm injuries [9]. The main purpose of repairing diaphragm injuries is to prevent delayed diaphragm herniation which is reported to have a high associated mortality rate. Most papers quote the high mortality of 36% in patients presenting with delayed herniation of abdominal contents into the chest as reported by Madden et al [16]. Degiannis et al. described a 25% mortality rate in a group of patients who presented with delayed diaphragm hernias over a 7-year period [17]. Not all data support this high mortality initially reported by Madden and Degiannis. Reber et al. reported on the outcome of 10 patients with late presentations of traumatic diaphragmatic hernias during a 16-year period. Only one patient died (10% mortality), and three (30%) sustained postoperative complications [18]. Feliciano et al. did a 9-year

review of patients who presented at one trauma center [19]. Seven patients presented with delayed diaphragm hernias. No patients died, but 5 out of 7 patients had postoperative complications. It is twenty-five years since the article by Madden et al. was published and, with modern critical care practices, the high mortality rate associated with delayed diaphragm hernia reported by Madden is not observed anymore. More recently, studies have reported lower mortality in patients presenting with delayed diaphragm hernia [20,21].

The results from animal studies are listed in Table 2 [23-26]. From this data, it is clear that in animal studies more than 90% of diaphragm injuries heal spontaneously in 6–40 weeks, but it is difficult to extrapolate this data directly to humans because the natural history of diaphragm injuries in humans has not been adequately studied. However, it must be true that a large percentage of diaphragm injuries in humans heal, or at least never become clinically apparent because studies done to detect an occult left diaphragm injury reported rates of 26% to 63% of diaphragm injuries in patients who sustained left sided TA stab wounds [3,26,27]. The rate of delayed diaphragm herniation reported in the literature varies from 2.7–4% [19,28]. This large difference in the rate of injury compared to the rate of delayed diaphragm herniation can only be true if most of these injuries heal or never become clinically apparent.

Table 2. Animal studies reporting on diaphragm injury healing rates

Study	Number of animals	Animal studied	Healing rate	Hernia rate	Maximum time to euthanasia
Zierold et al.[26]	7	Pigs	100%	nil	12 weeks
Shatney et al.[23]	15	Pigs	93%	0,06%	6 weeks
Gamblin at al.[25]	48	Rats	97%	0,02%	10 months
Perlingeiro et al.[24]	56	Rats	91%	8.9%	5 months

As discussed previously from the available evidence, mortality of delayed diaphragm injury is overestimated and the incidence of delayed herniation is low, therefore many patients will undergo unnecessary surgery to detect and repair diaphragm injuries that would never have resulted in a diaphragm hernia. This has significant cost implications in a resource-limited environment as patients who undergo surgery have a significantly longer hospital stay, 5 vs 2.9 days $p = < 0.001$, as well as the added procedural cost.

We are of the opinion that patients who present with a delayed diaphragm hernia most likely had a missed initial diaphragm injury that occurred within the first six weeks post injury. The initial injury presented late and if these patients were subjected to close follow-up these injuries would have been detected earlier. We, therefore, suggest that the herniation is an early event, and strangulation/complication is a delayed event because, in patients who present with late complications, there are always signs of a 'chronic' hernia at surgery. Established adhesions between the hernia sac and the diaphragm are a common finding at surgery pointing towards a chronic process.

We undertook this randomized study to firstly establish the incidence of occult diaphragm injury in our patient population and to follow up a control group of patients who should have a similar incidence of occult diaphragm injuries. The patients were followed up to establish the incidence of delayed diaphragm herniation in a truly asymptomatic group of patients and, if a hernia was detected, to establish the morbidity of early intervention. The incidence of diaphragm injury was 29% and it can, therefore, be assumed that the incidence of a diaphragm injury in Group B would be similar because the two groups were comparable in terms of patient characteristics. During the follow-up period, no delayed diaphragm hernias occurred, neither did any patient report any significant symptoms.

Limitations of study

Firstly, the study never recruited the intended sample size, which impacts negatively on the conclusions that can be made. This can possibly be overcome by repeating a larger multicentre trial. Secondly, a major limitation of this study was the number of patients lost to follow-up, especially in Group B. Five patients (16%) had no follow-up and four patients (12%) had limited follow-up ranging from 1–9 months before they were lost to follow-up. According to Leukhardt et al. lower income, higher poverty rates, and lower education were significantly associated with failure to follow up [29]. The patients included in this study meet the above criteria and that would account for the high rate in the failure of follow-up despite efforts made to make contact with the patients who failed to attend follow-up appointments. Even if a larger multicentre trial is undertaken, this problem is likely to persist. Thirdly, the radiological imaging was limited to

serial chest X-rays. The sensitivity of plain chest x-rays is 94% in the presence of herniation, but it can be as low as 30–62% in the absence of a hernia with a small diaphragmatic laceration. Despite this low sensitivity, chest X-ray is still the initial imaging modality of choice with MDCT, with magnetic resonance imaging being recommended if diagnostic doubt exits [30,31].

Conclusion

The incidence of occult diaphragm injury in left sided TA stab wounds is high. In a highly selected group of asymptomatic patients who have undergone a period of abdominal observation, it is safe to discharge these patients provided that they are followed up with clinical examination and serial chest X-rays. The optimal period of follow-up is still uncertain and could not be reliably established in this trial due to the slow rate of patient accrual, the high rate of patients lost to follow-up and the short follow-up time. If patients are treated conservatively, they should be made well aware that should any abdominal symptoms develop, even if years later, to report to a health facility immediately stating that they sustained a left TA stab in the past, alerting the treating physician to the possibility of the patient having a delayed diaphragm hernia. Because of the limitations of this trial, a larger multicentre, randomized trial to confirm these findings and to prove long-term safety of clinical and radiological follow-up is recommended. A study documenting the findings of a diagnostic laparoscopy 3–6 months after the initial injury would clarify the unanswered question relating to the natural history of left sided penetrating TA injuries in humans. Until the natural history of penetrating left sided diaphragm injury in humans is documented patients should continue to undergo diagnostic laparoscopy as the gold standard treatment.

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CHAPTER 11

Penetrating trauma to the mediastinal vessels: A taxing injury

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Abstract

More than 90% of thoracic great vessel injuries are due to penetrating trauma. The increased incidence of civilian penetrating (stab and low-velocity gunshot wounds) chest trauma and improved emergency medical services (EMS) have stemmed in an increasing number of seriously injured, but potentially salvageable patients, presenting to trauma centers. Penetrating mediastinal vascular injuries are associated with a high mortality. Unstable patients present a diagnostic and operative challenge to the surgeon, require damage control resuscitation (DCR) and immediate surgery. DCR begins with the restrictive fluid administration, permissive hypotension, early blood product therapy that includes initiation of massive transfusion protocol (MTP), temporary hemostasis by balloon tamponade, tube thoracostomy and or, resuscitative thoracotomy. Stable patients can undergo a rapid and aggressive workup with screening CTA followed by catheter angiography for unclear CTA findings, and when feasible, endovascular intervention.

Introduction

All thoracic injuries, due to both blunt and penetrating mechanisms account for 20-25% of traumatic deaths [1]. Trauma to the mediastinal vascular structures includes the aorta (ascending, arch and its branches, and descending aorta), the pulmonary vessels, the intrathoracic vena cava, and the innominate, and azygos veins. Reports of penetrating trauma to the mediastinal vessels are lacking in the literature until the 20th century due to the absence of survivors. More than 90% of thoracic great vessel injuries are due to penetrating trauma [2]. The increased incidence of civilian penetrating (stab and low-velocity gunshot wounds) chest trauma and improved emergency medical services (EMS) have stemmed in an increasing number of seriously injured, but potentially salvageable patients, presenting to trauma centers. Strategies for treating thoracic injuries were established only after the Second World War. Current knowledge regarding treatment of injured thoracic great vessels has been derived primarily from experience with civilian injuries. Great vessels injuries have been repaired with increasing frequency, a phenomenon that has paralleled the development of techniques for elective surgery of the thoracic aorta and its major branches. The management of patients with penetrating thoracic trauma is determined by the patient's hemodynamic status.

Penetrating trauma to the mediastinal vessels

The presence of a mediastinal vessel injury following penetrating trauma can be obvious or subtle in presentation. It depends on multiple factors such as the mechanism, length of the sharp object, type of firearm, distance of the patient from the firearm, and the vessel involved. The physician should be aware of the possibility of mediastinal vascular injury in case of transmediastinal gunshot wound or presence of a wound at the root of the neck. The patient may present as pulseless or moribund. The diagnosis is usually made during the resuscitative thoracotomy or urgent thoracotomy. In a stable patient or who becomes stable after resuscitation, the diagnosis can be made with computed tomographic angiogram or catheter angiography in selected patients. Patients may present with a mediastinal hematoma, massive hemothorax, cardiac tamponade, or external bleeding. Hypotension, upper extremity hypertension, unequal blood

pressures or pulse discrepancy in the affected vessel's distribution, a thrill or bruit at the root of the neck, expanding hematoma at the thoracic outlet, intra-scapular murmur, brachial plexus injuries, stroke or coma also support the diagnosis of a great vessel injury [3].

Approach to mediastinal vascular injury: hemodynamic abnormal

On presentation to the emergency department, all patients with possible mediastinal vascular trauma should undergo a rapid evaluation according to the Advanced Trauma Life Support (ATLS) guidelines. Hemodynamically unstable patients require immediate damage control resuscitation (DCR) followed by mandatory emergency surgery for nonresponders. For penetrating major vascular injuries, DCR begins with the restrictive clear fluid administration, permissive hypotension, early blood product therapy that includes initiation of massive transfusion protocol (MTP), temporary hemostasis by balloon tamponade, tube thoracostomy and or, resuscitative thoracotomy. The aim is to prevent or arrest the lethal triad of acidosis, hypothermia, and coagulopathy.

Restrictive fluid administration

Fluid administration for resuscitation of trauma patients presenting with hemorrhagic shock remains controversial. There is a recent paradigm shift of the historical practice of overzealous administration of clear fluids, to restrict fluid. Massive crystalloid and colloid fluid resuscitation result in dilutional coagulopathy, a hyperbolic systemic inflammatory response syndrome (SIRS), pulmonary edema, an increased incidence of adult respiratory distress syndrome (ARDS), polycompartment syndrome, electrolyte imbalance, and worse overall survival [4-9]. In a recent double-blind, randomized controlled trial, it was demonstrated that in penetrating trauma, resuscitation with colloids (hydroxyethyl starch 130/0.4) has a better effect on the renal outcome, and faster lactate clearance without clinically relevant coagulopathy compared with crystalloids (0.9% saline) [10].

Permissive hypotension

There is now more evidence available in support of permissive hypotension in resuscitating bleeding trauma patients. The current trend is to limit fluid administration, targeting a lower than the normal systolic blood pressure (SBP)

of 80–90 mmHg, or mean arterial pressure (MAP) of 50 mmHg until surgical control of the bleeding is achieved. Evolving evidence suggests that overzealous fluid administration before hemostasis leads to further bleeding through hydraulic acceleration of hemorrhage, soft clot dissolution by raising intravascular pressure and dilution of clotting factors [11].

Blood product therapy

The administration in a 1:1:1 ratio of packed red blood cells, fresh-frozen plasma, and platelets (of individual units) is related with improved survival [12]. Adjunctive treatment with recombinant factor VIIa, cryoprecipitate, and tranexamic acid [13,14] may improve coagulopathy. Additional benefits of earlier administration of blood products during the resuscitation phase include a substantial reduction of the volume of crystalloid fluid requirement during resuscitation [15,16], improved overall efficiency, decreased total blood product use during a patient's hospital stay and economic savings [12,17].

Balloon tamponade

Balloon tamponade by Foley catheter (FC) to achieve temporary control of bleeding vessels is a useful adjunct to damage control resuscitation. It is a simple technique of placing of an FC into a hemorrhaging wound, inflating the balloon with water or saline in an attempt to achieve hemostasis by compression of the injured vessels. This simple technique does not require any expertise or specialized equipment. It can temporarily arrest hemorrhage allowing for patient interhospital transfer, and further investigation to allow for diagnosis and planning of definitive surgery [18]. Although Foley catheter balloon tamponade (FCBT), mostly described to control bleeding in the neck [19]; it is also useful for the wound at the junction of neck and thoracic inlet, peri clavicular, or sternoclavicular regions **[Fig 1]**.

Tube Thoracostomy

Massive hemothorax following mediastinal vascular injury can lead to cardiopulmonary collapse. Immediate chest decompression by tube thoracostomy is an essential part of DCR. Unstable patients with penetrating thoracic trauma should undergo immediate bilateral tube thoracostomy. The chest tube can be connected to a cell saver device for autotransfusion. Immediate drainage of a large volume of blood (more than 1.5L) or ongoing bleeding (200-250mL/h) may indicate major vascular injury and mandates the need for immediate thoracotomy.

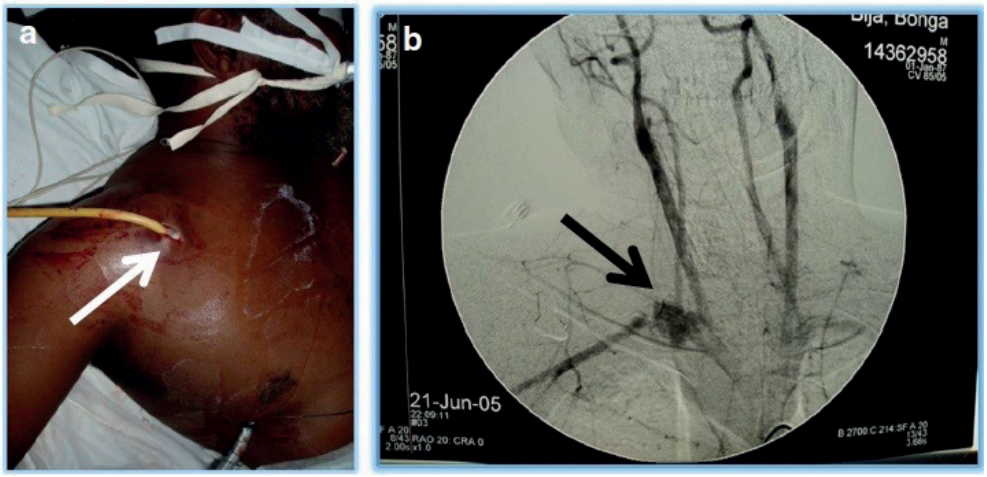

Fig.1 (a) Successful Foley catheter balloon tamponade in a patient with a right lateral infraclavicular stab wound (white arrow). (b) Catheter angiography showing a proximal right subclavian artery injury that was approached through a median sternotomy with the right supraclavicular neck extension (yellow arrow)

Resuscitative thoracotomy

Instant control of bleeding by emergency room thoracotomy is a part of DCR before definitive surgery. It allows the release of cardiac tamponade and arrest of bleeding from cardiac, lung, and great vessel injury and subsequently improves cardiac output [20]. It also enables resuscitation through open cardiac massage, defibrillation with internal paddles and intra-cardiac administration of drugs. Cross-clamping of descending thoracic aorta facilitates cerebral and coronary perfusion by diverting blood flow as well as slows down distal bleeding from combined intra-abdominal or pelvic injury. If acted timely, resuscitative thoracotomy (RT) can be lifesaving in carefully selected patients. Survival may reach up to 40% of trauma victims with penetrating thoracic wounds and cardiac tamponade [21]. Patients with isolated penetrating chest injuries have the greatest chance of survival than the patients with multi-cavity injuries [22-23]. When RT is performed, survival is higher with stab wounds (18-24%) than gunshot wounds (4-5%) [24-28]. The physiologic state just before surgery is commonly not described in the literature, and different vague terms such as “no signs of life,” “no vital signs,” “lifeless,” and “agonal” are frequently utilized. A recent survey reported a lack of agreement regarding the indications for RT as well as in defining “signs of life” [29, 30]. The high-quality prospective studies are also absent due to

nature and ethical issues involving the care of dying trauma victims [30]. Despite the limitations, RT is supported in patients with penetrating thoracic injury who present to the emergency room (ER) with any sign of life (SOL) or deteriorate shortly after arrival [21, 31, 32]. The available data also support refraining from RT in both penetrating and blunt trauma patients who never had witnessed SOL [31, 32]. Thus, most of the debate regarding the indications for RT **[Table 1]** is focused on patients who develop cardiopulmonary arrest before arrival to the hospital.

For RT, a standard incision is a left anterolateral thoracotomy that extends from the costal margin to the mid-axillary line in the 5th intercostal space, avoiding injury to the internal mammary artery and intercostal vessels. Incise the skin, subcutaneous tissue, pectoralis major, and the intercostals down to the pleura. Incise the pleura and use a Mayo scissors to divide the remaining muscle and pleura- avoid injury to the underlying lung. Insert a large Finochietto retractor to expose thoracic cavity. If the entrance wound is on the right side of the chest, consider a right anterolateral thoracotomy. If required, additional exposure may be gained by dividing the sternum transversely with a Lebske knife or trauma shears, or doing clamshell thoracotomy. After evacuating blood from the chest, attention is directed to the injury. If a great vessel is injured and bleeding, temporary control can be gained by direct digital pressure, occlusion with a Satinsky clamp or even by inserting and inflation of a Foley catheter balloon into the wound and held under tension. If hemopericardium is present, the pericardium may be opened with a vertical incision after careful identification and preservation of phrenic nerve. Once the hematoma is evacuated, the heart is delivered from the pericardial sac and hemorrhage can be controlled by applying digital pressure, suture or staples. Foley catheter balloon is also useful for temporary control. If air embolism is suspected, the pulmonary hilum is clamped, or the affected lung may be twisted 180^0 and air in the aorta evacuated. After the cause is addressed, a cross-clamp can be applied to the descending thoracic aorta after sweeping the lung anteromedially and exposing the posterior mediastinum. Temporary arresting mechanical ventilation and placement of a nasogastric tube are helpful adjuncts to visualize and localize a flaccid descending aorta. The intravascular volume is restored, and if the patient responds, he or she is transported to the operating room for definitive repair.

Table 1: Indications for resuscitative thoracotomy in penetrating chest injuries

Asystole with signs of life in the preceding five minutes
Pulseless electrical activity on ECG monitors with cardiac arrest
In-hospital hypovolemic cardiac arrest
A hypotensive patient with a precordial injury, who has a systolic blood pressure of less than 70mm Hg is not responding to fluid resuscitation
Drainage of >1.5 liters of blood on chest drain insertion
Continuous bleeding > 200ml per hour into chest drain
Cardiac tamponade
Thoracic great vessels injury
Loss of thoracic wall

Approach to mediastinal vascular injury: hemodynamic normal

Patients who stabilize after resuscitation, or, who present hemodynamically normal must be carefully monitored to detect early decompensation. Patients may appear stable following a transmediastinal gunshot wound, even when they have life-threatening injuries [33]. Penetrating transmediastinal injury is defined as evidence of a single missile entry and exit on opposite sides of the thorax, missile entry and missile retention on opposite sides of the thorax, and missile entry on one side of the thorax with missile retention in the mediastinum [34, 35].

Investigational workup for stable patients

Chest radiograph

All patients with suspected mediastinal vascular injury should have a chest radiograph or a Lodox Statscan™ (low-dose full-body digital X-ray). It is very useful to place radiopaque markers to identify the entrance and exit sites. Radiographic findings that may suggest a mediastinal vascular injury include abnormal central mediastinal opacities, massive hemothorax, foreign bodies (shrapnel or bullets) or missile trajectories close to the great vessels **[Table 2]**. A trajectory with a confusing course may indicate a migrating intrapleural or, intravascular or intracardiac bullet, suggesting distal embolization.

Table 2: Chest radiographic features of suggestive of mediastinal vascular injury

Massive left hemothorax
Apical pleural hematoma
Any abnormal opacity in the superior mediastinum
Obliteration or double shadow of aortic knob contour
Loss of perivertebral pleural stripe
Lateral displacement of trachea
Loss of aortopulmonary window

Computerized tomographic angiography (CTA)

A standard supine chest radiograph does not provide diagnostic sensitivity to rule out a vascular injury. Many authors recommend multidetector CT chest as a screening tool. The sensitivity and negative predictive values are almost 100% for mediastinal hematoma usually associated with aortic disruption [36-38]. CTA is safe and reduces the need for an invasive diagnostic procedure of selected patients with transmediastinal gunshot wounds [39]. It helps to define the trajectory relative to vascular and aerodigestive structures within the mediastinum and thoracic inlet [40]. Many surgeons use CT findings alone as a roadmap to diagnose an injury and unusual vascular anomalies to plan surgery. Motion artifact in the proximal ascending aorta can be difficult to interpret on CT. In this situation, a catheter angiography is indicated.

Transesophageal echocardiogram (TEE)

Multiplanar transesophageal echocardiogram (TEE) images the thoracic aorta consistently. Although the accuracy of TEE is operator dependent, the sensitivity and specificity of TEE in the diagnosis of mediastinal aortic injury reported as high as 100% [41, 42]. Distal ascending aorta and proximal aortic arch often obscured by tracheobronchial air artifact. Images can be unreliable for this segment. Moreover, the presence of atheromatous disease or pneumomediastinum may confound the detection of aortic injury. For these reasons, several authors do not advocate TEE in the acute setting especially in polytrauma patients [3]. TEE is portable, and the main advantage is it allows on-table evaluation of unstable patients [43].

Intravascular ultrasonography

Intravascular ultrasonography (IVUS) is relatively modern diagnostic tool to detect vascular injury. It is an expressly designed catheter with a high-frequency miniature ultrasound transducer attached at the distal end. The proximal end is connected to the computerized ultrasound equipment. It can obtain real-time 360^0 images of the aorta. It is performed by introducing the ultrasound probe through an arterial sheath. A recent study found that IVUS accomplished better than catheter angiography in patients who had equivocal CTAs [44]. At present the lack of a reference standard procedure, the high cost of the disposable transducers, and invasive nature limit the use of IVUS in the trauma setting.

Catheter angiography

In penetrating thoracic trauma, catheter angiogram is indicated in suspected mediastinal vascular injuries including aortic, innominate, carotid, or subclavian arterial injuries. For intraoperative proximal and distal control of these vessels, different incisions are required. Arteriography helps in localizing the injury and planning the appropriate incision. The catheter angiography is not always above limitations. Temporarily sealed off laceration or if the column of aortic contrast overlies a small area of extravasation may give a false impression of negative aortogram. Obtaining tangential views to possible injuries may help to overcome this limitation. An added advantage of catheter angiography is therapeutic endovascular intervention.

Surgical approach to mediastinal vessels

Penetrating injuries to the mediastinum usually have a high probability of injury to the vascular and other vital structures. Mandatory exploration was the practice in the past. With the evolution of modern diagnostic and radiologic investigations including combined arteriography, esophagoscopy, bronchoscopy, and echocardiography help to decrease unnecessary explorations in hemodynamically stable patients. A CT angiogram of the chest often shows the bullet trajectory as well as any injury to the vascular structures and dictate the need for surgery.

A detailed understanding of the normal and variant anatomy and structural relationships of mediastinal vessels is vital for the surgeon. Thoracic arch

anomalies are relatively common. Venous anomalies are infrequent with the most common being absence of the left innominate vein and persistent left superior vena cava. Knowledge of such anomalies is essential for both open and catheter-based therapies.

When the decision is made to operate on a patient with mediastinal vascular injury, median sternotomy is standard to access the superior mediastinum. A large red jelly mediastinal hematoma usually lies above the pericardium obscuring the anatomy. It signifies the major vascular injury and careful dissection is necessary to avoid major trouble. The pericardium is the anatomical barrier that prevents extension of the mediastinal hematoma. So in a hostile environment, it is a useful trick to open the pericardium and follow the aortic arch upward into the hematoma to identify the vessels of the superior mediastinum. After identifying the left innominate vein, the gatekeeper of the mediastinum, divides and ligate it to open up the superior mediastinum. It gives access to the superior aspect of the aortic arch and its branches. If the thymus is on the way, can be divided in between clamps and ligated. The next step is to identify bifurcation of innominate artery and the right vagus nerve that crosses in front of the proximal right subclavian artery and to secure it to prevent an iatrogenic injury. In the superior mediastinum, veins are lying superficially, and the arteries are deep. Venous injury can be controlled by a side-bitting clamp and simple lateral repair. If the repair is impossible, division and ligation can be done without any hesitation. Then the aim is to achieve proximal control by exposing the ascending aorta inside the pericardium. The distal control can be obtained by putting a clamp on the distal innominate, right subclavian, right carotid and proximal descending arteries [45].

Ascending aortic injury

The ascending aortic injury is relatively uncommon. Patients who reach to a trauma center with stable hemodynamics, the survival rate is almost 50% [46]. To gain access to the aortic arch, an extension of sternotomy wound to the neck is necessary [47]. Hemorrhage may limit the exposure. Temporary balloon tamponade can be useful in this situation. Lateral aortorrhaphy for simple anterior wall laceration and additional posterior wall injury makes repair difficult. In this case, cardiopulmonary bypass may be necessary.

Innominate arterial injury

Right cervical extension of median sternotomy is often essential for dealing the innominate artery. In this case, a division of the strap muscles down low, near the insertion into the sternum, to expose the carotid sheath is necessary. Simple repair is often impossible to this area. Bypass exclusion technique from the ascending aorta to the distal brachiocephalic trunk, just proximal to the bifurcation is a feasible option **[Fig 2]** [48]. The injured area is escaped until the bypass is performed. A 10-mm Dacron graft is sewn end to side to the ascending aorta with a partial occluding clamp proximal to the hematoma. The distal innominate artery is isolated with proximal to its bifurcation. This is divided and sewn end to end to the graft without systemic anticoagulation, hypothermia, shunts or cardiopulmonary bypass. After the restoration of flow, the area of hematoma is controlled with a large partial occluding clamp and the aortic arch is oversewn. The innominate vein may be ligated if concomitantly injured or previously divided [3].

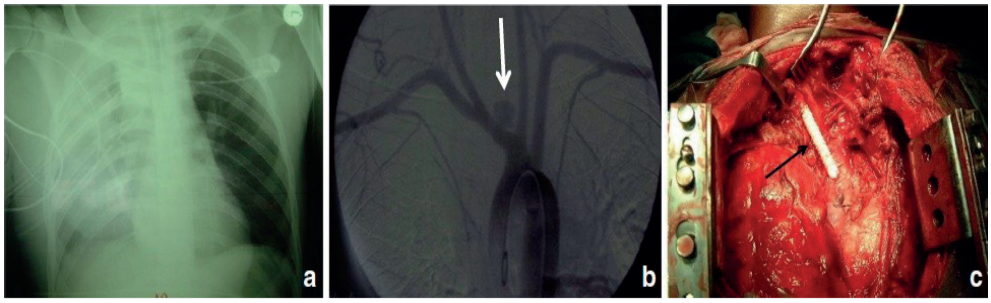

Fig. 2 (a) Admitting chest radiograph showing massive right haemopneumothorax with abnormal mediastinal opacity following stab wound. (b) Catheter angiography revealing innominate artery false aneurysm (white arrow). (c) Intraoperative repair with an interposition PTFE graft (black arrow)

Proximal left common carotid artery injury

Injury to the left proximal common carotid artery also approached in a similar fashion of an innominate artery injury through a median sternotomy with left cervical extension. Care must be taken to identify and preserve the left vagus nerve as it descends between the carotid and left subclavian arteries to cross in front of the aortic arch and give off the left recurrent laryngeal nerve. Initial attempts to partially occlude the aorta with side-biting (partially occluding) clamps may

afford control of the origin of the carotid without complete occlusion of the aorta. If this is not successful, then full clamping of the aorta may be necessary. Exposure of the right common carotid artery is carried out in a similar fashion. Management of the patient's hemodynamic parameters mandates full assistance of the anesthesiologist because of the profound increase in afterload resistance that will develop. Vascular clamp time should be kept to a minimum and should be restricted to within a 20-30 minute period. Bypass graft repair is ideal over end-to-end anastomosis for injury at the origin.

Proximal subclavian vessels injury

To approach the right subclavian vessels in the mediastinum or at the thoracic outlet a median sternotomy with cervical extension is employed. High left anterolateral thoracotomy (2^{nd} or 3^{rd} intercostal space) is for the proximal control of left sided subclavian artery injury. A separate left supraclavicular incision may be necessary for distal control. For exposure, the clavicular head of the sternocleidomastoid and the omohyoid divided close to the clavicle. After retraction of the internal jugular vein medially the subclavian vein can be accessed. The phrenic nerve is lying on the scalene fat pad should be identified and preserved at any cost. The subclavian artery is lying deep to the anterior scalene muscle. To get access to the subclavian arteries piecemeal division of the muscle with scissors are recommended to avoid injury to the brachial plexus. On the left side; thoracic duct enters at the junction of the left subclavian and internal jugular veins. If it is injured, needs suture ligation otherwise can be left alone [45]. Associated brachial plexus injury is also common in subclavian arterial injuries. Documentation of preoperative neurologic status is vital.

The descending thoracic aorta injury

Posterolateral thoracotomy via the fourth intercostal space is for the injury to the descending thoracic aorta. Proximal control can be achieved by encircling the vascular tape between left subclavian and left common carotid artery after exposing the transverse aortic arch. Then, another vascular tape passed to surround the left subclavian artery. Careful mobilization is vital to avoid injury to the left recurrent laryngeal nerve that is often difficult to visualize in the hematoma. Currently, vascular clamping and immediate reconstruction are the standard technique to repair. Three commonly employed adjuncts to this approach include pharmacologic agent; temporary, passive bypass shunts; and a pump-assisted

left heart bypass. In the latter approach, two options exist: traditional pump bypass, which requires heparin, and use of centrifugal (heparinless) pump circuits. All three of these adjuncts to the clamp-and-repair technique should be in the armamentarium of the surgeon, who must choose the approach most appropriate to the particular clinical situation [3]. Vascular clamps are applied in proximal aorta, distal aorta, and left subclavian artery. Upon entering the hematoma back-bleeding from intercostal arteries are often encountered. Indiscriminate ligation of intercostal vessels should be avoided. Mobilization of the aorta from esophagus minimizes the risk of secondary aortoesophageal fistula. Repair of a small laceration by primary suture, and relatively larger one either by end-to-end anastomosis or interposition graft. Most common complication after repair of descending thoracic aortic injury is paraplegia. Although the development of postoperative paraplegia is multifactorial including perioperative hypotension, indiscriminate ligation of intercostal arteries and longer clamp occlusion during repair [49].

Internal mammary artery

Injury to the internal mammary artery (IMA) can be fatal. In a young patient, blood loss can be more than 300mL/min following an IMA injury. They present with massive hemothorax or even cardiac tamponade. Such injuries are usually picked up during thoracotomy, and simple suture ligation is enough to control hemorrhage.

Pulmonary artery injury is typically uncommon. Mortality is as high as 70% with central pulmonary vessels injury [2]. Intrapericardial pulmonary arteries are approached via median sternotomy. The main and proximal left pulmonary arteries are exposed with minimum dissection [50, 51]. Dissection between superior vena cava ascending aorta is necessary to expose intrapericardial right pulmonary artery. Anterior injuries can be repaired primarily while posterior injuries are difficult to repair and usually require cardiopulmonary bypass.

Venous injuries

Conservative, nonoperative approach for isolated mediastinal venous injuries remains the standard. Patients who reach to the hospital with isolated venous injury are usually stable, unless the thoracic vena cava, pulmonary veins or subclavian veins are involved. Isolated mediastinal superior or inferior vena cava injury is infrequently reported. Injury to this area is associated organ trauma and

mortality as high as 60%. Repair of intrathoracic inferior vena cava is tough and require total cardiopulmonary bypass. Superior vena cava injuries are repaired by lateral venorrhaphy. The intracaval shunt is often necessary [52]. Complex injuries are better repaired by PTFE patch or dacron interposition tube graft than time intensive reverse saphenous vein graft. Temporary hilar occlusion may be necessary to control hemorrhage from pulmonary veins. In the event of pulmonary vein ligation, appropriate lobectomy and or pneumonectomy needs to be done. Subclavian veins are approached in a similar fashion of subclavian arteries. Bleeding is controlled by either lateral venorrhaphy where possible or ligation. Azygos vein injury is usually associated with concomitant injury to the innominate artery, trachea or bronchus, and superior vena cava and in most cases fatal. Surgical repair through median sternotomy is enormously difficult. It may even be difficult to reach through a right anterolateral thoracotomy, requiring an extension across the sternum. For successful repair combined incisions and approaches are frequently needed and best managed by ligation [53].

Damage control options

Damage control options are very limited in the mediastinal vascular injuries. In extremes, ligation of the injured artery is certainly an option accepting the risk of stroke. A temporary intraluminal shunt is not resounding and has no long-term survival benefit. In isolated subclavian vessels injury, if bleeding from a missile tract, inserting a Foley catheter and inflating the balloon to stop the bleeding temporarily followed by forearm fasciotomy is an option to buy valuable time [45].

Endograft repair

Endograft repair of mediastinal vascular injuries remains a technical challenge for the surgeons exclusively in injuries at the origin, ascending or arch of the aorta. In a stable patient, placement of the endo-aortic graft in descending thoracic aorta is rational **[Fig 3]**. Preoperative planning involves carefully protocolized CT angiogram defining the size, tortuosity, proximal and distal landing zone, angulation of arterial vessels for determination of appropriateness or feasibility of introducer sheaths and devices capable of covering the aortic injury. The American Association for the

Surgery of Trauma (AAST) multicenter study with its two follow-up manuscripts documented endovascular repair with a decrease in mortality and paraplegia but the increase in device-related and access complications and concern for long-term sequelae in blunt aortic injuries [54-56]. The effect of degenerative aortic dilation after endograft repair is a concern [57], and more studies are essential for assessing the long-term durability of endograft repair.

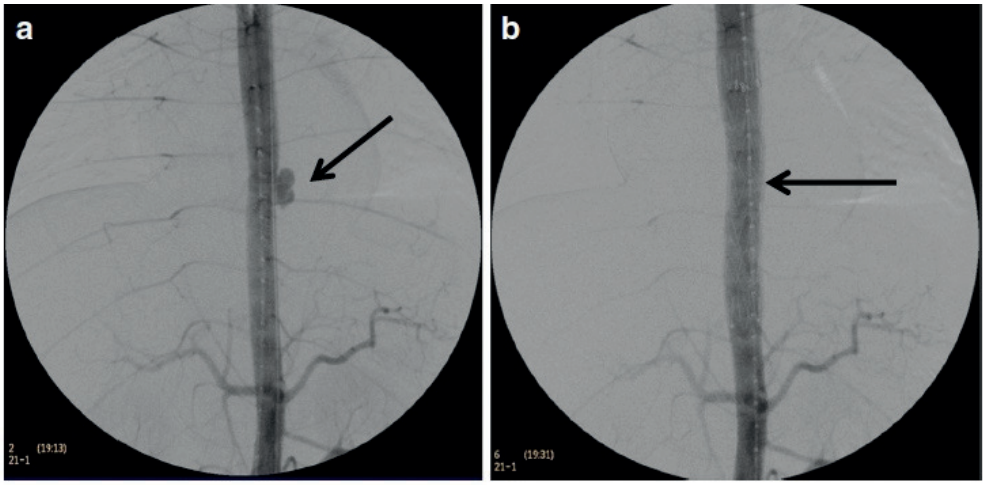

Fig. 3 (a) Descending thoracic aortic false aneurysm following a transthoracic gunshot injury (black arrow). (b) Endograft repair with successful deployment of a covered stent (black arrow)

Postoperative management

Multisystem insult including respiratory, cardiac, urinary, coagulation and the central nervous system carries significant risk for in-hospital mortality after repair of great vessels injury. Postoperatively it is mandatory to monitor a patient in an intensive care environment. Maintaining optimum hemodynamics with avoidance of both hypotension and hypertension is essential. Although urinary output is a good indicator of cardiac function, noninvasive or invasive cardiac function monitoring with Swan-Ganz catheter may often be necessary. Pulmonary complications including atelectasis, pneumonia, transfusion-related acute lung injury (TRALI), acute respiratory distress syndrome (ARDS) are common in this group of patients. Careful fluid administration, regular chest physiotherapy, early mobilization,

optimum pain control by epidural anesthesia may reduce these complications. Coagulation studies like thromboelastogram (TEG) are monitored carefully and corrected with appropriate transfusion of blood or blood component. In the case of acute kidney injury, renal replacement therapy may also require. Removal or change of lines and tubes as earliest possible to reduce the source of infections. Antibiotic therapy should be reserved for established source of infection.

Conclusion

Penetrating mediastinal vascular injuries are associated with a high mortality. Unstable patients present a challenge to the surgeon and require resuscitation and immediate surgery. Stable patients can undergo a rapid and aggressive workup with screening CTA followed by catheter angiography for unclear CTA findings, and when feasible, endovascular intervention **[Fig 4]**.

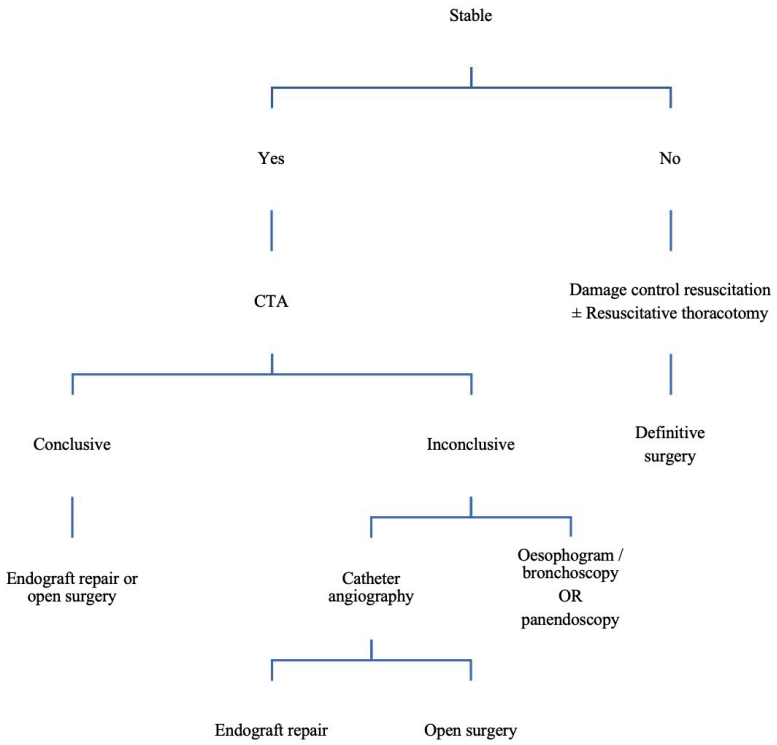

Fig 4. Management algorithm for patients with mediastinal injuries

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CHAPTER 12

Vertebral artery injury in major trauma patients in Saudi Arabia: A retrospective cohort study

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Abstract

Blunt vertebral artery injury (VAI) is associated with severe cervicocephalic trauma and may have devastating consequences. This study aimed to determine the incidence and nature of VAI in polytrauma patients. The secondary objective was to assess the association of VAI with previously suggested risk factors. It was a retrospective observational study of all polytrauma patients admitted to the trauma unit between April 2018 and July 2019, who had CT neck angiography to diagnose blunt VAI according to modified Denver criteria. Out of 1084 admitted polytrauma patients, 1025 (94.6%) sustained blunt trauma. Of these, 120 (11.7%) underwent screening CT neck angiography. VAI was detected in 10 (8.3%; 95% CI: 4.1-14.8) patients. There were three patients with Grade I injury, two with Grade II, and five with Grade IV injury. Among all trauma admissions, the incidence of diagnosed VAI was 0.9% (95% CI: 0.5-1.8). Among patients suspected of VAI, there was no univariable association of VAI with C-Spine fracture: OR 4.2 (95% CI: 0.51-34.4; p=0.18). There were two (20%) deaths related to VAI. Traumatic VAI was uncommonly detected in this major trauma service in Saudi Arabia. High suspicion and liberal screening by CT angiography in cases where VAI is possible should be considered to avoid missed injuries.

Introduction

Blunt cerebrovascular injury (BCVI) includes any form of non-penetrating damage to the internal carotid and vertebral arteries [1]. The understanding of BCVI has significantly improved over the past decade of trauma care due to advanced imaging modalities. BCVI includes two clinical entities: vertebral artery injury (VAI) and carotid artery injury. Blunt VAI is an uncommon entity, but important to diagnose with a view to preventing medium to longer-term stroke [2]. VAI presents a clinical challenge since it is difficult to detect, has a diverse presentation, and there are no widely accepted guidelines on diagnosis and management. VAI, although frequently asymptomatic, can have disastrous consequences related to basilar territory infarction and death.

A high index of suspicion for VAI, based on the mechanism of trauma and the nature of associated injuries, should be considered. Cervical spine fractures have been previously reported as being the only independent predictor of VAI [3]. Other potential risk factors include high-energy mechanisms, facial fractures, the base of skull fractures, and diffuse axonal injury with GCS <6 [4]. The reported incidence is highly variable in the literature (0.5–2% of all trauma patients) [5]. For those reasons, there have been several screening criteria set up for the detection of VAI, including the Denver, Memphis, and Boston criteria based on injury mechanism, injury pattern, and symptoms [6-10]. The modified Denver criteria are the most widely used in practice [4]. However, a balance between excess imaging and missed VAI has not been adequately validated in terms of diagnostic accuracy (sensitivity, specificity, positive predictive value, and negative predictive value) and cost-effectiveness. It has been suggested that early diagnosis and management (conservative versus interventional) may improve outcomes.

This study aimed to determine the incidence and nature of VAI in blunt polytrauma patients in a major trauma centre in Saudi Arabia. The secondary aim was to determine variables independently associated with VAI.

Methods

Setting: King Saud Medical City (KSMC) is a tertiary care centre in Riyadh with 1,400 inpatient beds. In 2018, a total of 36,052 trauma patients presented to the emergency department (ED) of KSMC, of which 3,552 patients were admitted. A dedicated trauma unit admits all polytrauma patients.

Design: This was an observational study based on the retrospective data of all polytrauma patients admitted under the trauma unit between 01 April 2018 and 31 July 2019, who had CT neck angiography to diagnose VAI according to the modified Denver criteria [4]. All blunt polytrauma patients who present to our ED are investigated with whole-body CT as part of the trauma imaging protocol, which includes CT brain, face, cervical spine, chest, abdomen, and pelvis. If the whole-body CT report suggests BCVI according to modified Denver criteria, we investigate further with a neck CT angiogram. We searched the "Carestream Vue Motion" radiology image database used in our institution to identify all patients who underwent CT angiography neck after trauma patients during the study period. After the selection of these patients, an explicit chart review of medical records was conducted to extract the data.

Data: Extracted data included demographic details (gender, age), mechanism of injury, injuries of the head, face, & neck, and the CT angiography of neck findings. Furthermore, we extracted data on the modified Denver criteria [4], such as traumatic brain injury (TBI) with neurologic exam incongruous with head CT scan findings, the base of skull fractures involving the carotid canal, Le Fort fracture type 2 or 3, mandibular fracture, cervical spine fracture, and its pattern, and occipital condyle fracture. If the CT angiography of the neck detected VAI, the grading of injury, the segment of the vertebral artery involved, site of injury, associated vascular injuries, management, and complications, including disability and death, were also extracted.

Grades of VAI*:* Radiologically, the VAI is classified into five categories. The Grade I is a mild intimal injury or irregular intima with <25% luminal narrowing, Grade II is dissection with raised intimal flap/intramural hematoma with luminal narrowing >25% / intraluminal thrombosis, Grade III is pseudoaneurysm, Grade IV is vessel occlusion/thrombosis, and Grade V is complete transection of the vessel [4].

***Segments of Vertebral arteries**:* The vertebral artery is typically divided into four segments: V1 (pre-foraminal) is from the origin to the transverse foramen of C6, V2 (foraminal) is from the transverse foramen of C6 to the transverse foramen of C2, V3 (atlantic, extradural or extraspinal) is from C2 to the dura, and V4 (intradural or intracranial) is from the dura to their confluence to form the basilar artery [11].

***Treatment and follow up of VAI**:* The treatment and follow up protocol is described in figure 1 [1].

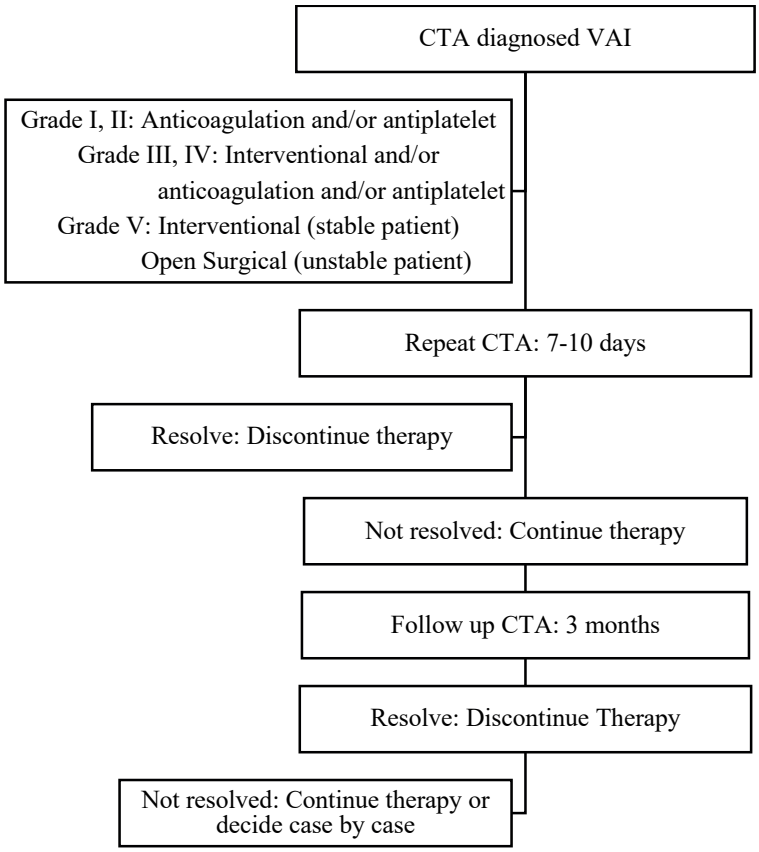

Figure 1: Treatment and follow up of VAI.

Analysis: Categorical variables were presented using frequency tables and differences assessed using Fisher's exact test or the chi-square test. Numerical variables were summarised using mean and standard deviation for continuous

variables, and for ordinal variables or variables with skewed distribution, median & interquartile range were used. Differences between means were reported using Student's t-test, and the difference between medians reported using the Wilcoxon Rank Sum test, Variables exhibiting some association on univariable analysis ($p<0.10$) were further assessed using multivariable logistic regression analysis. The performance of the model was assessed using the area under the receiver operator curve. Hosmer-Lemeshow goodness of fit as reported and variance inflation factors were used to assess for multi-collinearity. The independent association of variables with VAI was reported using adjusted OR and 95% confidence intervals. A p-value of <0.05 was considered statistically significant. All the analyses were conducted using Stata v 15.1 (College Station, Texas, USA).

The study was approved by the Institutional Review Board (IRB) of the KSMC with a reference number of H1R1-08-Apr19-04.

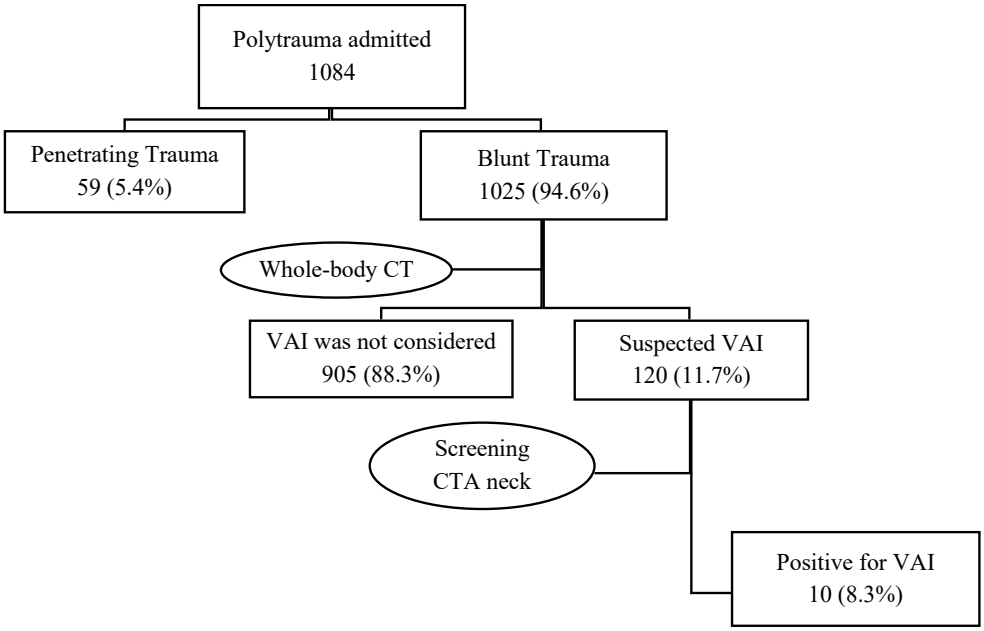

Figure 2: Selection of patients

Results

A total of 1084 polytrauma patients were admitted during the study period, of which 59 (5.4%) patients were penetrating trauma. Out of 1025 (94.6%) blunt trauma patients, 120 (11.7%) underwent screening CT neck angiography (Figure 2). Demographics were mainly young males with a mean age of 33.8 (SD 13.0) years. The age distribution is presented in Figure 3.

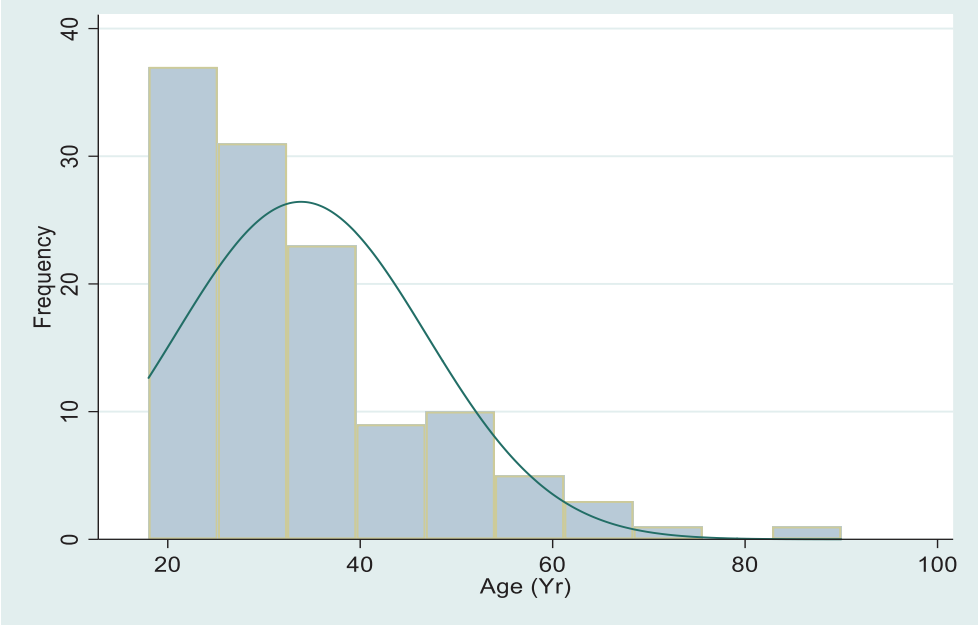

Figure 3: Demographics age distribution

There were 84 (70%) patients with C-Spine fractures. Among the other indications for CTA neck, according to modified Denver criteria, were traumatic brain injury (TBI) with neurologic exam incongruous with head CT scan findings (n=46), the base of skull fractures (n=8), facial fractures (n=49). Of these, 18, 2, and 19 patients did not have C-Spine fractures, respectively. A comparison of variables, sub-grouped by the diagnosis of C-Spine fractures is presented in Table 1.

Table 1: Comparison of patients with suspected VAI with or without C-Spine fractures

	C-Spine fracture (n=84)	No C-Spine fracture (n=36)	p-value
Age (mean years, SD)	31.7 (12.2)	34.8 (13.3)	0.24
Male sex (%)	74 (88.1%)	31 (86.1%)	0.76
Mechanism			0.27
- Motor Vehicle Collision (%)	73 (86.9%)	28 (77.8%)	
- Falls (%)	10 (11.9%)	7 (19.4%)	
- Assault (%)	1 (1.2%)	1 (2.8%)	
Respiratory rate, breath/min, mean (SD)	19.7 (2.6)	20.3 (19.4)	0.23
Pulse rate, beat/min, mean (SD)	88.2 (19.3)	99.4 (21.9)	0.006
Systolic Blood Pressure, mm Hg, mean (SD)	122.8 (20.0)	121.8 (22.6)	0.80
Glasgow Coma Scale			0.27
- 3-8 (%)	1 (1.2%)	1 (2.8%)	
- 9-12 (%)	10 (11.9%)	7 (19.4%)	
- 13-15 (%)	73 (86.9%)	28 (77.8%)	
International Normalized Ratio, mean, (SD)	1.1 (0.15)	1.1 (0.16)	0.88
Injury Severity Score			0.88
- 0-15 (%)	32 (38.1%)	12 (33.3%)	
- 16-25 (%)	32 (38.1%)	15 (41.7%)	
- >25 (%)	20 (23.8%)	9 (25%)	
Intubated (%)	39 (46.4%)	27 (75%)	0.004
Blood transfusion (%)	20 (23.8%)	16 (44.4%)	0.024
Traumatic Brain Injury (%)	28 (33.3%)	18 (50%)	0.08
Base of Skull fracture (%)	6 (7.1%)	2 (5.6%)	0.009
Facial fracture (%)	30 (35.7%)	19 (52.8%)	<0.001

There were 10 (8.3%; 95% CI: 4.1-14.8) patients with VAI. Among all trauma presentations, the incidence of VAI was 0.9% (95% CI: 0.5-1.8). There was no univariable association of VAI with C-Spine fracture: OR 4.2 (95% CI: 0.51-34.4; p=0.18). When adjusted for potential confounders, VAI was not independently

associated with any of the potential predictive variables (Table 2), and in particular, when adjusted for other variables, the presence of a C-Spine fracture was not significantly associated with VAI (OR 3.32 (95% CI: 0.30-6.2).

Table 2: Results of the multivariable logistic regression model

Variable	Adjusted OR (95% CI)	p-value
C-Spine fracture	3.32 (0.30-6.2)	0.32
Pulse rate	0.99 (0.96-1.03)	0.91
Intubation	1.05 (0.26-4.15)	0.94
Blood transfusion	2.22 (0.55-9.0)	0.26
Facial fracture	0.48 (0.08-3.0)	0.43

The area under the receiver operating characteristic (AUROC) for the model was 0.65 (95% CI: 0.50-0.81) (Figure 4). The p-value for Hosmer-Lemeshow Goodness of fit was 0.76. Variance inflation factors for all variables were less than 1.6, with a mean VIF of 1.27.

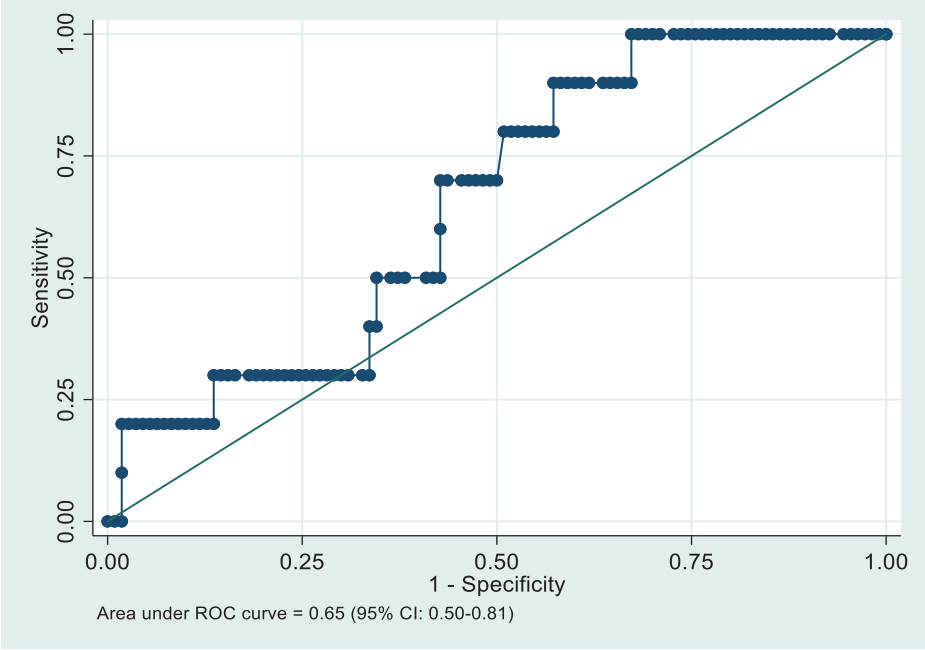

Figure 4: Area under the receiver operating characteristic (AUROC) curve

There were three patients with Grade I injury, two with Grade II, and five patients with Grade IV injury. The nature (Table 3), outcome, and follow up at three months (Table 4) of the VAI are described below.

Table 3: Nature of the VAI

Sl. No.	Grade of injury	Segment involved	Side of VAI injury	Nature of C-spine fractures	Associated vascular injuries
1	IV	V3	Left	C1 left lateral mass fracture	No
2	IV	V3	Bilateral	C2 right transverse process fracture	Bilateral internal carotid arteries
3	I	V3	Right	C1 right lateral mass fracture	No
4	I	V3	Left	C0 left occipital condyle fracture	No
5	II	V2	Right	C2 right pedicle and transverse process fracture	No
6	IV	V1, V2	Right	C5 right transverse foramen with facet dislocation	No
7	II	V2	Left	C2, C3, C4 left transverse process fractures	No
8	I	V1	Right	C6-C7 fracture-dislocation	No
9	IV	V1, V2, V3	Bilateral	C6, C7 left transverse process fractures	Bilateral Subclavian arteries
10	IV	V1, V2, V3	Right	C6 right foramen transversarium fracture	No

There were only two (20%) deaths related to VAI.

The first patient was a 27-year-old female unrestrained front seat passenger involved in high-speed motor vehicle collision sustained severe head, face, neck, and chest trauma. On presentation, she was hemodynamically stable, GCS 3 (intubated, and ventilated), and her ISS was 22. CT angiography neck and brain showed bilateral internal carotid arteries were tapered and blocked entirely in the proximal extracranial portion about 1.8 cm after the origin. Bilateral vertebral

arteries were also not showing any distal flow above the C1 level. There was diffuse brain edema with the multiple hypodense areas in the brain with the obliteration of the sulci. She was admitted to ICU and died after five days.

Table 4: Outcome, and follow up (at three months) of the VAI

Sl. No.	Grade of injury	Outcome	Follow up CTA neck
1	IV	Discharged	No interval change
2	IV	Death	N/A
3	I	Discharged	Normal
4	I	Discharged	Normal
5	II	Discharged	No interval change
6	IV	Discharged	No interval change
7	II	Discharged	Interval improvement
8	I	Discharged	Normal
9	IV	Death	N/A
10	IV	Discharged	No interval change

The second patient was a 39-year-old male restrained driver involved in high-speed motor vehicle collision sustained head, neck, and severe chest injuries. On presentation, the patient was hypotensive, GCS 3 (intubated, and ventilated), and his ISS was 29. He responded to fluid resuscitation, and bilateral intercostal drains were inserted for hemo-pneumothoraces. His CT neck and chest angiography demonstrated bilateral subclavian and vertebral arteries injury. There was also right posterior superior mediastinal hematoma with no visible underlying active contrast extravasation. CT brain confirmed bilateral cerebellar and pontomedullary areas of low attenuation, most likely acute ischemic insult. Considering his poor prognosis, the patient was palliated and died after 13 days of ICU stay.

The three Grade I VAI was treated with an antiplatelet agent (low dose Aspirin, 81 mg) alone. The remaining five (Grade II and IV) patients with VAI were treated with an anticoagulant and an antiplatelet agent (low dose Aspirin, 81 mg). Regarding

anticoagulant, we initially started Enoxaparin 1 mg/kg subcutaneous injection 12 hourly. On discharge, we converted to oral Apixaban 10 mg bid for one week and then 5 mg bid for the rest of three months duration). All of them had GCS 15 on discharge. In three months follow up at the outpatient department, no further complications or neurological deterioration were observed.

There were no other patients identified with symptoms of VAI at discharge.

Discussion

The diagnosis of blunt VAI was rare in a high-volume major trauma centre in Saudi Arabia. We were unable to demonstrate independent associations with common risk factors, demonstrating difficulty in the prediction of this condition. In particular, the discriminatory ability for C-Spine fractures screen patients could not be proven. Our results are consistent with previous studies reporting inadequate diagnostic utility of screening tools [12].

The finding of cervical vertebral fracture involving the foramen transversarium or in its anatomical vicinity in 9 of the 10 cases of VAI suggests a clinically significant finding and a high degree of suspicion to image the vertebral artery in such patients. The only patient who did not have a cervical vertebral fracture had a C0 left occipital condyle fracture. While this is strictly not part of the cervical vertebrae, it is clinically prudent to consider the two occipital condyles and the fist cervical vertebra as one functional unit. As such, although statistical significance could not be demonstrated due to the small numbers, there were signals of association of VAI with sub-types of cervical vertebral fractures.

Blunt trauma to the cervical spine can cause injury to the vertebral artery, although no specific cervical vertebral fracture pattern has been associated with VAI [13]. However, the initial presentation of unilateral VAI is usually asymptomatic; only 12-20% of the patients present with ischemic signs and symptoms [14]. Fractures involving the transverse foramen and subluxation are highly associated with VAI by 46% to 75% of cervical trauma [15]. Bilateral injury to the cerebrovascular arteries occurs in 18-25% of patients with VAI. Only 9 case reports were published regarding blunt trauma to three or four cerebrovascular arteries [16]. The mortality

due to blunt carotid injury is 13-38%, whereas the death due to VAI is about 8-18% [17].

Stroke is the most feared complication of VAI and reported in 10-13% of patients. Therefore, early screening in patients with VAI may decrease the incidence of stroke [18]. Even in cases where antiplatelet agents may be contra-indicated due to concomitant injuries, the advantages of screening for BCVI at the time of presentation aids planning for the treatment, close follow-up, and possible preventing delayed presentation with ischaemic posterior circulation events.

Catheter angiography is the gold standard modality to diagnose VAI, but since it is time-consuming and expensive, thus computerized tomographic angiography (CTA) has become the most common screening method for VAI in acute trauma setting [19]. As described in the literature, the sensitivity of CTA neck to diagnose VAI reaches up to 99% [20], and it is considered as a modality of choice for diagnosis. Magnetic resonance imaging has shown that satisfactorily results in many studies with the advantage of avoiding contrast. Still, the major disadvantage is a lack of timely availability at many institutions and the incompatibility of ventilatory and orthopaedic fixation equipment with the magnet.

This study is limited in being a retrospective cohort, and only a small sample of patients with VAI were identified. However, it includes consecutive patients during the time period from the most active trauma centre in the country. With only 10 cases of VAI, our attempts to develop a model to predict VAI was grossly underpowered and may suffer from Type II error. There was a signal that c-spine fractures were associated with VAI (odds ratio, OR=3.32), but our confidence in this point estimate was limited due to the small number of cases. While we reported on the hospital outcome of death, functional status, and longer-term functional outcomes of survivors should be the focus of future studies. A national trauma registry with systematic data collection of data on patient outcomes would be invaluable to assess such uncommon but clinically significant injuries. The investigations and association of variables to VAI will require ongoing surveillance using this registry.

Conclusion

Traumatic VAI was found to be an uncommon entity in the largest major trauma service in Saudi Arabia. Deaths in the setting of diagnosed VAI were uncommon. The association with traditional risk-factors could not be proven. We, therefore, continue to recommend the utilization of local protocols for assessment of VAI and ongoing surveillance for missed injuries.

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PART 5

In-Hospital Trauma System: Complications

CHAPTER 13

Surgical site infections after trauma laparotomy: An observational study from a major trauma center in Saudi Arabia

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Abstract

Objectives

To determine the incidence of surgical site infection (SSI) after trauma laparotomy and evaluate variables on presentation to the emergency department (ED) associated with the development of SSI.

Methods

A retrospective cohort study was undertaken of patients presenting directly from the scene who underwent trauma laparotomy between January 2016 and December 2017. The primary outcome variable was SSI, as defined by the Centers for Disease Control and Prevention guideline. A univariate assessment with demographics, vital signs, and acute management was reported.

Results

A total of 70 patients were included for data analysis. Of these, 9 (12.9%; 95% confidence interval (CI): 6.9-22.7%) patients developed SSI, including 5 patients with bowel injury (small bowel; n=3, colonic injuries; n=2). Most cases were diagnosed after 7 days in the hospital. All patients developed superficial incisional (skin and subcutaneous tissue) SSI. No predetermined variables, including bowel injury (p=0.08) or duration of surgery (p=0.09), demonstrated a statistically significant association with the development of SSI.

Conclusion

Rates of SSI after trauma laparotomy were similar to previous reports from other centers. Surgical site infection after trauma laparotomy was diagnosed at a delayed time point after surgery, and patient demographics, injury characteristics, and acute surgical management did not appear to be associated with subsequent diagnosis of SSI.

Introduction

Physical injury or trauma is predicted to become the third largest contributor to the global burden of disease by 2020. Worldwide, more than 5 million people die as a result of trauma each year, with trauma as the leading cause of death for young adults [1]. Trauma represents 10% of the world's deaths more than the deaths from malaria, tuberculosis, and HIV/AIDS combined [2,3]. This global disease burden affects productive members of society, often leading to long-term disability and dependency among long-term survivors. Abdominal injury occurs in 15% of major trauma cases, and exploratory laparotomy is performed in 25% [4]. While surgical site infection (SSI) after laparotomy is a growing global concern, reports on incidence, outcomes, and associated variables are limited. A single Colombian study of 614 patients reported that 13.8% of patients undergoing trauma laparotomy developed SSI [5]. Other studies have reported that SSIs represent 38% of nosocomial infection in surgical patients [6]. The burden of trauma in the Kingdom of Saudi Arabia is substantial. Between 1971-1997, 564,762 people died or were injured in road traffic accidents alone [7]. Many facets of pre-hospital and in-hospital trauma care are being addressed to improve patients' outcomes and reduce this burden. This study aimed to determine the incidence of SSI after laparotomy among trauma patients that presented to King Saud Medical City, Riyadh, Kingdom of Saudi Arabia (KSA) and to determine if preselected emergency department variables were associated with the development of SSI.

Methods

King Saud Medical City is a tertiary care center with 1,400 inpatient beds. A dedicated trauma unit manages all polytrauma patients, with a trauma surgeon operating on all penetrating and blunt chest, abdomen, and neck trauma when indicated. In 2017, a total of 29,671 trauma patients presented to King Saud Medical City emergency department, of which 3,459 patients were admitted.

A retrospective cohort study of patients presenting directly from the scene who underwent trauma laparotomy was undertaken. All cases of trauma laparotomy performed between January 2016 and December 2017 were included in this study. Cases transferred from other hospitals and underwent relook laparotomy

were excluded. All data were extracted by a single investigator using explicit chart review and were verified by a second investigator, using the chart review methodology described by Gilbert et al [8].

Data related to demographics, injury details, management, and outcomes of SSI and mortality at hospital discharge were extracted from medical records. King Saud Medical City operative triage had been defined as E1 (immediate life or limb-saving surgical intervention), and E2 (potential life or limb-saving surgical intervention within 6 hours). All physiological parameters were evaluated at the time of admission (on arrival). Afterhours was defined as the patient being operated upon by the on-call team (18:00-07:00). The day of the week when surgery was conducted, it was reported due to the previously reported association of adverse events after elective surgery [9]. All patients received cefuroxime and metronidazole as prophylactic preoperative broad-spectrum antibiotics.

Our primary outcome was the presence of abdominal SSI. The definition of SSI was based on the Centers for Disease Control and Prevention guideline [10]. A positive SSI was defined as the presence of symptoms and signs of infection, such as fever, localized pain or tenderness, redness, swelling, purulent discharge, and presence of the organism in an aseptically obtained culture within 30 days after laparotomy. Surgical site infection was sub-grouped as superficial incisional (skin and subcutaneous tissue), deep incisional (fascia and muscle), and organ/space (intra-abdominal) SSI.

Statistical analysis

Categorical variables were assessed using frequency tables. Numerical variables were evaluated with summary statistics (for continuous variables, mean and standard deviation; for ordinal variables or skewed distribution of variables, median and interquartile range). Differences were assessed by using Student's t-test for continuous variables and Fisher's exact test or the Chi-square test for difference between proportions. A p-value of <0.05 was considered statistically significant. All analyses were conducted using Stata v 11.3 (College Station, Texas, USA).

The study was approved by the King Saud Medical City Institutional Review Board (IRB ref: H1R1-08-Nov 17-02). The IRB committee approved a waiver of the requirement to seek informed consent from participants for retrospective review of their data.

Results

Over a 24-month period, 128 eligible trauma laparotomy patients were identified from the operation log. Of these, 17 medical records could not be located. Data was extracted from the remaining 111 patient files. In 41 cases, following chart review, the presence or absence of SSI could not be determined, or a large number of preselected exposure variables were missing. The remaining 70 patient records were included for data analysis (**Figure 1**).

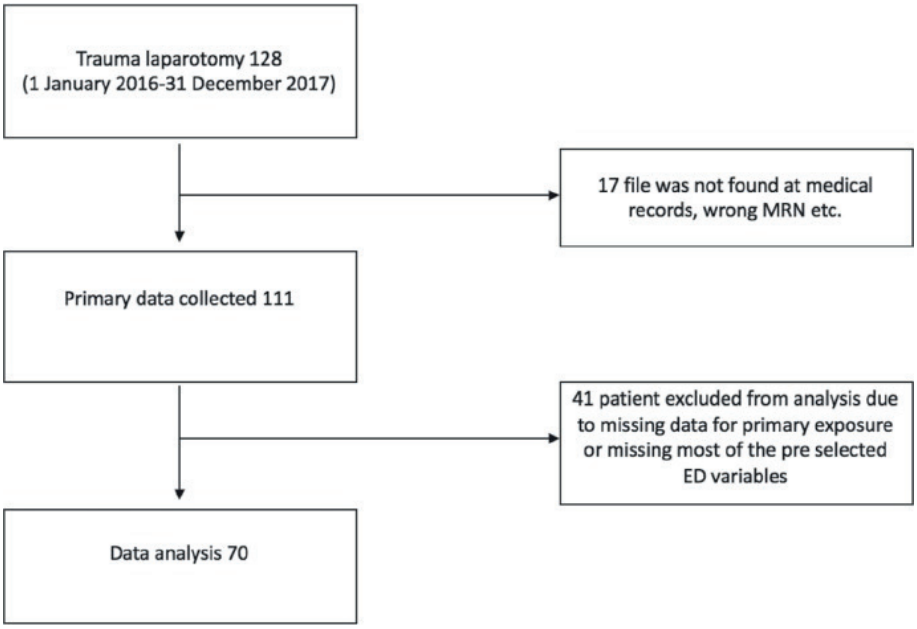

Figure 1. Sample selection

Table 1. Demographics, injury details, and management (N=70)

Variable	n (%)
Age (years) (Mean±SD)	30.8±13.2
Male gender	64 (91.4)
Mechanism	
MVC*	42 (60)
Falls	5 (7.1)
Penetrating	23 (32.9)
Day of injury	
Sunday	8 (11.4)
Monday	6 (8.6)
Tuesday	20 (28.6)
Wednesday	9 (12.9)
Thursday	5 (7.1)
Friday	10 (14.3)
Saturday	12 (17.1)
Heart rate (bpm) (Mean±SD)	101.5±23.9
Systolic blood pressure (mmHg) (Mean±SD)	111.7±23.8
Respiratory rate (breath/min) (Mean±SD)	22.0±7.3
Glasgow coma scale (GCS)	15 (IQR 11-15)
International normalized ratio (Mean±SD)	1.5±0.9
Lactate (Mean±SD)	4.7±4.1
Base excess (Mean±SD)	-4.8±3.8
Hemoglobin (gm/dl) (Mean±SD)	12.5±3.0
White cell count (x10^9/L) (Mean±SD)	16.3±8.7
Surgery after hours	36 (51.4)
ED to OR (min) (Mean±SD)	325.1±285.6
E2 operative triage	25 (35.7)
Duration of surgery (min) (Mean±SD)	130.2±67.9
Diabetes mellitus	1 (1.4)
Body mass index	
Normal weight <25	48 (68.6)
Overweight 25-29	16 (22.9)
Class 1 obese 30-34.9	4 (5.7)
Class 2 obese 35-39.9	1 (1.4)
Morbid obese 40-49.9	0
Super obese >50	1 (1.4)
ICU stay (days) (Mean±SD)	8.04±12.6
Total hospital stay (days) (Mean±SD)	20.20±22.16

SD - standard deviation, MVC - motor vehicle crash, ED - emergenc department, OR - operating room, ICU - intensive care unit, E2 - potential life or limb-saving surgical intervention within 6 hours, *reference variable

Of patients included in this study, 64 (91.4%) were male, with a mean age of 30.8±13.2 years. The majority of the cases (67.2%) were due to blunt trauma (motor vehicle crash [60%]). Most trauma laparotomies occurred on Tuesday (28.5%). The mean time from emergency department to operating room was 325.1±285.6 min. Almost half (51.4%) of the laparotomies were performed after hours. The mean operating time was 130.2±67.9 min. One patient had been diagnosed with diabetes mellitus, and one patient was extremely obese (body mass index [BMI]>50). No other comorbidities were identified. The mean stay days in the intensive care unit (ICU) was 8 days and hospital stays was 20 days (**Table 1**).

Nine (12.9%; 95% CI: 6.9-22.7) patients developed SSI. Of these, 5 patients had bowel injury (small bowel; n=3, colonic injury; n=2). The most common organisms were Escherichia coli (n=4), followed by Enterobacter cloacae (n=2), Pseudomonas aeruginosa (n=1), and Klebsiella pneumoniae (n=1). One patient had polymicrobial growth. All of these patients developed superficial incisional (skin and subcutaneous tissue) SSI. **Figure 2** illustrates the time at which SSIs occurred, with most cases diagnosed after 7 days in the hospital.

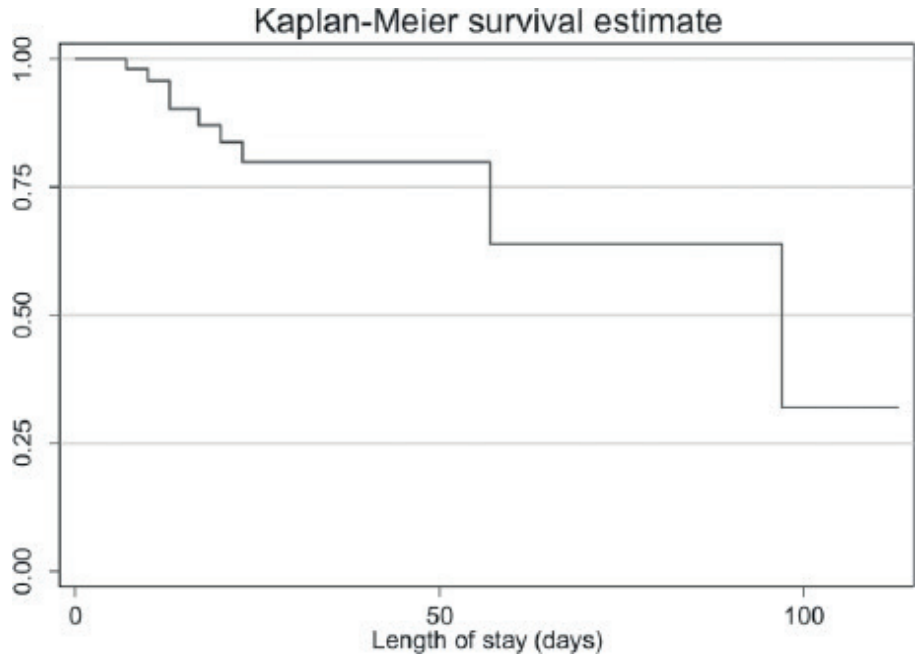

Figure 2. Surgical site infection over time.

No predetermined variables, including bowel injury (p=0.08) and duration of surgery (p=0.09), demonstrated a significant association with SSI (**Table 2**).

Table 2. Univariable association of variables with SSI.

Variable	OR (95% CI)	*P*-value
Age (years)	1.02 (0.97-1.07)	0.37
Male gender	0.71 (0.07-6.9)	0.77
Mechanism of injury		
MVC*		
Falls**	0.9 (0.2-4.0)	0.89
Penetrating		
Day of week		
Sunday	0.96 (0.10-8.90)	0.73
Monday**		
Tuesday	0.39 (0.02-7.11)	0.52
Wednesday	2.0 (0.14-27 .4)	0.60
Thursday**		
Friday	3.0 (0.25-36.3)	0.39
Saturday	1.4 (0.10-18.6)	0.80
Heart rate (HR) (bpm)	1.00 (0.97-1.03)	0.90
Systolic blood pressure (SBP) (mmHg)	0.99 (0.96-1.02)	0.65
Respiratory rate (RR) (breath/min)	0.97 (0.86-1.11)	0.72
Glasgow coma scale (GCS)	0.98 (0.81-1.17)	0.80
International normalized ratio (INR)	1.64 (0.89-3.03)	0.11
Lactate (mmol/l)	1.01 (0.83-1.22)	0.92
Base excess (BE)	0.90 (0.73-1.10)	0.29
Hemoglobin (Hb) (gm/dl)	1.27 (0.86-1.89)	0.23
White cell count (WCC) (x10^9/L)	0.90 (0.78-1.02)	0.11
After hours	1.21 (0.30-4.9)	0.79
Operative triage	2.56 (0.62-10.6)	0.19
Bowel injury	4.2 (0.82-21.6)	0.08
Duration of surgery	1.01 (0.99-1.02)	0.09
Time to theater	1.0 (0.99-1.0)	0.36

SSI - surgical site infection, MVC - motor vehicle crash, OR - odds ratio, CI - confidence interval, bpm - beats per minute, *reference variable, **no cases of SSI

Discussion

This study demonstrated that at least one in 8 patients developed SSI after trauma laparotomies in this single large trauma center in KSA. Demographics, injury severity, and times to operative management were not associated with subsequent development of SSI. Causative factors remain undetermined and require further evaluation of surgical technique and post-surgical management.

There is a paucity of data for SSI rates after trauma laparotomy, with no agreed benchmarks for trauma centers. The study's SSI rate of 12.9% appears acceptable relative to a previously published estimate of 13.8%.5 As this institute embarks upon a system-wide program to improve trauma care, it provides a baseline for further improved care.

Trauma from motor vehicle crashes is an increasing concern in Kingdom of Saudi Arabia, representing the second most common cause of death in all age groups [11]. King Saud Medical City in Riyadh, Kingdom of Saudi Arabia is a major trauma hospital in the region and SSI is considered a common postoperative complication. Surgical site infection represents the most frequent adverse postoperative event in health care and is one of the most frequent types of hospital-acquired infection (HAI) [12]. Although the rate of SSI is higher in developing countries, reports from these countries are limited [12].

Non-operative management is the prevailing standard of care for hemodynamically stable patients. However, for those requiring laparotomy, the delay of operative intervention is associated with postoperative complications [13]. There is a scant information in the literature on the incidence of SSI after trauma laparotomy or the effects of hollow viscus injury, the duration of surgery, or the type of injury. Our cohort study suggests that a more detailed analysis of surgical technique and postoperative management in the ICU is required to understand the determinants of SSI and to develop management protocols to prevent SSIs.

Study limitations

This is a retrospective cohort, with data solely dependent on what was documented in the patients' files. Accuracy was difficult to verify. A large number of patient records had missing data; therefore, the affected cases were deleted from the analysis. Some demographic patient details were also lacking, and we were unable to determine the causes of delay to the operating theater. Only univariate analyses are presented since the multivariable analysis was not possible without any statistically significant associations. The sample size was small but provides baseline data for evaluating outcomes and measuring improvements after trauma laparotomy. Prospective analysis, aided by the newly launched trauma registry, will be used to further evaluate SSI and its association with other outcome measures, such as patient satisfaction and correlation with other healthcare-associated infections.

In conclusion, demographic and injury characteristics were not associated with an increased risk of SSI after trauma laparotomy. Potential clinically significant variables, such as bowel injury, time to the theater, and operating time require further evaluation in prospective studies. In this series, all SSI after trauma laparotomy were diagnosed after 7 days in the hospital.

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CHAPTER 14

Incidence and nature of lower-limb deep vein thrombosis in patients with polytrauma on thromboprophylaxis: a prospective cohort study

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Abstract

Purpose

Deep vein thrombosis (DVT) is common among the severely injured and may lead to pulmonary embolism (PE), which can be life threatening. Thromboprophylaxis may reduce the incidence of venous thromboembolism (VTE); it does not guarantee complete protection. This study's primary aim was to determine the incidence and nature of lower-limb DVT in polytrauma patients taking prophylaxis. The secondary objective was to assess the incidence of DVT-related complications, including the development of PE and death.

Patients and Methods

This prospective observational study included patients age 18 years or older who presented with polytrauma directly from the scene and were admitted into the trauma unit between March 1, 2020, and August 31, 2020. All patients underwent lower-limb ultrasound during their hospital course to diagnose DVT.

Results

A total of 169 patients underwent extremity Doppler ultrasound to detect DVT. Of these, 69 patients (40.8%) were considered at the highest-risk for VTE development. For VTE prophylaxis, 115 patients (68%) received pharmacologic agents, and 54 patients (32%) had intermittent pneumatic compression on admission. Three patients (1.8%) developed DVT despite prophylaxis. Four patients (2.4%) developed PE during the index presentation and were diagnosed between days 3 and 13 after injury. Early DVT was not detected in any patients with diagnosed PE. Overall, nine patients (5.33%) died, but no in-hospital deaths were related to DVT and/or PE.

Conclusion

The incidence of DVT in polytrauma patients remains low in our small series, perhaps because of the mandatory VTE risk assessment for all hospitalized patients and the early initiation of prophylaxis. Using a trauma center registry to measure DVT and PE incidence regularly is recommended to improve trauma care quality.

Introduction

Deep vein thrombosis (DVT), a common type of venous thrombosis, and its complication, pulmonary embolism (PE), can be life threatening. In the United States, 187,000 people age 45 years or older are newly diagnosed with venous thromboembolism (VTE) each year [1]. The annual incidence of VTE ranges from 1.69 to 1.98 per 1,000 in the general population, including annual DVT and PE incidences of 1.24 and 0.6 per 1,000 per year, respectively [2]. After a trauma, the incidence of VTE varies from 7% to 58%, depending on patient demographics, mechanism of injury, diagnoses, and type of VTE prophylaxis used [3]. The association between trauma, particularly lower-extremity fractures, and VTE has been recognized for almost a century. Several autopsy studies have confirmed the relationship between injury and VTE, even when VTE was not diagnosed premortem [4,5]. In 1967, Freeark et al[6] demonstrated with a venogram that 35% of patients with fractures develop venous thrombosis. The asymptomatic thrombus formation was observed within 24 h of injury, both in the injured and the uninjured limbs [6].

The endothelial injury, stasis of blood flow, and hypercoagulability known as Virchow's triad plays an essential role in thrombus formation. Notably, severe trauma often precipitates one or all of these risk factors, which increases the risk of VTE [7]. Intimal damage caused by direct injury to the vessels leads to thrombosis. Prolonged bed rest, immobilization, hypoperfusion, and paralysis caused by trauma promote venous stasis [8]. Most trauma patients are also in a hypercoagulable state at admission. The rate of DVT doubles in such patients despite prophylaxis [9]. Severe trauma also activates the prothrombotic state, which contributes to thrombus formation [10].

Using different types of VTE prophylaxis—mechanical or pharmacologic—for trauma patients is currently the standard practice. Early commencement of VTE prophylaxis may not be possible in high-risk multi-trauma patients. Examples of these high-risk situations include lower limb fractures with plaster, severe head trauma, high-grade abdominal organ injury, or excessive bleeding. For patients with high-risk major trauma, the American College of Chest Physicians (ACCP) recommends mechanical prophylaxis, preferably with intermittent pneumatic compression (IPC), when not contraindicated by lower-extremity injury. They

suggest adding pharmacologic prophylaxis, such as low-molecular-weight heparin (LMWH) or unfractionated heparin (UFH), when the risk of bleeding diminishes or the contraindication to heparin resolves (grade 2C). They discourage periodic surveillance with venous compression ultrasound or insertion of an inferior vena cava (IVC) filter for the primary prevention of VTE (grade 2C). They also recommend continuing the VTE prevention in the hospital until patients are ambulatory. Patients who undergo major orthopedic surgery may need extended thromboprophylaxis in the outpatient period for up to 35 days after the day of surgery (grade 2B). In chronically immobilized persons residing at home or in a nursing home, the ACCP guidelines suggest against the routine use of thromboprophylaxis (grade 2C) [11].

This study's primary aim was to determine the incidence and nature of lower-limb DVT in polytrauma patients on VTE prophylaxis. The secondary objective was to assess DVT-related complications, including the development of PE or death.

Patients and Methods

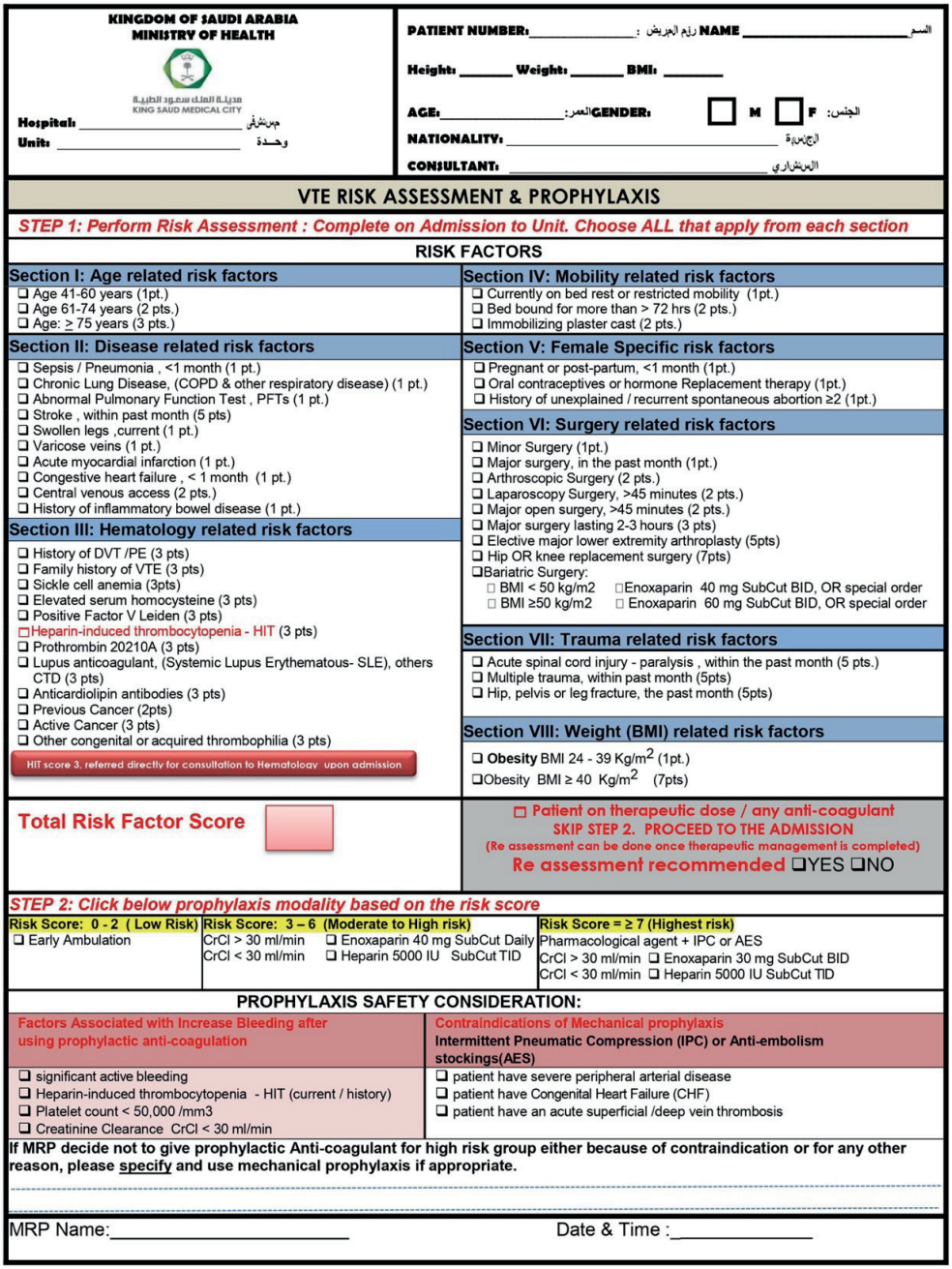
Settings: King Saud Medical City (KSMC) is a tertiary care center with a capacity of 1,400 inpatients beds. A dedicated trauma unit manages all patients admitted for polytrauma [12] The trauma unit admits 50–70 patients with polytrauma per month. According to the hospital policy, all patients must have a VTE risk assessment before admission to the hospital and must start VTE prophylaxis according to the recommendation unless otherwise contraindicated. The attending physician fills out the VTE risk assessment form electronically in the hospital information system (Medisys).

Design: This prospective, observational study included patients age 18 years or older presenting with polytrauma directly from the scene and admitted to the trauma unit between March 01, 2020, and August 31, 2020. The study excluded patients transferred from another facility, because they spent a variable period before transfer to KSMC and had an unknown prophylaxis status. Also, non-Saudi patients without insurance coverage who could not pay the additional cost associated with ultrasounds or who did not consent to the procedure were excluded from the study.

VTE risk assessment tool: An expert panel led by the Saudi Association for Venous Thromboembolism (a subsidiary of the Saudi Thoracic Society), with methodological guidance from the McMaster University Guideline Working Group, adopted a VTE risk assessment tool from a validated Caprini risk assessment model and developed a clinical practice guideline to assist healthcare providers in VTE prevention as part of a Saudi Ministry of Health initiative to improve medical practices in the Kingdom (Figure 1) [13]. Using this evaluation and the VTE risk scores, the patients were classified as having a low risk (risk score, 0–2), a moderate- to high- risk (risk score, 3–6), or the highest-risk (risk score ≥ 7) for VTE (Figure 1).

VTE prophylaxis: Pharmacologic prophylaxis was prescribed for all patients as per the recommendation of the VTE risk assessment tool immediately on admission. Patients with moderate- to high-risk received enoxaparin 40 mg subcutaneously daily. Patients in the highest-risk group received enoxaparin doses of 30 mg twice daily in addition to IPC. When the patient's creatinine clearance was < 30 mL/min or when enoxaparin was contraindicated (eg, pregnancy), the patient received 5,000 IU of UFH subcutaneously three times daily (Figure 1) [13]. If pharmacologic prophylaxis was not possible on admission because of bleeding risk or active bleeding, mechanical prevention with an IPC device was applied. The pharmacologic agent was commenced when bleeding risk was minimized within 72 h of admission. The IPC was discontinued for patients with moderate- to high-risk group but continued in the highest-risk group. VTE prevention measures were continued in the hospital until the patient was ambulatory. After major orthopedic surgery, prevention continued up to 35 days after surgery. Prophylaxis was used during the entire hospital stay in chronically immobilized patients but was discontinued upon discharge to home or to a nursing home [11].

Bleeding risk assessment: Bleeding risk was assessed before pharmacologic VTE prophylaxis began. A patient was considered at high risk for bleeding if there was evidence of active bleeding, severe traumatic brain injuries with intracerebral hemorrhage, or high-grade intraabdominal solid organ injuries (grade II or above according to the American Association for the Surgery of Trauma injury scoring scales); if there was a history or current evidence of heparin-induced thrombocytopenia; or if the platelet count was < 50,000/mm^3 (Figure 1) [13].



KINGDOM OF SAUDI ARABIA
MINISTRY OF HEALTH

مدينة الملك سعود الطبية
KING SAUD MEDICAL CITY

Hospital: _____ مستشفى
Unit: _____ وحدة

PATIENT NUMBER: _____ : رقم المريض NAME _____ الاسم
Height: _____ Weight: _____ BMI: _____
AGE: _____ :العمر GENDER: ☐ M ☐ F :الجنس
NATIONALITY: _____ الجنسية
CONSULTANT: _____ الاستشاري

VTE RISK ASSESSMENT & PROPHYLAXIS

STEP 1: Perform Risk Assessment : Complete on Admission to Unit. Choose ALL that apply from each section

RISK FACTORS

Section I: Age related risk factors
- ❑ Age 41-60 years (1pt.)
- ❑ Age 61-74 years (2 pts.)
- ❑ Age: ≥ 75 years (3 pts.)

Section II: Disease related risk factors
- ❑ Sepsis / Pneumonia , <1 month (1 pt.)
- ❑ Chronic Lung Disease, (COPD & other respiratory disease) (1 pt.)
- ❑ Abnormal Pulmonary Function Test , PFTs (1 pt.)
- ❑ Stroke , within past month (5 pts)
- ❑ Swollen legs ,current (1 pt.)
- ❑ Varicose veins (1 pt.)
- ❑ Acute myocardial infarction (1 pt.)
- ❑ Congestive heart failure , < 1 month (1 pt.)
- ❑ Central venous access (2 pts.)
- ❑ History of inflammatory bowel disease (1 pt.)

Section III: Hematology related risk factors
- ❑ History of DVT /PE (3 pts)
- ❑ Family history of VTE (3 pts)
- ❑ Sickle cell anemia (3pts)
- ❑ Elevated serum homocysteine (3 pts)
- ❑ Positive Factor V Leiden (3 pts)
- ❑ Heparin-induced thrombocytopenia - HIT (3 pts)
- ❑ Prothrombin 20210A (3 pts)
- ❑ Lupus anticoagulant, (Systemic Lupus Erythematous- SLE), others CTD (3 pts)
- ❑ Anticardiolipin antibodies (3 pts)
- ❑ Previous Cancer (2pts)
- ❑ Active Cancer (3 pts)
- ❑ Other congenital or acquired thrombophilia (3 pts)

HIT score 3, referred directly for consultation to Hematology upon admission

Section IV: Mobility related risk factors
- ❑ Currently on bed rest or restricted mobility (1pt.)
- ❑ Bed bound for more than > 72 hrs (2 pts.)
- ❑ Immobilizing plaster cast (2 pts.)

Section V: Female Specific risk factors
- ❑ Pregnant or post-partum, <1 month (1pt.)
- ❑ Oral contraceptives or hormone Replacement therapy (1pt.)
- ❑ History of unexplained / recurrent spontaneous abortion ≥2 (1pt.)

Section VI: Surgery related risk factors
- ❑ Minor Surgery (1pt.)
- ❑ Major surgery, in the past month (1pt.)
- ❑ Arthroscopic Surgery (2 pts.)
- ❑ Laparoscopy Surgery, >45 minutes (2 pts.)
- ❑ Major open surgery, >45 minutes (2 pts.)
- ❑ Major surgery lasting 2-3 hours (3 pts)
- ❑ Elective major lower extremity arthroplasty (5pts)
- ❑ Hip OR knee replacement surgery (7pts)
- ❑ Bariatric Surgery:
  - ☐ BMI < 50 kg/m2 ☐ Enoxaparin 40 mg SubCut BID, OR special order
  - ☐ BMI ≥50 kg/m2 ☐ Enoxaparin 60 mg SubCut BID, OR special order

Section VII: Trauma related risk factors
- ❑ Acute spinal cord injury - paralysis , within the past month (5 pts.)
- ❑ Multiple trauma, within past month (5pts)
- ❑ Hip, pelvis or leg fracture, the past month (5pts)

Section VIII: Weight (BMI) related risk factors
- ❑ **Obesity** BMI 24 - 39 Kg/m^2 (1pt.)
- ❑ Obesity BMI ≥ 40 Kg/m^2 (7pts)

Total Risk Factor Score ☐

☐ Patient on therapeutic dose / any anti-coagulant
SKIP STEP 2. PROCEED TO THE ADMISSION
(Re assessment can be done once therapeutic management is completed)
Re assessment recommended ❑YES ❑NO

STEP 2: Click below prophylaxis modality based on the risk score

Risk Score: 0 - 2 (Low Risk)	Risk Score: 3 – 6 (Moderate to High risk)	Risk Score = ≥ 7 (Highest risk)
❑ Early Ambulation	CrCl > 30 ml/min ❑ Enoxaparin 40 mg SubCut Daily CrCl < 30 ml/min ❑ Heparin 5000 IU SubCut TID	Pharmacological agent + IPC or AES CrCl > 30 ml/min ❑ Enoxaparin 30 mg SubCut BID CrCl < 30 ml/min ❑ Heparin 5000 IU SubCut TID

PROPHYLAXIS SAFETY CONSIDERATION:

Factors Associated with Increase Bleeding after using prophylactic anti-coagulation	Contraindications of Mechanical prophylaxis **Intermittent Pneumatic Compression (IPC) or Anti-embolism stockings(AES)**
❑ significant active bleeding ❑ Heparin-induced thrombocytopenia - HIT (current / history) ❑ Platelet count < 50,000 /mm3 ❑ Creatinine Clearance CrCl < 30 ml/min	❑ patient have severe peripheral arterial disease ❑ patient have Congenital Heart Failure (CHF) ❑ patient have an acute superficial /deep vein thrombosis

If MRP decide not to give prophylactic Anti-coagulant for high risk group either because of contraindication or for any other reason, please specify and use mechanical prophylaxis if appropriate.

MRP Name:_____ Date & Time :_____

Figure 1: VTE risk assessment tool

VTE treatment: Patients with diagnosed DVT and/or PE received therapeutic anticoagulation with enoxaparin (1 mg/kg body weight twice daily) or UFH infusion (initial bolus of 80 units/kg followed by 18 units/kg/h [grade 2C]) [11]. After the patient was able to take oral medications, enoxaparin or UFH was converted to an oral anticoagulant, such as apixaban 10 mg twice daily for 1 week and then 5 mg twice daily for a total of 3 months after the diagnosis (grade 2B) [14]. Additional evaluation and treatment were decided by the treating physician in the outpatient department. Thrombolytic therapy was considered for the PE with hypotension (grade 2B) [14].

Data collection, instruments used, and measurements: All patients who met the inclusion criteria had the first mandatory ultrasound of lower limbs within 48 h of admission to identify any early DVT evidence. The next follow-up ultrasound of the lower limbs occurred after 1 week. Subsequent follow-up ultrasounds were performed if there was clinical suspicion of DVT such as limb swelling, fever, or tenderness, during the hospital stays. CT angiogram of the chest was performed to diagnose and confirm PE on the basis of clinical suspicion and bedside investigation findings. PE was suspected in the case of unexplained hypotension, sudden respiratory deterioration requiring mechanical ventilation, a sudden requirement of high ventilatory settings, hypoxia in arterial blood gas, changes in a chest radiograph, high D-dimer, ECG changes, or right ventricular dilatation on echocardiogram. The patients who were diagnosed with PE had an additional lower-limb ultrasound to rule out the development of an associated DVT, irrespective of clinical signs. Patients who tested positive for DVTs did not undergo routine CT chest angiograms unless clinical signs and symptoms of PE developed, because these patients were already on therapeutic anticoagulation as a treatment for VTE.

We measured data related to demographics, age, gender, nationality, mechanism of injury, baseline characteristics on presentation to the emergency department, associated risk factors, comorbidities, surgeries, injury severity score (ISS), ICU admissions, length of hospital stay, VTE risk score and category, VTE incidence, deaths and DVT prophylaxis used. All data were extracted by a single investigator using a detailed chart review and were verified by a second investigator using the chart review methodology described by Gilbert et al [15].

The primary goal was to determine the incidence and nature of lower-limb DVT (above or below the knee) in patients with polytrauma. The secondary aim was to report VTE-associated complications, such as PE or death. A VTE-related death was defined as a death caused by confirmed PE with or without pre-existing DVT. Deaths related to injury or complications other than PE, such as coagulopathy, acute respiratory distress syndrome, multiorgan failure, or septicemia, were excluded.

Statistical analysis: The data were subgrouped by VTE risk into a moderate- to high-risk group and a highest-risk group. Demographics, mechanism of injury, baseline injury characteristics on admission, associated risk factors, comorbidities, surgeries, ICU admission, ISS, duration of hospital stay, VTE incidence, and deaths were compared between the two subgroups. The continuous and normally distributed data were summarized using means (and standard deviations [SD]) and were compared using Student's t-test. Skewed and ordinal data (eg, Glasgow Coma Scale) were summarized using medians (interquartile ranges [IQRs]) and were compared using the nonparametric Mann-Whitney U test. Countable data were summarized using proportions (%) and were compared using the nonparametric chi-squared test. A p value of < 0.05 was considered significant.

Ethics: The experiment protocol for involving human data followed national/ international/ institutional guidelines and the Declaration of Helsinki. The study was approved by the institutional review board of King Saud Medical City (reference number: H1RI-03-Oct18-03). Informed consent from the patient or legal guardian was obtained for study participation.

Results

We recruited 169 patients who underwent lower-extremity Doppler ultrasound on admission and at 1 week and who were observed until hospital discharge. Most patients were young (mean age, 38.1 years), were male (88.2%), and had sustained blunt trauma (96.5%); these characteristics are consistent with the demographics of trauma patients in Saudi Arabia. Sixty-nine patients (40.8%) were considered at the highest-risk for VTE development.

The highest-risk group had a statistically significantly lower coma scale (median, 15 vs. 10; p = 0.002), higher heart rate (mean, 92.4 vs. 99 bpm; p = 0.013), lower hemoglobin level (mean, 11.9 vs. 10.9 g/dL; p = 0.007), and more frequent red cell transfusion (10% vs. 27.5% of patients; p = 0.003). The highest-risk group of patients also had significantly higher ISS (p < 0.000), greater rates of ICU admission (41% vs. 66.7%; p = 0.001), and more extended hospital stays (20.8 vs. 33.2 days; p = 0.000) than the moderate- to high-risk group. A total of 92 patients (54.4%) required single or multiple surgeries. Of these, 85 patients (92.4%) began prophylaxis preoperatively, and seven patients (7.6%) began prophylaxis postoperatively because they required immediate surgery for damage control. In the entire cohort, 32 patients (18.9%) had lower-extremity fractures. A total of 22 patients (13%) received 35 days of prophylaxis from the day of major orthopedic and pelvic surgeries. Some patients presented with comorbidities: 16 patients (9.5%) had hypertension, 12 (7.1%) had diabetes, and six (3.6%) had ischemic heart disease. Patients who had a history of ischemic heart disease were receiving antiplatelet therapy, and at discharge no extended prophylaxis beyond their regular chronic medications (including antiplatelet therapy) was prescribed for these patients. No patients had a history of oral contraceptive use, a history of prior DVT and/or PE, or a family history of VTE before admission. The demographics, age, gender, nationality, mechanism of injuries, baseline characteristics on presentation to the emergency department, associated risk factors, comorbidities, surgeries, ISS, ICU admission, hospital length of stay, VTE incidence, and deaths for the moderate- to high-risk and the highest-risk groups are listed in Table 1.

Table 1. The demographics, mechanism of injuries, baseline characteristics on presentation to the emergency department, associated risk factors, comorbidities, surgeries, ISS, ICU admission, hospital length of stay, VTE incidence, and deaths for the moderate- to high-risk and the highest-risk groups

Variable	Total (n=169)	Moderate- to high risk for VTE (n=100)	The highest-risk for VTE (n=69)	p-value
Age (mean years, SD)	38.1 (14.7)	34.7 (10.9)	42.9 (17.8)	p=0.000*
Sex				p=0.936
Male sex (%)	149 (88.2%)	88 (88%)	61 (88.4%)	
Female sex (%)	20 (11.8%)	12 (12%)	8 (11.6%)	
Nationality:				p=0.128
Saudi (%)	101 (59.8%)	55 (55%)	46 (66.7%)	
Non-Saudi (%)	68 (40.2%)	45 (45%)	23 (33.3%)	
Mechanism of injury:				p=0.800
Motor vehicle accident (%)	146 (86.4%)	85 (85%)	61 (88.3%)	
Low fall (<1meter, %)	3 (1.8%)	2 (2%)	1 (1.5%)	
High fall (>1 meter, %)	12 (7.1%)	7 (7%)	5 (7.2%)	
Assault (%)	2 (1.2%)	1 (1%)	1 (1.5%)	
Penetrating (%)	6 (3.5%)	5 (5%)	1 (1.5%)	
GCS (median, IQR)	14 (8-15)	15 (9-15)	10 (7-15)	p=0.002*
SBP (mean mmHg, SD)	119.5 (20.5)	119.3 (18.4)	119.8 (23.8)	p=0.431
HR (mean beat/min)	95.1 (19)	92.4 (18.8)	99 (18.7)	p=0.013*
Shock Index (HR/SBP)	1.2 (5.0)	1.4 (6.5)	0.9 (0.3)	p=0.242
Hemoglobin (mean g/dL, SD)	11.5 (2.5)	11.9 (2.3)	10.9 (2.7)	p=0.007*
Lactate (mean mmol/L, SD)	2.6 (1.6)	2.5 (1.4)	2.8 (1.9)	p=0.136
INR (mean, SD)	1.1 (0.2)	1.03 (0.23)	1.09 (0.24)	p=0.089
PH (mean, SD)	7.35 (0.08)	7.36 (0.08)	7.34 (0.09)	p=0.112
HCO3 (mean, SD)	21.8 (3.7)	22.1 (3.2)	21.3 (4.3)	p=0.096
Base deficit (mean, SD)	-1.9 (3.5)	-1.8 (3.6)	-2.1 (3.4)	p=0.273
Red cell transfusion in ED (%)	29 (17.2%)	10 (10%)	19 (27.5%)	p=0.003*
Intubated (%)	78 (46.2%)	39 (39%)	39 (56.5)	p=0.025*

BMI >24 (%)	29 (17.2%)	13 (13%)	16 (23.2%)	p=0.084
History of antiplatelet therapy (%)	6 (3.6%)	2 (2%)	4 (5.8%)	P=0.190
Comorbidities:				
Hypertension (%)	16 (9.5%)	10 (10%)	6 (8.7%)	p=0.775
Diabetes (%)	12 (7.1%)	6 (6%)	6 (8.7%)	p=0.502
Ischemic heart disease (%)	6 (3.6%)	2 (2%)	4 (5.8%)	p=0.190
Previous stroke (%)	0	0	0	Invalid
Cancer (%)	0	0	0	Invalid
Surgeries:				
number of patients (%)	92 (54.4%)	49 ((49%)	43 (62.3%)	p=.087
Types of surgeries†:				
Craniotomy/Craniectomy (%)	15 (8.9%)	8 (8%)	7 (10.1%)	p=0.232
Facial (%)	14 (8.3%)	8 (8%)	6 (8.7%)	p=0.872
Neck exploration (%)	1 (0.6%)	1 (1%)	0 (0%)	Invalid
Thoracotomy (%)	5 (3%)	3 (3%)	2 (2.9%)	p=0.969
Laparotomy (%)	13 (7.7%)	6 (6%)	7 (10.1%)	p=0.320
Vascular (%)	4 (2.4%)	2 (2%)	2 (2.9%)	p=0.706
Pelvic fixation (%)	8 (4.7%)	3 (3%)	5 (7.2%)	p=0.201
Upper limb (%)	16 (9.5%)	10 (10%)	6 (8.7%)	p=0.776
Lower limb (%)	32 (18.9%)	16 (16%)	16 (23.2%)	p=0.241
Vertebral Column (%)	19 (11.2%)	9 (9%)	10 (14.5%)	p=0.267
ISS:				P<0.000*
<16 (%)	76 (45%)	54 (54%)	22 (31.9%)	
16-25 (%)	62 (36.7%)	40 (40%)	22 (31.9%)	
>25 (%)	31 (18.3%)	6 (6%)	25 (36.2%)	
ICU admissions (%)	87 (51.5%)	41 (41%)	46 (66.7%)	p=0.001*
Hospital length of stay (mean days, SD)	25.9 (22.3)	20.8 (18.2)	33.2 (25.5)	p=0.000*
VTE (%):	7 (4.2%)	2 (2%)	5 (7.2%)	p=0.092
DVT (%)	3 (1.8%)	1 (1%)	2 (2.9%)	p=0.358
PE (%)	4 (2.4%)	1 (1%)	3 (4.3%)	p=0.159
Death‡ (%)	9 (5.33%)	4 (4%)	5 (7.2%)	p=0.356

Notes: *Significant p-values, †Same patient had single or multiple surgeries. ‡No deaths were related to VTE. **Abbreviations:** ISS, injury severity score; ICU, intensive care unit; VTE, venous thromboembolism; SD, standard deviation; GCS, Glasgow coma scale; IQR, interquartile range; SBP, systolic blood pressure; HR, heart rate; INR, international normalized ratio; BMI, body mass index; DVT, deep vein thrombosis; PE, pulmonary embolism.

A total of 115 patients (68%, 95% CI = 0.61 - 0.75) received pharmacologic agents for VTE prophylaxis; 54 patients (32%, 95% CI = 0.25 - 0.39) underwent IPC on admission (Table 2).

Table 2. VTE prophylaxis on admission

VTE prophylaxis	Total (n=169)	Moderate- to high-risk for VTE (n=100)	The highest-risk for VTE (n=69)	p-value
Pharmacological agents (Enoxaparin† or UFH‡)	115 (68%)	72 (72%)	43 (62.3%)	p=0.185 (Chi-squared 1.76)
IPC*	54 (32%)	28 (28%)	26 (37.7%)	

Notes: †Enoxaparin: Patients with moderate- to high-risk received enoxaparin 40 mg subcutaneously daily. Patients in the highest-risk group received enoxaparin doses of 30 mg twice daily in addition to IPC. ‡UFH: When the patient's creatinine clearance was < 30 mL/min or when enoxaparin was contraindicated (eg, pregnancy), the patient received 5,000 IU of UFH subcutaneously three times daily in both groups. *IPC: If pharmacologic prophylaxis was not possible on admission because of bleeding risk or active bleeding. The pharmacologic agent was commenced when bleeding risk was minimized within 72 h of admission. The IPC was discontinued for patients with moderate- to high-risk group but continued in the highest-risk group. **Abbreviations:** VTE, venous thromboembolism; UFH, unfractionated heparin; IPC, intermittent pneumatic compressor.

The mean durations of use for a pharmacologic agent and IPC prophylaxis were 25.9 days (SD, 22.3 days) and 14.7 days (SD, 11.2 days), respectively. A total of seven VTE events (4.2%, 95% CI = 0.02 – 0.08) were reported. Only three events (1.8%, 95% CI = 0.00 – 0.05) were detected by DVT; of these, one occurred in a patient in the moderate- to high-risk group, and two occurred in patients at the highest-risk for DVT development. All patients who were positive for DVT received pharmacologic prophylaxis. All patients with DVT events were asymptomatic on admission and at 1 week. One patient was symptomatic on day 21, and DVT was confirmed by lower-limb Doppler ultrasound. Two instances of DVT occurred above the knee, and one patient presented with DVT both above and below the knee. There were no additional diagnoses of DVT at hospital discharge. Four patients (2.4%, 95% CI = 0.01 – 0.06) were diagnosed with PE during the index presentation. All PE occurrences were diagnosed between 3 and 13 days after injury. Early DVT was not detected in any of the patients with a diagnosed PE. No bleeding events were reported in this series. The characteristics of patients

who tested positive for DVT and PE are described in Table 3. In this cohort, nine patients (5.33%) died, but no in-hospital deaths were related to DVT or PE.

Table 3. Characteristics of positive DVT and PE patients

Sl. No.	Patient	Risk Category	ICU	ISS	Extremities Fractures	Associated Injuries	Site & Type of DVT	Associated DVT and/or PE	Day of Diagnosis
1	DVT	Moderate-to High	Yes	17	Right tib/fib fractures	Severe TBI, C2 fracture, and bilateral lung contusions	Right above knee (occlusive)	No PE	7
2	DVT	Highest	Yes	38	Right tib/fib fractures	Severe TBI, bilateral lung contusions and haemothoraces	Left above and below knee (occlusive)	No PE	7
3	DVT	Highest	Yes	27	No	Severe TBI and facial fractures	Bilateral above Knee (non-occlusive)	No PE	21
4	PE	Moderate-to High	Yes	17	No	Severe TBI, facial fractures, Bilateral lung contusions, and T6-11 fractures	Bilateral segmental	No DVT	9
5	PE	Moderate-to High	No	22	Left femur	Bilateral lung contusions, multiple rib fractures, and L1-4 fractures	Bilateral lobar and segmental	No DVT	3
6	PE	Highest	Yes	33	No	TBI, facial fractures, bilateral lung contusions, right 3rd rib fracture, and L1 compression fracture	Right segmental	No DVT	5
7	PE	Highest	Yes	26	No	Facial fractures, left hemopneumothorax, left pubic rami fractures.	Bilateral segmental	No DVT	13

Abbreviations: DVT, deep vein thrombosis; PE, pulmonary embolism; ICU, intensive care unit; ISS, injury severity score; TBI, traumatic brain injuries; C2, second cervical vertebra; T6-11, sixth to eleventh thoracic vertebrae; L1-4, first to fourth lumbar vertebrae; L1, first lumbar vertebra.

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Discussion

The optimal approach to VTE prophylaxis in patients with trauma remains ill defined. To our knowledge, no level-1 evidence or randomized, controlled trial on this topic exists to date [11,14]. Moreover, the risk stratification of patients with trauma and single or multiple injuries is extremely difficult. LMWH, such as enoxaparin, has remained a standard of care for VTE prophylaxis for more than a decade. LMWH has shown better efficacy and equal or even better safety than UFH [16]. Meta-analyses have also confirmed a higher benefit and risk ratio for LMWH than for UFH as a VTE prophylaxis [16]. LMWH is associated with a 10 times lower incidence of heparin-induced thrombocytopenia compared with UFH.

Bleeding is even less frequent with prophylactic LMWH. Even in renal impairment, LMWH has demonstrated a higher efficacy and safety ratio than UFH [16]. A study by Geerts et al [17] has shown that LMWH is more effective than UFH in patients with trauma to prevent VTE. Although the ACCP guidelines do not recommend using an IVC filter as VTE prevention (grade 2C), some authorities support its use in high-risk patients when neither pharmacologic nor mechanical prophylaxis is feasible [11,18].

IPC was used on admission in 54 patients (32%). Subsequently, all patients received pharmacologic prophylaxis and/or IPC, according to the risk assessment categories, within 72 h. Current studies and guidelines support starting pharmacologic prophylaxis even earlier. The recommendation is to start LMWH within 36–72 h of admission in conjunction with neurosurgical consultation for traumatic brain injury [19,20]. In patients with abdominal solid-organ injuries, the introduction of LMWH within 48 h in the absence of ongoing bleeding appears safe [19,20].

Currently, no consensus exists for routine screening of DVT or VTE in asymptomatic patients [11]. The ACCP guidelines do not recommend periodic surveillance DVT with Doppler ultrasound for high-risk or critically ill patients after trauma (grade 2C) [11]. However, according to the Eastern Association for the Surgery of Trauma, some high-risk patients may benefit from routine screening for DVT [21]. DVT screening for asymptomatic patients is often debated among surgeons, and clinical importance remains unclear [22]. Some older studies have found it clinically beneficial [22]. Recently, one group has shown that PE rates in patients with trauma decreased with routine surveillance and early management of DVT [23]. Others suggest that routine surveillance for DVT in the presence of appropriate VTE prophylaxis is not effective at preventing clinically relevant VTE, so the increased cost of medical testing is not warranted. Furthermore, routine surveillance may incur risks associated with anticoagulation treatment for clinically irrelevant DVT and/or PE treatment [24].

The incidence of VTE remained low (1.8% for DVT, 2.4% for PE, and 4.2% overall) in this study compared with other studies because of the policy-driven application of early thromboprophylaxis and satisfactory compliance. A systematic review reported that patients with trauma who received no prophylaxis had an overall

VTE incidence of 12%, and those who received only mechanical prophylaxis had a 7% incidence [25]. Other studies reported incidences of VTE after trauma of 4.6%–28% with prophylaxis [26–28] and up to 90% without prophylaxis [29,30]. Geerts et al [29] reported that DVT incidence in 349 patients with trauma was 58%; these cases were diagnosed by venography 1–3 weeks after admission, and patients received no prophylaxis. A recent Cochrane database review of 16 studies and 3,005 patients concluded that prophylaxis reduced the risk of VTE (mechanical: risk ratio [RR], 0.43 [95% CI, 0.25–0.73]; pharmacologic: RR, 0.48 [95% CI, 0.25–0.95]; both approaches: RR, 0.34 [95% CI, 0.19–0.60]) [25].

None of the patients in this study with PE had DVT. A weak association exists between the incidence of DVT and PE. PE in trauma is difficult to predict and is not associated with traditional risk factors. Studies have shown that patients with trauma who develop PE may not have evidence of lower-extremity thrombosis [24,31–34]. Whether the risk factors for PE differ from those associated with DVT in injured patients is not well studied. Independent risk factors for DVT in trauma include a delay of > 48 H in prophylaxis after injury. Conversely, independent risk factors for PE include male gender and serum lactate level > 5 mmol/L [33, 34]. Some studies have suggested that early PEs identified on imaging may result from severe chest trauma rather than an actual thromboembolic event [35,36]. Another study showed that long bone fractures, admission to the general ward, and female gender were associated with early PE (< 96 h) [37]. Major surgery within 48 h and severe brain and chest injury have been related to delayed PE [35–37].

The small cohort of patients was a limitation of this study. The study included consecutive patients during the study period from the most active trauma center in the country. However, the study would have had more strength if baseline data about the incidence of DVT and/or PE (nonfatal and fatal) were known before the risk assessment tool was used. Polytrauma often induces coagulopathy [38]. Trauma-induced coagulopathy remains one of the most diagnostically and therapeutically challenging conditions. Elevated D-dimer is also common after acute trauma [39]. Therefore, levels of fibrinogen and D-dimer as baseline investigations would have been beneficial to this study. Although only 169 patients with polytrauma underwent Doppler ultrasound, we attempted to develop a model to improve the patient outcomes after trauma.

Conclusions

The incidence of DVT in patients with polytrauma remained low in this small series. Reasons include the mandatory VTE risk assessment for all hospitalized patients and the early initiation of prophylaxis. DVT events despite prophylaxis reflect questions about the preventability of post-injury DVT. Diagnosis of PE in patients with trauma depends on a high index of clinical suspicion and the presence of clinical signs or symptoms, even in the absence of DVT. Traditional anticoagulation and/or mechanical prevention may not be adequate to prevent VTE in injured patients. Consideration should be given to more innovative options (eg, low-dose apixaban). We also recommend using a trauma center registry to measure DVT and PE incidence regularly to improve trauma care quality.

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PART 6

In-Hospital Trauma System: Outcomes

CHAPTER 15

Is case triaging a useful tool for emergency surgeries? A review of 106 trauma surgery cases at a level 1 trauma center in South Africa

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Abstract

Background

The optimal timing for emergency surgical interventions and implementation of protocols for trauma surgery is insufficient in the literature. The Groote Schuur emergency surgery triage (GSEST) system, based on Cape Triaging Score (CTS), is followed at Groote Schuur Hospital (GSH) for triaging emergency surgical cases including trauma cases. The study aimed to look at the effect of delay in surgery after scheduling based on the GSEST system has an impact on outcome in terms of postoperative complications and death.

Methods

Prospective audit of patients presenting to GSH trauma center following penetrating or blunt chest, abdominal, neck and peripheral vascular trauma who underwent surgery over a 4-month period was performed. Post-operative complications were graded according to Clavien-Dindo classification of surgical complications.

Results

One-hundred six patients underwent surgery during the study period. One-hundred two (96.2%) cases were related to penetrating trauma. Stab wounds comprised 71 (67%) and gunshot wounds (GSW) 31 (29.2%) cases. Of the 106 cases, 6, 47, 40, and 13 patients were booked as red, orange, yellow, and green, respectively. The median delay for green, yellow, and orange cases was within the expected time. The red patients took unexpectedly longer (median delay 48 min, IQR 35–60 min). Thirty-one (29.3%) patients developed postoperative complications. Among the booked red, orange, yellow, and green cases, postoperative complications developed in 3, 18, 9, and 1 cases, respectively. Only two (1.9%) postoperative deaths were documented during the study period. There was no statistically significant association between operative triage and post-operative complications ($p = 0.074$).

Conclusion

Surgical case categorization has been shown to be useful in prioritizing emergency trauma surgical cases in a resource constraint high-volume trauma center.

Background

Trauma is an epidemic in South Africa [1]. The significant number of our emergency general surgical cases is injury related. These are potentially life-threatening, and urgent surgical intervention is required to reduce mortality and morbidity.

Emergency surgical cases are admitted to health institutions in an unplanned and unscheduled manner. Patients usually present with acute surgical conditions that require prompt and focused treatment to avoid increased morbidity and mortality. Currently, no specific national or provincial guidelines exist in South Africa for the categorization or triaging of emergency surgical cases. In the current climate of shrinking elective theater time and increasing surgical waiting time, the present focus is to decrease waiting times by addressing issues that have a detrimental effect on overall theater efficiency. However, emergency surgical caseloads form a significant and increasing percentage of all patients utilizing theater facilities. Finding ways to manage better this category of patients should result in more efficient utilization of available theater time without impinging on the throughput of cases on elective slates. Given this, a policy document or guideline was introduced at Groote Schuur Hospital (GSH) for use in the categorization and prioritization of emergency surgical cases before operative surgical management. At GSH, the Groote Schuur emergency surgery triage (GSEST) system is based on similar principles to the Cape Triaging Score (CTS) [2]. The color coding categories are similar, but the definitions and emphasis relating to levels of surgical acuity, and urgency for operative intervention differ. The surgical team admitting a patient after consultation with the anesthetist handles the initial categorization of the case.

The study aimed to look at the effect of delay in surgery after scheduling based on the GSEST system has an impact on outcome in terms of postoperative complications and death.

Methods

The University of Cape Town (UCT) Human Research Ethics Committee (HREC) approved the study. We conducted a descriptive, non-interventional, observational study based on the prospective analysis of data collected during 1 December 2013

to 31 March 2014. All adult (age > 13 years) acute trauma admissions presenting with penetrating or blunt chest, abdominal, neck, and peripheral vascular injury who underwent surgery were included. Burns, isolated head, orthopedic, hand, and maxillofacial trauma patients were excluded as the respective specialties managed these patients. Collected data included: patient demographic details, mechanism of injury, time of injury, Injury Severity Score (ISS), time of booking the case, triage color code, the delay from scheduling to the start of the case, reasons for the delay, and outcome regarding postoperative complications and death.

Emergency cases were scheduled according to priority as red, orange, yellow, and green for operation (Table 1). Prioritization was done by the attending trauma surgeon based on patient's hemodynamics after discussion with the anesthetist.

Table 1. Groote Schuur emergency surgery triage (GSEST) system

Icon	Case category	Parameters
Red	Immediate	Immediate life-saving operation, resuscitation simultaneous with surgical treatment, e.g., resuscitative laparotomy, ruptured aortic aneurysm threatened airway, cord prolapse, fetal bradycardia
Orange	Expedited	Operation as soon as possible after resuscitation (within 1 to 2 hours), e.g., ruptured ectopic pregnancy, leaking aortic aneurysm, cranial decompression, positive DPL in multiple traumas, threatened limb, emergent fetal concern
Yellow	Urgent	Operation within 6 h of booking, e.g., compound fractures, appendicitis, incarcerated hernia/intestinal obstruction, EUA for non-accidental injuries
Green	Emergent	Operation not immediately life or limb saving but have to be done within 24 h of booking, e.g., ORIF of simple fractures, bleeding hemorrhoids, I&D abscess
Blue	Scheduled	Semi-urgent cases, to be done within 72 h. Operation during in hours on next available slate if possible

The red cases are an immediate priority (resuscitation with immediate operation cases). These cases usually present with hemorrhage or bleeding, requiring instant, life-saving surgical hemostasis. The orange categories are a very urgent priority (potentially life/limb threatening pathology) that should be done within 2 h. The yellow groups are an urgent priority (significant pathology) that should be done in 6 h, and the green cases are a delayed priority (minor injury/illness) that should be done within 24 h. Green cases become yellow after 24 h. Yellow cases become orange after 6 h. Booked cases are assessed on an ongoing basis and re-categorized as required. Post-operative complications were categorized according to the updated Clavien-Dindo classification of surgical complications [3, 4].

Categorical variables were evaluated using frequency tables. Associations between categorical variables were determined by contingency tables and chi-square tests of association. Numerical variables were evaluated with summary statistics (median, interquartile range, etc.). Relationships between numerical and categorical variables were determined using non-parametric tests: Mann-Whitney in instances where the categorical variable has two categories and Kruskal-Wallis otherwise. A p-value of < 0.05 was considered as statistically significant.

Results

One-hundred six patients underwent surgery during the study period with a higher male to female ratio of 14:1. The median age was 26 (IQR 22–32) years. One-hundred two (96.2%) cases were related to penetrating trauma. Stab wounds comprised 71 (67%) and gunshot wounds (GSW) 31 (29.2%) cases. On presentation 82 (77.4%), patients were admitted with ISS of greater than 15 (5–48). Trauma surgical procedures included laparotomy (48), vascular (27), subxiphoid pericardial window (13), thoracotomy (4), and sternotomy (1). There were also 13 other relatively non-urgent procedures such as debridement, removal of Foley's cath used for penetrating neck wound tamponade, skin grafting for fasciotomy wounds, etc. Of 106 cases, 6, 47, 40, and 13 cases were booked as red, orange, yellow, and green, respectively. The median delay for green, yellow and orange cases was within expected time. The red patients took unexpectedly longer (median delay 48 min, IQR 35–60 min) to reach the theater (Table 2).

Table 2. Operative triage vs. delay (min) from booking to operation

Red	Immediate	6	48	35–60
Orange	< 2 h	47	120	53–185
Yellow	< 6 h	40	213	113–300
Green	< 24 h	13	110	65–265

The main (49.1%) reason for the delay in starting the trauma cases was a priority of another emergency (general surgical, gynecological, etc.) booked in that category. Out of six red cases, three were delayed due to unavailability of theater or unable to open an additional theater immediately at that moment (Table 3). One red patient died who presented with a thoracic GSW was unstable on presentation and needed an emergency room thoracotomy and delay to shift to the theater was 55 min after booking.

Table 3. Operative triage vs. Reasons for the delay

Cause	Red (N)	Orange (O)	Yellow (Y)	Green (N)	Total (N) (%)
No theater available	3	26	11	2	42 (39.6%)
Priority of other case	0	16	26	10	52 (49.1%)
Delay in shift to theater	3	5	3	1	12 (11.3%)
Total	6	47	40	13	106 (100%)

N Number of patients

Thirty-one (29.3%) patients developed postoperative complications (Table 4). Among the booked red, orange, yellow, and green cases, postoperative complications developed in 3, 18, 9, and 1 cases, respectively (Table 5). There was no statistically significant association between operative triage and post-operative complications ($p = 0.074$).

Table 4. Types of complications according to Clavien-Dindo classification

I	Wound sepsis (5), Ileus (1)
II	Pneumonia (1)
IIIa	Loculated haemothorax (1)
IIIb	Empyema of chest (3)
IVa	Acute kidney injury (6), respiratory failure (9)
IVb	Multiorgan dysfunction (3)
V	Death (2)
Total	31

Table 5. Operative triage vs. complications (yes/no)

Color code	Complications	No complications	Total
Red	3	3	6
Orange	18	29	47
Yellow	9	31	40
Green	1	12	13
Total	31	75	106

Discussion

Emergency surgical cases differ from elective cases that are planned. During planned or elective operation the length of surgery, hospital stay, and morbidity and mortality can be predicted or inferred. Conversely, emergency surgical cases present in an unpredicted fashion. Prompt, efficient and appropriate treatment of emergency surgical cases is a cost-effective strategy that has the potential to reduce the length of hospital stay, use of high care and intensive care facilities as well as the use of laboratory and other investigative procedures.

The concept of triage is imperative to manage multiple emergency cases with competing and diverse needs. Deficiency of a triage system leads to longer waiting times, poor clinical risk assessment, and management with subsequently

increased morbidity and mortality [2]. An efficient triage system minimizes the risk to the patient and promotes effective use of available resources. The rationale and practice of triaging in mass casualty incidents are accepted worldwide [5]. Different triage systems exist for prehospital assessment and in-hospital casualty triage [6,7,8], yet no widely accepted methods exist for theater bookings. Triage systems should be implemented for the care of surgical emergencies [5] including trauma surgery. Early management of trauma cases is pertinent, as a delay to operative management may increase the risk of adverse outcomes [9].

Triaging of emergency surgical cases were introduced at GSH for the categorization and prioritization of emergency surgical cases at the point of contact with the surgical team before the operative surgical management of a patient. The objective is to improve communication and teamwork between anesthetic, surgical, and nursing personnel involved in the care of these patients.

Limitations

It is an observational study of a small number of trauma cases over 4-month period. The GSEST system describes the emergencies of all kinds including obstetric and gynecological. There are a few general surgical trauma diagnoses are included. It would be useful to have few more parameters perhaps in a separate column, e.g., what general surgical trauma diagnoses fit into the different category?

Future directions

Every minute is essential for the severely injured trauma patient. Delays at any stage from the scene to the operating theater may impact negatively on the outcome regarding complications and death [9]. Triaging is a crucial element for such cases. A more extensive comparative research is required before and after the introduction of GSEST system to look at the effectiveness including over- and under-triage rate, accuracy, likelihood ratios, etc.

Conclusion

Emergency trauma surgical cases vary in degree of acuity and complexity. Categorization allows the surgical and anesthetic teams to plan perioperative optimization and prioritize treatment of patients based on their clinical status and expected a progression of the disease. Assessing the South Africa's excessive rate of penetrating wounds needing an emergency operation, it is of utmost importance to create, implement, use, and disseminate national guidelines and standard for these to improve outcomes and life losses.

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CHAPTER 16

Contemporary damage control surgery outcomes: 80 patients with severe abdominal injuries in the right upper quadrant analyzed

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Abstract

Background

Damage control laparotomy (DCL) is a well-established surgical strategy in the management of the severely injured abdominal trauma patients. The selection of patients by intra-abdominal organs involvement for DCL remains controversial. The aim of this study was to assess the injury to the abdominal organs that causing severe metabolic failure, and needing DCL.

Methods

Severely injured abdominal trauma patients with a complex pattern of injuries were reviewed over a 52-month period. They were divided into DCL and definitive repair (DR) group according to the operative strategy. Factors identifying patients who underwent a DCL were analyzed and evaluated.

Results

Twenty-five patients underwent a DCL, and 55 patients had DR. Two patients died before or during surgery. The number and severity of overall injuries were equally distributed in the two groups of patients. Patients who underwent a DCL presented more frequently hemodynamically unstable ($p = 0.02$), required more units of blood ($p < 0.0001$) and intubation to secure the airway ($p < 0.0001$). The onset of metabolic failure was more profound in these group of patients than DR group. The mean Basedeficit was −7.0 and −3.8, respectively, ($p = 0.003$). Abdominal vascular ($p = 0.001$) and major liver injuries ($p = 0.006$) were more frequently diagnosed in the DCL group. The mortality, complications ($p < 0.0001$), hospital ($p < 0.0001$), and ICU stay ($p < 0.009$) were also higher in patients with DCL.

Conclusion

In severely injured with an intricate pattern of injuries, 31% of the patients required a DCL with 92% survival rate. Severe metabolic failure following significant liver and abdominal vascular injuries dictates the need for a DCL and improves outcome in the current era.

Introduction

Damage control laparotomy (DCL) is useful for a subset of abdominal trauma patients. The patients with gunshot wounds to the abdomen and significant blunt abdominal trauma who present with hemodynamic instability, acidosis, and coagulopathy are likely to benefit from a DCL [1–5]. This approach resulted in improved survival of critically injured and shocked patients based on the retrospective case series and when compared with historical controls (Table 1). However, there is concern about the lack of research relating to the indications and timing for a DCL [6].

The liver is the most commonly injured organ following abdominal trauma [24]. The mortality associated with severe isolated hepatic injury is 10% which reaches up to 70% with associated three or more major organ injury [25, 26]. An early decision is crucial to initiate a DCL after rapid assessment of internal injuries and before severe metabolic failure has set in [27]. But concern has been expressed about identifying patients who might benefit from a damage control approach and patients who could tolerate definitive repair (DR) of the injuries [28, 29]. An appropriate selection for DCL is critical to decreasing morbidity, and unnecessary use of hospital facilities and expenses.

We compared two groups of patients with major abdominal injuries who were selected for a DCL and who were treated with DR of injuries. The aim of this study was to assess the injury to the abdominal organs causing severe metabolic failure, needing DCL.

Table 1. DCL criteria in patients with major blunt or penetrating abdominal trauma

Criteria for damage control laparotomy
Complex pattern of injuries [4,5,7,8]
Operating time definitive repair of injuries >60-90 min [7-9]
Initial hypothermia: T <350C [10-13]
Initial acid-base status: PH <7.2; Base deficit >10-15; lactate >5 mmol/L [12-16]
Non-surgical bleeding, onset of coagulopathy [17-20]
Transfusion requirements >10 units of packed red blood cells [18,19, 21-23]

Methods

Major abdominal trauma was defined as two or more organs injured in the right upper quadrant (RUQ) of the abdomen in patients with an injury severity score (ISS) of >15 [30] and abbreviated injury score (AIS) (Abdomen) of ≥3 [31]. These patients were identified from a prospective trauma database during September 2008 to December 2012 at a level 1 trauma centre of Groote Schuur Hospital and included in the study for retrospective analysis. Patients with a single injury to the RUQ, ISS of <15, AIS < 3 or patients who died during surgery were excluded.

Outcome

The primary outcome was survival to discharge. The secondary outcome was morbidity defined as general, and organ-specific complications, duration of intensive care (ICU), and hospital stay in days. Complications were graded by using the Clavien-Dindo grading system for the classification of surgical complications [21].

Grading of injuries

Intra-abdominal injuries were graded according to the Organ Injury Scale of the American association of surgery for trauma (AAST) [32]. High-grade of injuries were considered to be grade 3 to 5.

Operative management

Following an initial resuscitation according to the principles of the Advanced Trauma Life Support (ATLS®) [33], the physiological parameters were documented. Potential candidates for a DCL were non-responders to shock management, hypothermia, onset of metabolic failure, or a combination of these. Metabolic failure was defined as worsening metabolic acidosis (Base deficit), with or without coagulopathy (non-mechanical bleeding). Indications for surgery were hemodynamic instability, peritonitis or CT findings suggestive

of bowel injury requiring surgical repair. Operative management included DR of injuries or DCL. It was based on the institutional and definitive surgical trauma care (DSTC®) guidelines [34]. A DCL was defined as a limited operation for control of hemorrhage and contamination, secondary resuscitation in the ICU and DR during a reoperation. The decision to perform or to convert to a DCL was based on the preoperative physiological status, the severity of abdominal injuries and estimated time for repair of intra-abdominal injuries exceeding total operating time >60–90 min. A massive fluid resuscitation, a decrease in base deficit after hemorrhage control, and the use of inotropes to improve hemodynamics were indications for conversion to a damage control strategy.

When severe shock, hypothermia, acidosis, and massive transfusion have led to coagulopathy and diffuse non-mechanical bleeding, the intra-abdominal cavity was packed. Patients with intra-abdominal packing were managed with an open abdomen. Emergency reoperation was undertaken for the development of abdominal compartment syndrome or failure to attain the endpoints of resuscitation due to continuous hemorrhage. Treatment of complications was multidisciplinary when appropriate and included endovascular, endoscopic, and interventional CT or ultrasound guided drainage.

Ethics

Ethics approval was granted from the human research ethics committee (HREC) of the faculty of health sciences of the university of Cape Town with a reference number of 048/2007.

Statistics

Results were presented as number (%) or as IQR. Patient groups were compared using the Pearson's chi-squared test or Fisher's exact test for categorical variables, and the Mann–Whitney test for non-normally distributed data. Statistical analysis was performed using statistical software (SPSS Inc, Chicago, IL,version 20). P values of <0.05 were considered to be statistically significant.

Results

Four hundred and twelve patients were diagnosed with a liver injury following RUQ abdominal trauma during the study period. One hundred and ninety-four patients were selected for non-operative management. Two hundred and eighteen patients with a liver injury underwent surgery. Eighty-two (38%) patients with a complex pattern of injuries were identified. Figure 1 presents a management flowchart of all patients with abdominal trauma and a concomitant liver injury.

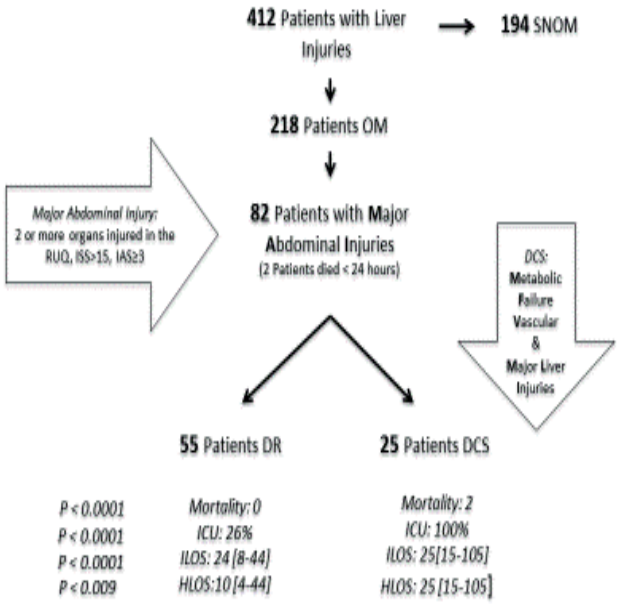

Figure1. Management flowchart patients with abdominal trauma and a concomitant liver injury. SNOM Selective non-operative management, OM operative management, RUQ right upper quadrant, ISS injury severity score, AIS abdominal injury score, DCS damage control surgery, DR definitive repair, ILOS intensive care unit length of stay, HLOS hospital length of stay

Two patients died during or before the operation and were excluded for further analysis. Eighty patients (Men 73, women 7, the mean age of 26 with a range of 13–57 years) who survived more than 24-h were included and further analyzed. Eleven (14%) patients sustained blunt trauma and 69 (86%) penetrating, of which

7 (10%) and 62 (90%) sustained stab wounds and gunshot wounds, respectively. The median ISS was 21 (IQR 16–32).

In 80 patients, 108 high-grade of injuries in the RUQ of the abdomen were diagnosed, liver (46), extrahepatic biliary tract (2), major vascular (12), right kidney (26), duodenum (10), and pancreas (12). Other associated intra-abdominal injuries diagnosed were stomach (21), diaphragm (15), small bowel (26), colon (17), spleen (13), left kidney (13), ureter (5), bladder (4), vascular (10), and pelvic fractures (4). Thirty-four (42.5%) patients had isolated abdominal injuries. Forty-six (58%) patients sustained injuries in body regions other than the abdomen, included head and neck (9), face (5), thorax (36), and extremities (18).

Table 2. Types of surgical procedures in 25 patients who underwent a DCL

Surgical procedures	N
Perihepatic packing	20
Inferior vena cava packing	4
Drainage of laceration of the common bile duct	2
Kidney packing	3
Duodenal primary repair	3
Nephrectomy	6
Infrarenal inferior vena cava ligation	2
Distal pancreatectomy	3
Colon ligation	5
Small bowel ligation	1

The indications for surgery were hemodynamic instability in 17 (21%) patients, an acute abdomen in 56 (70%) patients, and 7 (9%) patients had CT findings of intra-abdominal injuries that required surgical repair. Fifty-five (69%) patients had DR of their injuries, and 25 (31%) patients underwent a DCL. The operative procedures in 25 patients who underwent a DCL are presented in (Table 2), and the postoperative general and organ-specific complications are presented in (Table 3).

Table 3. Complications among 25 patients who underwent DCL

Clavien-Dindo classification of postoperative complications	N
I: Any deviation from the normal postoperative course	18
II: Requiring pharmacological treatment with drugs	29
III a: Requiring surgical, endoscopic, or radiological intervention not under general anesthesia	11
III b: Requiring surgical, endoscopic, or radiological intervention under general anesthesia	10
IV a: Life-threatening complication requiring ICU management with single organ dysfunction	25
IV b: Life-threatening complication requiring ICU management with multiple organ dysfunction	7
V: Death of a patient	2
Total complications	102

The magnitude of injuries

The higher ISS, major abdominal vascular injuries, and more high-grade liver injuries were diagnosed in patients who underwent a DCL (Table 4).

Table 4: General patient's characteristics and magnitude of injuries

	DR	DCL	*P* value
	N = 55 (69%)	*N* = 25 (31%)	
Sex, *N* (%)			
M	51 (93%)	22 (88%)	0.67
F	4 (7%)	3 (12%)	
Age in years	25	30	0.03
Mechanism, *N* (%)			
Blunt	7 (13%)	4 (16%)	0.73
Penetrating	48 (87)	21 (84%)	
Gunshot wound	42/48 (87%)	20/21 (95%)	0.43
Stab wound	6/48 (13%)	1/21 (5%)	
Injury severity score	19	26	0.002
High-grade liver injury, *N* (%)	26/55 (47%)	20/25 (80%)	0.006[a]
Abdominal vascular injury, *N* (%)	9 (16%)	13 (52%)	0.001[b]
Extrahepatic biliary tree injury, *N* (%)	3 (5%)	2 (8%)	1.00
Pancreatic injury, *N* (%)	20 (36%)	11 (44%)	1.00
Duodenal injury, *N* (%)	14	5	1.00
Right kidney injury, *N* (%)	28	10	0.45
Bowel injury, *N* (%)	22 (40%)	11 (44%)	0.74
Abdominal injuries, *N* (%)			
3 organs	14 (25%)	2 (8%)	0.16
4 organs	11 (20%)	9 (36%)	
5 organs	17 (31%)	6 (24%)	
>5 organs	13 (24%)	8 (32%)	

DR Definitive repair, *DCL* damage control laparotomy, *N* = Number

[a]Odds ratio 4.46 (95% confidence interval 1.47–13.59)

[b]Odds ratio 5.54 (95% confidence interval 1.92–16.00)

The physiological status

Patients who required a DCL presented more often with hypotension, required more frequently intubation to secure the airway and had received more units of blood products transfusion. The DCL group also had more profound metabolic acidosis than DR group (Table 5).

Table 5. Physiological parameters in 80 patients with severe abdominal trauma comparing patients undergoing DR versus DCL

	DR	DCL	*P* value	Odds ratio
	N = 55 (69%)	*N* = 25 (31%)		(95% CI)
Blood pressure < 90 mmHg on admission, *n* (%)	3 (5)	6 (24)	0.02	5.47 (1.24–24.10)
Intubation on admission, *n* (%)	8 (15)	16 (64)	<0.0001	10.44 (3.45–31.65)
Glascow Coma Scale ≤ 8 on admission, n (%)	1(2)	3 (12)	0.09	7.36 (0.73–75.69)
Hemoglobin in gm/dl, mean (SD)	11 (2)	10 (3)	0.06	
pH, mean (SD)	7.34 (0.09)	7.28 (0.08)	0.01	
Lactate in mmol/L, mean (SD)	2.6 (2.1)	3.9 (2.8)	0.03	
Base deficit, mean (SD)	−3.8 (4.0)	−7.0 (4.9)	0.003	
Metabolic failure (base excess ≤−5), *n* (%)	20 (36)	17 (68)	0.009	3.72 (1.36–10.15)
Blood transfusion *n* (%)	18 (33%)	21 (84%)	<0.0001	10.79 (3.22–36.14)
Units of blood, median, range	0 (0–7)	4 (0–12)	<0.0001	

DR Definitive repair, *DCL* damage control laparotomy, *n* number, *SD* standard deviation, *CI* confidence interval

Outcome

Patients who underwent a DCL had an increased mortality (8% vs. 0%), more postoperative general, liver-related and duodenal complications. Hospital stay and the number of patients requiring ICU and ICU stay were also higher in patients who had a DCL (Table 6).

Table 6. Morbidity in 80 patients undergoing DR versus DCL

Morbidity	DR [*N* = 55 (69%)]	DCL [*N* = 25 (31%)]	*P* value
Patients with general complications	27 (49%)	24 (96%)	<0.0001[b]
Hospital stay in days	10 (4–44)	25 (15–105)	<0.0001[b]
Patients requiring ICU	14 (26%)	25 (100%)	<0.0001[c]
ICU stay in days	24 (8–44)	25 (15–105)	0.009[b]
Mortality	0 (0%)	2 (8%)	0.10[a]

DR Definitive repair, *DCL* damage control laparotomy

[a]Data were analyzed with a Pearson Chi-squared analysis

[b]Fisher's exact test

[c]Mann–Whitney test

Deaths

Two patients died during hospital stay (at day 12 and day 15). The first patient was a 35-year-old male who sustained multiple gunshot wounds (abdominal, groin and buttocks and extremities). This patient had a Gr V liver, and right kidney injury. A nephrectomy was performed, and the bleeding from liver was controlled with packing. Despite the control of surgical bleeding, this patient developed severe abdominal sepsis and required multiple relook laparotomies. Eventually, this patient died due to multi-organ failure on day 15.

The second patient was a 23-year-old male who sustained an abdominal gunshot wound and precordial stab. This patient had an open skull fracture and thoracoabdominal injury. An exploratory laparotomy and sternotomy were performed. A cardiac injury, diaphragm injury, grade 5 liver injury, pancreatic and gastric injury were identified. Despite the control of bleeding with packing, this patient developed abdominal sepsis and died due to multi-organ failure on day 15 of post-injury.

Discussion

Definitive organ repair cannot be undertaken safely in a patient with a critical physiological status. These patients are more likely to die from their intra-operative metabolic failure than they are from the failure to complete organ repairs. Hypotension on admission, intubation on admission, requiring more units of blood transfused during resuscitation and presenting with a severe metabolic acidosis, abdominal vascular and high-grade liver injuries dictated the need for a damage control strategy in patients with major abdominal trauma evaluated in our study. Since the introduction of damage control surgery, it has been accepted that patients with severe injury and physiological derangements are selected for a DCL [3–5, 26, 35]. On the other hand, DCL should not be performed in patients who can tolerate DR of the injuries, causing an increase in morbidity and subsequent increase in the use of hospital facilities and costs [27, 28].

In liver trauma, packing has been a well-accepted surgical technique to control bleeding [26]. In patients with a complex pattern of injuries, control of bleeding is essential, and the severity of trauma and physiological derangements influence the decision to pack and delay definitive organ repair. The first step is the recognition of patients in the resuscitation room likely to need a DCL. The second step is to perform an exploratory laparotomy and to make a quick decision whether the patient needs a DCL or can tolerate DR. After control of bleeding, a rapid assessment to classify the severity of trauma and estimate the time required for definitive repair. At this stage, timing to initiate DCL is depending on physiological status or metabolic derangement. Previous studies have demonstrated that changes in core temperature, acidosis, and coagulation are essential, and initial preoperative temperature, PH, BE, transfusion requirements,

and hemodynamic status are also important to make a decision for DCL (Table 1). The role of postoperative angiography described in this study is limited. Due to an active surgical management policy with ligation of visible vessels in case of liver trauma, rendered early postoperative angiography rarely necessary. In this study, postoperative angiography was not performed routinely. Although many arterial bleeders are deep in parenchyma and do not manifest clearly at laparotomy other authors recommend as the appropriate strategy to proceed with a postoperative angiography in the angiosuite after DCL for complex liver injury [26]. Although there is no consensus on a validated definition of "severely injured" patients, in this study, we defined patients who sustained a complex pattern of injuries involving three or more organs in the RUQ of the abdomen with AIS > 3, and ISS > 15 as severely injured [17].

This study was performed in a busy level 1 trauma centre. The rate of DCL in this group of patients was 31% that is much higher comparing to the 6–18% described in the literature [36]. We did not feel we over triaged patients requiring a damage control laparotomy. The reason for a higher rate is most likely due to the selection of patients who sustained major abdominal trauma to the RUQ. The overall mortality in patients undergoing DCL was 8%. In the literature, the mortality rates for DCL varies from 26 to 67% [17]. Mortality following penetrating abdominal trauma is 10%, whereas mortality following severe blunt abdominal exceeds 40% [24]. Due to high interpersonal violence in Cape Town, the majority (84%) of the patients present with penetrating abdominal trauma than blunt trauma. It may explain a lower overall mortality rate in our study comparing with the literature. However, all patients who were selected for DCL and reached to the operating room had an 92% survival.

While the number of patients in this prospective series of severely injured patients with a complex injury pattern is low, comparison of small groups in this paper using significance testing needs to be interpreted in the light of the very low power to detect statistically significant differences. A clinical interpretation and familiarity with surgical strategies and techniques taught in the DSTC® or similar course have to be considered during comparisons and not just a statistical description. While an increase in the incidence of patients who undergo DCL has been noted, we should be aware of the rise in morbidity in patients who unnecessarily suffer a DCL. Despite reports of increased survival after the introduction of DCL and

implementation of a damage control strategy in the field of emergency surgery [1, 2], few authors conclude that evidence that supports the safety and efficacy of damage control is limited [36]. They call for the need of randomized controlled trials (RCT). An RCT would be confronted with the same dilemma, at the first overuse of DCL in patients who could also tolerate DR, or vice versa an increase in mortality or morbidity in patients who are selected for DR.

In conclusion, the current study did focus on criteria for selection of patients with severe abdominal injuries in the right upper quadrant of the abdomen who might benefit from DCL. 31% of the severely injured patients with a complex pattern of injuries required a DCL with 92% survival rate. A moderate onset of metabolic failure or hypotension on arrival is not a precise indication to perform a DCL. The onset of severe metabolic failure following major liver and abdominal vascular injuries dictates the need for a DCL with improved outcomes in the current era.

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CHAPTER 17

Comparison of trauma management between two major trauma services in Riyadh, Kingdom of Saudi Arabia and Melbourne, Australia

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Abstract

Introduction

The burden of injury in the Kingdom of Saudi Arabia (KSA) has increased in recent years, but the country has lacked a consistent methodology for collecting injury data. A trauma registry has been established at a large public hospital in Riyadh from which these data are now available.

Objectives

We aimed to provide an overview of trauma epidemiology by reviewing the first calendar year of data collection for the registry. Risk-adjusted analyses were performed to benchmark outcomes with a large Australian major trauma service in Melbourne. The findings are the first to report the trauma profile from a centre in the KSA and compare outcomes with an international level I trauma centre.

Methods

This was an observational study using records with injury dates in 2018 from the registries at both hospitals. Demographics, processes and outcomes were extracted, as were baseline characteristics. Risk-adjusted endpoints were inpatient mortality and length of stay. Binary logistic regression was used to measure the association between site and inpatient mortality.

Results

A total of 2436 and 4069 records were registered on the Riyadh and Melbourne databases, respectively. There were proportionally more men in the Saudi cohort than the Australian cohort (86% to 69%). The Saudi cohort was younger, the median age being 36 years compared with 50 years, with 51% of injuries caused by road traffic incidents. The risk-adjusted length of stay was 4.4 days less at the Melbourne hospital (95% CI 3.95 days to 4.86 days, $p<0.001$). The odds of in-hospital death were also less (OR 0.25; 95% CI 0.15 to 0.43, $p<0.001$).

Conclusions

This is the first hospital-based study of trauma in the kingdom that benchmarks with an individual international centre. There are limitations to interpreting the comparisons, however the findings have established a baseline for measuring continuous improvement in outcomes for KSA trauma services.

Introduction

The burden of traumatic injuries in the Kingdom of Saudi Arabia (KSA) has increased significantly in recent years, with road trauma being reported in 2017 as being the leading cause of premature death [1]. However, to obtain a complete epidemiological picture, it is important to understand that traumatic injuries also occur from other causes. Falls are reported as being the next most frequent cause of injury in the KSA [2,3]. Injury prevention strategies proposed in epidemiological studies previously focused on road safety initiatives [4,5] on which the kingdom has been working since the early 2000s [6]. Public health strategies to address other causes of injury seem to be limited. Strategies for burns and falls injuries had been suggested as priority areas to target prevention of paediatric trauma [7]. Dijkink et al [8] noted as recently as 2016 that, although classified as a high-income country, Saudi Arabia had only a level II trauma system, as measured by the WHO Maturity Index [9]. This meant that there was no organized method of using available injury data to inform clinical knowledge or quality improvement. A trauma registry would be the most efficient method for collating injury data and the benefits have long been recognised elsewhere [10-12]. The need to collect national trauma data in Saudi Arabia was acknowledged by the Ministry of Health (MOH) in 2014 with the planned national implementation of an electronic injury surveillance system [13]. Ongoing innovations in Saudi healthcare were detailed in Vision 2030 [14]. Improvements in the national trauma systems have now been initiated and have enabled the collection of trauma data that are available for use by the trauma community.

The aim of this study was to review the first full calendar year of data collected by a trauma registry to provide an overview of trauma epidemiology at a large Saudi Arabian public hospital; apply established performance indicators to establish a baseline from which to measure continuous improvement; and perform preliminary risk-adjusted analyses to benchmark outcomes with the largest Australian major trauma service situated in the state of Victoria. The findings are the first to report the major trauma profile from a single centre in the KSA and compare trauma outcomes with an individual international level I trauma centre.

Methods

Setting

In 2016, the largest MOH hospital in the kingdom, the King Saud Medical City (KSMC), situated in Riyadh, began a collaboration with the Alfred Hospital in Melbourne to improve the care of injured people. A key component of this project was the successful implementation of the Saudi TraumA Registry (STAR). Data collection commenced in August 2017 [15]. This registry was developed as a potential prototype of the kingdom's first national trauma registry. The STAR collected data from all patients who presented to the KSMC who met predetermined inclusion and exclusion criteria, which were strictly observed to ensure the cohort was within the population of interest. Inclusion criteria were patients who had presented to hospital as a result of acute physical injury(ies); had either died in the emergency department (ED) as a result of injury(ies); been admitted for greater than 2 calendar days; been admitted to the intensive care unit (ICU) or had died from injury(ies) following inpatient admission. The 83 variables in the dataset included 11 demographic fields, 12 relevant to the injury event, 58 reflecting the care provided at the KSMC including procedures performed, and 2 that described the injuries ((online supplemental file 1: Saudi TraumA Registry (STAR) Minimum Dataset V 4.0). The overall Injury Severity Score (ISS) of each case was derived from the Abbreviated Injury Scale (AIS) codes allocated by trained coders to each diagnosed injury [16]. The severity of each injury is assigned as one to six, that is: minor, moderate, serious, severe, critical and maximal. Any patient with an ISS of greater than 12, or who died as a consequence of their injuries, was coded on the database as major trauma [17], which was standardised in Australian/ New Zealand trauma registries following an AIS version update, to allow for historical cohort comparisons.

Methodology

All records with dates of injury from 1 January 2018 to 31 December 2018 inclusive were extracted from the STAR database. The records were extensively cleaned to optimize the quality of the analyses. The majority of errors that required correction were chronological; anomalous in that the information did not match other values within the record; and AIS coding errors where the description of the injury did not match the body region and/or the severity of the code. A series of error reports were submitted to the STAR team who amended the errors and

resubmitted the record for inclusion in the analyses. Edits built into the STAR database did not allow fields to remain empty. However, data collectors entered default or erroneous values in some cases, which were rectified where possible. Cases were excluded where there was insufficient information. The STAR trauma profile was analysed from all the records where injury event data had been entered. Patients aged less than 15 years were included to report overall patient demographics at the KSMC.

Two system indicators and five process indicators were analysed. These were presentation to at least one other hospital prior to admission to the KSMC or admission to the KSMC directly from the scene; direct admissions to the KSMC that were attended at the scene by a Saudi Red Crescent Authority (SRCA) ambulance; the length of time spent in the ED; length of stay (LOS) in the ICU; non-risk-adjusted LOS in hospital: median time to surgery, including the casemix of surgical procedures; and non-risk-adjusted outcomes. To enable benchmarking, we extracted data from the Alfred Hospital Trauma Registry (AHTR), which is a trauma epidemiology and performance monitoring programme that has collected trauma data at that site since July 2001. The Alfred Hospital, which is the source of the data, receives the highest number of adult major trauma patients in Australasia [18]. In 2019 the AHTR contributed to over 40% of the Victorian State Trauma Registry (VSTR) dataset, which collects data from every hospital and healthcare facility in the state. The AHTR is the model for the STAR and deploys the same inclusion criteria.

All records with dates of injury between 1 January 2018 and 31 December 2018 inclusive were extracted from the AHTR database. Baseline characteristics were determined from those records from each site that were identified as being complete and accurate enough to provide robust risk-adjustment analysis. The Alfred Hospital does not admit paediatric patients, therefore, for benchmarking purposes, all patients in the STAR database who were aged less than 15 years at the time of injury were excluded from those analyses.

The primary endpoints were inpatient mortality and LOS. Binary logistic regression was used to associate between site and inpatient mortality. Potential confounding variables assessed were gender, age group, injury cause, Glasgow Coma Score (GCS) arrival motor score, individual body components AIS scores and

ISS group. Starting from the most significant factor identified in the univariable analysis, we used the likelihood ratio test to evaluate whether inclusion of the next most significant variable helped improve the model fit. This was sequentially undertaken until all variables were evaluated. For LOS, we used quantile (median) regression to analyse the data since LOS was significantly positively skewed. We used a similar model selection process for inpatient mortality to build a multivariable model. Data analysis was undertaken in Stata V.16 (Stata Corp, College Station, Texas, USA). Level of significance was set at 5%.

Patient and public involvement

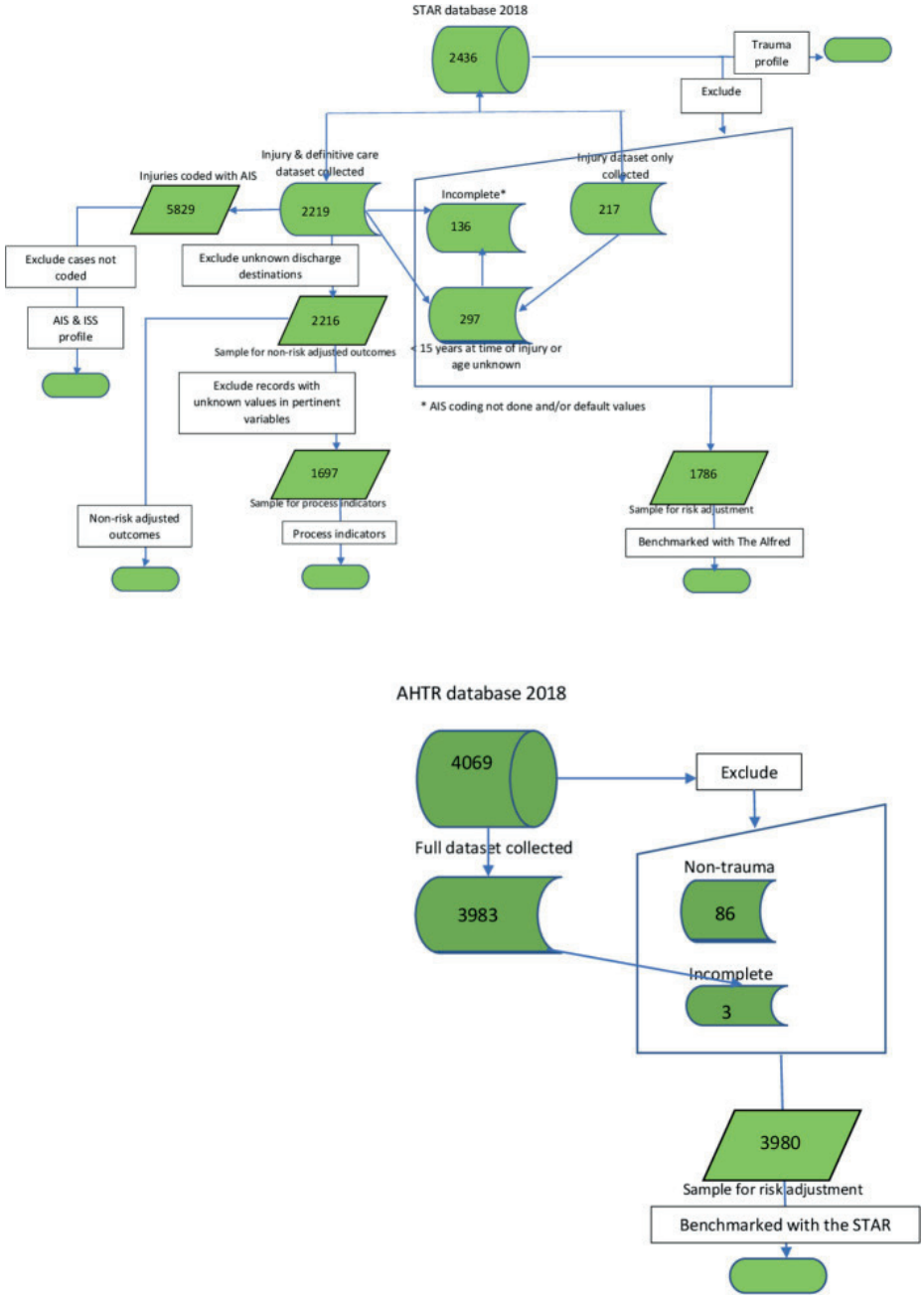
Patient consent was not obtained due to the low risk analyses of de-identified, aggregate data and waived accordingly by the ethics committees. The study design precluded the involvement of patients or the public in the reporting of our findings.

Results

In 2018, 2436 records of eligible patients were registered on the STAR database. The definitive care dataset was completed for 2219 records. The injury event dataset only was completed in 217 cases. A further 136 records were otherwise incomplete, with either AIS coding not done or default values entered. These records, and patients who were aged less than 15 years at the time of injury (n=295) or records with age unknown,2 were included in the trauma profile but were excluded from the risk-adjustment analysis. The risk-adjusted sample size was 1786 records (figure 1).

The AHTR included 4069 patients on its database in 2018. Of these, 3980 were included in the risk-adjustment analysis. Eighty-six records with no injuries identified and three records that were incomplete were excluded (figure 1).

Figure 1. Flow chart of inclusions and exclusions of STAR and AHTR data. AHTR, Alfred Hospital Trauma Registry; AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; STAR, Saudi TraumA Registry.



STAR trauma profile

The whole STAR cohort of 2436 records were analysed to obtain the trauma profile (table 1). The median age was 29 years with an IQR of between 20 and 44 years, including paediatric patients aged <15 years. Nationality was reported as Saudi for 60% of records. Overall, 85% of patients were men. Most injury events (92%) were of the 'blunt' type, 4% were penetrating trauma and 3% of cases were burns. One per cent of cases were classified as 'other', which included electrical injury suffocation and asphyxia. Seven records had an unknown cause of injury. Overall, 51% of all injuries were due to road traffic incidents. Of the 2219 records where the definitive care dataset was complete, seven patients did not have injury coding performed, due to either having died or having been discharged before any diagnoses were made. Of the remaining 2212 records, the majority (78%) had an ISS of less than or equal to 12. Five hundred and seven records (23%) were classified as major trauma, where the ISS was >12 or where the patient had died. These included records where no or minimal coding had been performed, but the patient was known to have died.

Table 1. STAR trauma and injury profile

Characteristic	N	%
Total records	2436	
- Saudi nationality	1463	60.1
Gender		
- Male	2074	85.1
- Females	362	14.9
Age in years at event; median (IQR)	29 (20-44)	
- 0 - 14 & unknown	297	12.2
- 15 – 24	596	24.5
- 25 – 40	896	36.8
- 41 – 60	414	17.0
- 61 – 70	89	3.7
- 71 – 80	82	3.4
- 81+	62	2.5
Type of injury		
- Blunt	2230	91.5
- Penetrating	97	4.0
- Burns	81	3.3

- Other	21	0.9
- Unknown	7	0.3
Cause of injury		
- Burns - all types	81	3.3
- Cause with systemic effect (drowning, suffocation, asphyxia and electrical injury)	11	0.5
- Falls - both high & low	865	35.5
- Motor vehicle occupants	852	35.0
- Motorcyclists	112	4.6
- Other specified external cause	48	2.0
- Pedal cyclist - rider or passenger	7	0.3
- Pedestrian	237	9.7
- Penetrating wounds incl gunshots & stabbing	97	4.0
- Struck by object or person	119	4.9
- Unspecified External Cause	7	0.3
Injury Severity Score range		
Total records	2219	
- 0	7	0.3
- ≤ 12	1734	78.1
- 13-25	401	18.1
- 26-40	64	2.9
- >40	13	0.6
Severity of individual injuries		
Total injuries coded	5829	
- Minor or severity unknown	565	9.7
- Moderate	3748	64.3
- Serious	1284	22.0
- Severe	152	2.6
- Critical	75	1.3
- Maximal	5	0.1
Trauma status		
- Major	507	22.8
- Non-major	1712	77.2

STAR, Saudi TraumA Registry.

Process and system indicators

A sample size of 1697 records had sufficient known values with which to analyse prespecified process and system indicators. Records with unknown values in the relevant variables were excluded (522). Almost one-quarter of patients (414, 24.4%) attended at least one other hospital prior to presentation to the KSMC. Of the 1283 patients (75.6%) who were admitted directly to the KSMC, 605 (47.2%) were known to have been attended at the scene by an SRCA ambulance. The median time spent in the ED was 7 hours and 16 min (IQR 4 hours 17 min–10 hours

Table 2. Characteristics of STAR and AHTR cohort

Characteristic	STAR	AHTR
Total records	1786	3980
Gender		
- Female	244 (13.7%)	1250 (31.4%)
- Male	1542 (86.3%)	2730 (68.6%)
Age in years at event; mean (SD)	36.2 (17.4)	49.8 (21.9)
Cause of injury		
- Burns - all types	49 (2.7%)	172 (4.3%)
- Cause with systemic effect (drowning, suffocation, asphyxia and electrical injury)	9 (0.5%)	28 (0.7%)
- Falls - both high & low	595 (33.3%)	1409 (35.4%)
- Motor vehicle occupants	664 (37.2%)	841 (21.1%)
- Motorcyclists	85 (4.8%)	360 (9.0%)
- Other specified external cause	35 (2.0%)	202 (5.1%)
- Pedal cyclist - rider or passenger	5 (0.3%)	276 (6.9%)
- Pedestrian	177 (9.9%)	215 (5.4%)
- Penetrating wounds incl gunshots & stabbing	81 (4.5%)	161 (4.0%)
- Struck by object or person	86 (4.8%)	306 (7.7%)
- Unspecified External Cause	0 (0.0%)	10 (0.3%)
Injury Severity Score range		
- <12	1365 (76.4%)	2609 (65.6%)
- 12-25	369 (20.7%)	1098 (27.6%)
- 26-40	45 (2.5%)	202 (5.1%)
- >40	7 (0.4%)	71 (1.8%)

Note: There was a statistically significant p value of < 0.001 in all categories.
STAR, Saudi TraumA Registry; AHTR, Alfred Hospital Trauma Registry.

54 min). The median LOS in the ICU for the 358 patients admitted therein was 9 days (IQR 4–17 days). The median non-risk-adjusted LOS in hospital was 8 days (IQR 4–14 days).

There were 2035 surgical procedures performed in the operating theatre on 1432 patients. Median time to surgery was 115 hours (IQR 32–243). Of these, 1362 (67%) were orthopaedic procedures including spinal fixations. Ninety-eight (5%) neurosurgical procedures were performed. The median time to theatre for initial craniotomies/craniectomies was 10 hours (IQR 7–21). Seventy-five (4%) laparotomies were performed. Thirteen thoracotomies and eight tracheostomies were performed, comprising only 1% of surgical procedures. There were 479 (24%) 'other' operations performed, including vascular surgery, skin grafts and soft tissue repairs. The discharge destination was known for 2216 records, and unknown for 3 records. The vast majority of patients were discharged home (88.5%). Other discharge destinations were to other hospitals for acute or convalescent care (2.7%); or patients who absconded or discharged against medical advice (5.2%). Seventy-seven patients died in hospital as a result of injury, which is a case fatality rate of 3.5% (95% CI: 2.7% to 4.3%) overall. The case fatality rate for major trauma was 15.2%.

Trauma profile comparison with the AHTR

The proportion of men (table 2) was higher at KSMC relative to the Alfred (86.3% compared with 68.6%). The mean age of STAR records at the time of injury was found to be 36 years compared with 50 years at the Alfred.

Length of stay

The risk-adjusted LOS (table 3) at the Alfred was 4.4 days less (95% CI 3.95 days to 4.86 days, $p<0.001$) than at the KSMC, adjusting for GCS on arrival, age and the severity of injuries.

Table 3. Risk adjusted length of stay

N = 5302	Coefficient (95% CI)	P-value
- KSMC	1.0	Reference
- Alfred	-4.40 (3.95 – 4.86)	<0.001
Glasgow Coma Score: motor function on arrival to the KSMC		
- Obeys command	1.0	Reference
- No movement	2.07 (1.01 – 3.03)	<0.001
- Extension to pain	2.68 (-0.19 – 5.54)	0.068
- Flexion to pain	15.79 (13.28 – 18.29)	<0.001
- Withdraws to pain	1.43 (-0.77 – 3.63)	0.202
- Localises to pain	1.55 (0.26 – 2.83)	0.018
ISS categories		
- <12	1.0	Reference
- 12-25	0.13 (-0.48 – 0.73)	0.681
- 26-40	2.06 (0.68 – 3.43)	0.003
- >40	3.43 (0.84 – 6.03)	0.009
Age at injury event (years)		
- 15-24	1.0	Reference
- 25-40	0.06 (-0.45 – 0.56)	0.824
- 41-60	0.37 (-0.16 – 0.89)	0.170
- 61-70	1.04 (0.35 – 1.73)	0.003
- 71-80	1.74 (1.04 – 2.43)	<0.001
- 81+	2.10 (1.40 – 2.80)	<0.001
Chest injury severity		
- No chest injury	1.0	Reference
- Minor	-0.12 (-1.00 – 0.76)	0.796
- Moderate	0.91 (0.22 – 1.61)	0.010
- Serious	1.69 (1.06 – 2.32)	<0.001
- Severe	4.35 (3.10 – 5.60)	<0.001
- Critical	3.35 (0.92 – 5.79)	0.007
Abdominal injury severity		
- No abdominal injury	1.0	Reference
- Minor	0.43 (-0.41 – 1.28)	0.313
- Moderate	1.83 (0.89 – 2.77)	<0.001
- Serious	2.40 (0.96 – 3.85)	0.001
- Severe	5.37 (3.86 – 6.88)	<0.001
- Critical	4.68 (1.22 – 8.14)	0.008

Spinal injury severity		
- No spinal injury	1.0	Reference
- Minor	1.40 (-0.38 – 3.18)	0.123
- Moderate	1.69 (1.24 -2.13)	<0.001
- Serious	2.84 (2.14 -3.54)	<0.001
- Severe	8.80 (6.61 -10.99)	<0.001
- Critical	9.97 (7.63 -12.32)	<0.001
- Maximal	-5.53 (-18.12 -7.06)	0.389
Upper limb injury severity		
- No upper limb injury	1.0	Reference
- Minor	-0.05 (-0.64 – 0.54)	0.871
- Moderate	1.14 (0.68 – 1.59)	<0.001
- Serious	4.26 (2.39 – 6.12)	<0.001
- Severe	2.23 (-6.53 – 10.99)	0.617
Lower limb injury severity		
- No lower limb injury	1.0	Reference
- Minor	-0.07 (-0.65 – 0.51)	0.814
- Moderate	2.45 (1.93 – 2.97)	<0.001
- Serious	5.30 (4.72 – 5.89)	<0.001
- Severe	7.88 (6.25 – 9.50)	<0.001
- Critical	6.28 (3.57 - 8.98)	<0.001
Other injury or burns severity		
- No other or burns injury	1.0	Reference
- Minor	-0.15 (-1.42 – 1.12)	0.821
- Moderate	3.62 (0.05 – 7.20)	0.047
- Serious	3.53 (0.19 – 6.87)	0.038
- Severe	14.87 (7.69 – 22.05)	<0.001
- Critical	0.41 (-2.98 – 3.80)	0.814
- Maximal	-5.50 (-18.11 – 7.12)	0.393
Head injury severity		
- No head injury	1.0	Reference
- Minor	0.05 (-0.58 – 0.68)	0.879
- Moderate	0.31 (-0.35 – 0.96)	0.361
- Serious	1.63 (0.93 – 2.34)	<0.001
- Severe	4.35 (3.27 – 5.43)	<0.001
- Critical	7.09 (5.53 – 8.65)	<0.001

ISS, Injury Severity Score; KSMC; King Saud Medical City.

Mortality

Adjustment for GCS on arrival, age, severity of injury and cause of injury (table 4) showed that the odds of in-hospital death from traumatic injuries at the Alfred were less than at the KSMC (OR 0.25; 95% CI: 0.15 to 0.43, p<0.001).

Table 4. Risk adjusted mortality

N = 5287	Odds Ratio (95% CI)	P-value
- KSMC	1.0	Reference
- Alfred	0.25 (0.15-0.43)	<0.001
Glasgow Coma Score: motor function on arrival to the KSMC		
- Obeys command	1.0	Reference
- No movement	34.23 (18.97 – 61.76)	<0.001
- Extension to pain	24.04 (7.32 – 78.99)	<0.001
- Flexion to pain	10.95 (3.32 – 36.10)	<0.001
- Withdraws to pain	9.71 (2.86 – 32.90)	<0.001
- Localises to pain	4.92 (2.18 – 11.10)	<0.001
ISS categories		
- <12	1.0	Reference
- 12-25	3.98 (2.49 – 6.38)	<0.001
- 26-40	5.12 (2.63 – 9.96)	<0.001
- >40	15.79 (6.84 – 36.43)	<0.001
Age at injury event (years)		
- 15-24	1.0	Reference
- 25-40	0.85 (0.43 – 1.68)	0.635
- 41-60	1.49 (0.74 – 3.00)	0.260
- 61-70	4.03 (1.70 – 9.53)	0.002
- 71-80	6.89 (3.19 – 14.90)	<0.001
- 81+	16.58 (7.57 – 36.30)	<0.001
Cause of injury		
- Falls both high and low	1.0	Reference
- Cause with systemic effect	10.71 (3.66 – 31.33)	<0.001
- Motor vehicle occupants	0.70 (0.41 – 1.19)	0.193
- Motorcyclists	0.13 (0.03 - 0.59)	0.008
- Other specified external cause	0.23 (0.03 – 1.77)	0.159
- Pedal cyclist - rider or passenger	0.26 (0.05 – 1.39)	0.116
- Pedestrian	1.36 (0.71 – 2.63)	0.357
- Struck by object or person	0.25 (0.05 – 1.25)	0.092

ISS, Injury Severity Score; KSMC, King Saud Medical City.

Discussion

This study describes the trauma profile at a large tertiary referral hospital in KSA, which will contribute to the knowledge required to improve the trauma system. We have established a prototype for the national trauma registry that is essential for the kingdom to understand how and why injuries occur. The over-representation of men at 85% and the young mean age of 33 years at the time of injury have implications for the community. The post-discharge levels of disability were not included in this study, however Gabbe et al [19] noted compelling evidence of ongoing problems following serious injury that are likely to be lifelong.

The study found that 51% of all trauma in the STAR cohort, including paediatric patients, was due to road traffic incidents. These included motor vehicle events where the victims were drivers or passengers, pedestrians, motorcycle riders, motorcycle passengers and pedal cyclists. This was consistent with the known problem of road trauma in the kingdom and confirmed the need for public safety initiatives and regulation. Mansuri et al [20] noted that some measures are already in place, including seat belt legislation.

An integrated trauma system requires a multidisciplinary response to treating injuries, which begins with the care delivered at the scene of injury. In the KSA, the SRCA is the primary first responder [21]. Optimising initial care is essential to improved outcomes. The STAR dataset includes a number of relevant prehospital variables, the values for which can only be sourced from the SRCA Patient Care Record. In this study, 47.2% of patients who presented to the KSMC from scene were attended by the SRCA. The relationship between the SRCA and the STAR will develop as the 'feedback loop' of performance monitoring becomes a routine part of the prehospital sector's quality assurance activities. The study also revealed that almost one-quarter of all presentations to the KSMC had attended at least one other hospital prior to admission. Ongoing data collection will reveal whether more patients are transported directly from scene with improved prehospital triage.

There is little consensus on the best process indicators to monitor the quality of in-hospital Care [22]. The STAR is an integral component of the KSMC Trauma Unit quality assurance programme and can provide regular reports of selected indicators. Our study revealed that the median length of time that KSMC patients

spent in the ED in 2018 was 7 hours. Australian data show that the median length of time spent in the ED for injured patients in the financial year 2016–2017 was 4.26 hours [23]. We did not attempt to determine optimal time frames, however monitoring processes allows more accurate identification of delays and barriers to optimising performance [24]. Post-discharge from ED, the clinical pathway diverged for trauma patients at the KSMC. A majority (64.5%) underwent procedures in the operating theatre. We found that the time to initial procedure in the operating theatre varied considerably, most likely for clinical and logistic reasons. Time-critical procedures such as craniotomy were prolonged, with a median time to craniotomy/craniectomy of 10 hours. Although there is no consensus on the timing of craniotomy/craniectomy [25–27], it is a further useful measure to monitor the KSMC's clinical practice.

The STAR data showed that the LOS at the KSMC was between 1 and 207 days, excluding five people who died in the ED. The median LOS overall was 8 days. The Australian Trauma Registry [11] reported a median hospital stay of 7 days for major trauma, which is very similar to 6.5 days reported by the VSTR. Our study did not differentiate between major and non-major trauma for LOS, however the availability of state and national Australian data, and this initial use of Alfred Hospital data, allows for other more focused studies. To explore the differences between the process indicators that the STAR data have described at the KSMC, the comparison given in Australian and/or Victorian data was beyond the scope of this study. We showed that the length of time spent in ED; the time to theatre, specifically craniotomy; and the LOS are longer at the KSMC. There are some likely reasons for this—for example, the time from injury to admission to rehabilitation for patients with traumatic injuries is reported as being significantly longer in Saudi Arabia than elsewhere [28 29]. This may cause a shortage of acute beds, and therefore patients delay in ED until a bed can be found. Similarly, anecdotally, there are difficulties with access to specialty surgeons, which impedes the flow of patients from ED to theatre and to the wards. The STAR dataset is not designed to evaluate these issues, however it can provide answers to some questions, such as the efficacy of the trauma team activation system, which is in place at the KSMC and functions well (not reported here). Findings from the STAR data can now be applied at the KSMC to quantify and measure improvements.

This is the first step in developing a robust model of risk-adjusted comparisons for processes and outcomes that will be further improved as more data become

available. Cameron [30] asserted that accurate benchmarking is a work in progress and that the standardisation of variables and comparing 'like with like' is yet to occur. Nevertheless, for the first time in the kingdom, there is a method available of benchmarking outcomes internationally.

Limitations

There were several limitations to the study. Patients for whom information was not available for the entire episode of care limited the dataset. Data collection commenced at the time of admission to the KSMC but the record may not have been completed at the time of discharge. The lack of complete data caused the sample size of complete cases to vary between analyses. Likewise, the completeness of the data differed between variables, with some variables reporting a high proportion of 'unknown' values. The reduced sample size of known values limited the interpretation of the findings. The benchmarking model was limited due to the differences between the two systems. Cultural differences in approach to 'end-of-life' decisions, such as early extubation in severe head injuries and discharge for palliative care, are examples of benchmarking challenges. The possibility of unmeasured confounders is high. In particular, a longer follow-up time for the STAR cohort, with patients remaining in hospital, provided higher exposure for the primary outcome of in-hospital death. Furthermore, the collection of data at one centre only is not necessarily generalisable to the whole of the KSA. A population-based measurement of trauma care would develop with the contribution of multiple sites to the registry.

Conclusion

This is the first hospital-based study of major trauma in the KSA that benchmarks with an individual international centre. There were demonstrated differences in the demographics, processes and outcomes that require further exploration. The application of accepted performance indicators has established a baseline to measure continuous improvement. An increased understanding of the causes and effects of injury events will assist the kingdom to meet the challenges of caring for people who sustain serious injuries and suffer the consequences of ongoing disability.

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PART 7

Trauma System: Rehabilitation

CHAPTER 18

Does access to acute intensive trauma rehabilitation (AITR) programs affect the disposition of brain injury patients?

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Abstract

Early incorporation of rehabilitation services for severe traumatic brain injury (TBI) patients is expected to improve outcomes and quality of life. This study aimed to compare the outcomes regarding the discharge destination and length of hospital stay of selected TBI patients before and after launching an acute intensive trauma rehabilitation (AITR) program at King Saud Medical City. It was a retrospective observational before-and-after study of TBI patients who were selected and received AITR between December 2018 and December 2019. Participants' demographics, mechanisms of injury, baseline characteristics, and outcomes were compared with TBI patients who were selected for rehabilitation care in the pre-AITR period between August 2017 and November 2018. A total of 108 and 111 patients were managed before and after the introduction of the AITR program, respectively. In the pre-AITR period, 63 (58.3%) patients were discharged home, compared to 87 (78.4%) patients after AITR ($p = 0.001$, chi-squared 10.2). The pre-AITR group's time to discharge from hospital was 52.4 (SD 30.4) days, which improved to 38.7 (SD 23.2) days in the AITR ($p < 0.001$; 95% CI 6.6-20.9) group. The early integration of AITR significantly reduced the percentage of patients referred to another rehabilitation or long-term facility. We also emphasize the importance of physical medicine and rehabilitation (PM&R) specialists as the coordinators of structured, comprehensive, and holistic rehabilitation programs delivered by the multi-professional team working in an interdisciplinary way. The leadership and coordination of the PM&R physicians are likely to be effective, especially for those with severe disabilities after brain injury.

Introduction

Trauma is a significant public health burden in Saudi Arabia due to the high road traffic crash rate [1]. It has severe, devastating, and often life-threatening consequences. Care for the injured after a crash is exceptionally time sensitive; delays in any stage can make a difference in outcomes. Survivors of significant trauma may experience severe functional impairment and reduced quality of life [2]. Severe injuries are often associated with motor, sensory, and autonomic impairments, including loss of bladder control and bowel evacuation. These contribute to significant morbidity and impact an individual's ability to move about their home and community and bathe and dress independently [3–5].

Advanced rehabilitation services have become critical for enhancing a patient's functional health status following significant trauma. Early intensive rehabilitation significantly reduces dependency, lessening the need for ongoing community care [6]. The World Health Organization recommends that rehabilitation be available and accessible to anyone who experiences a severe traumatic injury [7]. Acute intensive trauma rehabilitation (AITR) programs following traumatic injuries have also improved functional recovery. However, access is often limited and not available at all hospitals [8]. For example, only 1.5% of patients in Beijing, China, receive this service compared with 50% to 58% in Ontario, Canada [9, 10].

In Saudi Arabia, King Fahad Medical City (KFMC) rehabilitation hospital is the only hospital under the Ministry of Health providing holistic rehabilitation services in the region since 2004 [11]. Due to the limited number of inpatient beds and a huge burden of rehabilitation candidates, the waiting time for patients' acceptance is 6–12 months. Another private rehabilitation center is also available that has limited access due to eligibility and insurance coverage. On the other hand, King Saud Medical City (KSMC) in Riyadh is a major trauma center in the region. It receives the most severely injured polytrauma patients from all over the country. A dedicated trauma unit has managed all polytrauma patients since 2016.

KSMC lacked consultant physiatrists, and the physical medicine and rehabilitation (PM&R) department was severely understaffed for such a major hospital in the region until 2017. With only one PM&R registrar, the focus of services was on outpatient care. There were the physiotherapy, occupational therapy, speech-

language pathology, and prosthesis and orthosis departments, which were all inadequately involved with patient care because there was no integration between services. Since the trauma unit's inception in 2016, we have been trying to improve trauma care, especially chronic care, for severely injured brain trauma patients. Since then, we have undertaken different administrative measures, including recruiting PM&R professionals, increasing logistics, and collaborating with the KFMC rehabilitation center. As a part of that collaboration, one visiting consultant physiatrist from KFMC used to visit the KSMC trauma unit once a week to assess the chronic trauma patients and select rehabilitation candidates. He also provided expert opinion for interim hospital care before those patients were transferred to his rehabilitation center. The waiting time for the transfer was long. These chronic patients were receiving essential non-intensive hospital care—such as physiotherapy, occupational therapy, tracheostomy care, and speech-language therapy—in the trauma unit. It was causing bed occupation, increased length of hospital stay, and increased cost. Around this time, two more consultant physiatrists joined KSMC. Subsequently, an integrated multidisciplinary AITR program was implemented at KSMC in December 2018.

This study aimed to compare the outcomes regarding discharge destination and length of hospital stay of selected traumatic brain injury (TBI) patients before and after the launch of the multidisciplinary AITR program.

Materials and methods

Setting

KSMC is one of the largest hospitals in Saudi Arabia, with 1,400 inpatient beds. KSMC's emergency department (ED) is the busiest in the kingdom [12]. Three physiatrists oversee the KSMC PM&R department. The department started the AITR program in coordination with physiotherapy, occupational therapy, speech-language pathology, prosthesis and orthosis, and the social work department in December 2018.

AITR

AITR is an acute in-hospital intensive rehabilitation program for a selected group of severely injured trauma patients who receive at least two to three sessions

of different therapies—including physiotherapy, speech-language therapy, occupational therapy, and Botox therapy—for three to four hours each day with breaks in between, five days a week, as decided by the physiatrist [13].

The AITR program was created with specific clinical goals. The multidisciplinary team's training was designed to help people regain function, acquire activities of daily living (ADL) independence, and reintegrate into their homes and communities. The program included physical and sensory-motor training from physiotherapy, functional re-training such as self-care and instrumental ADL from occupational therapy, and psycho-social re-training including social skills from speech therapy [13].

Assessment and selection of TBI patients for AITR

The PM&R department engages with trauma patients' management at an early stage of their in-hospital courses. A consultant physiatrist does weekly rounds on trauma patients to assess needs and select candidates for AITR. When a patient has fully recovered from an acute head injury, has regained consciousness, and is able to participate in rehabilitation, the physiatrist sets up short-term integrated goals for the patients in collaboration with the treating trauma surgeon and other relevant departments (e.g., physiotherapy, occupational therapy, speech-language pathology, prosthesis and orthosis, and social work) in a multidisciplinary team meeting. Assessment is based on a favorable outcome regarding achievement of independence in daily activities after providing the service. The plans are then revised with patient progress. The persistent vegetative and worse-prognosis patients are recommended for nursing care only. After AITR, if a patient is improved with the achievement of independence in daily activities, they are discharged home with outpatient follow-up at our PM&R department as needed. If the patient needs further rehabilitation to achieve the goals, they are transferred to a long-term rehabilitation facility. The selection criteria or preconditions for AITR are described in Table 1.

Design

This was a retrospective observational before-and-after study of TBI patients who were referred to PM&R and received AITR between December 01, 2018, and December 31, 2019. The TBI patients who died in the hospital, transferred to another hospital during acute care, or were discharged from the hospital

after rapid and good recovery that did not require rehabilitation and remained persistent vegetative were excluded. The data were compared with the pre-integration of inpatient rehabilitation for TBI patients who were assessed and selected for rehabilitation care between August 01, 2017, and November 30, 2018.

Table 1. Patient selection criteria for AITR

1. The patient must be medically stable.
- Medical stability refers to optimizing the patient's physical condition, including diseases or dysfunction of the viscera (e.g., respiratory, cardiovascular, gastrointestinal, urologic, endocrine, and neurological disorders).
- Criteria:
  I. The patient must be afebrile for 48 hours, may have low-grade temperature if a source has been identified and a treatment plan is in place.
  II. The patient must not require suctioning more frequently than every four hours.
  III. The patient should have a stable cardiac rhythm.
  IV. The patient who requires oxygen must have adequate oxygen saturation on portable oxygen.
  V. The patient must be off from continuous positive airway pressure (CPAP), except for sleep apnea treatment.
  VI. If the patient has a chest tube, it must be stable to gravity for at least 48 hours.
  VII. The patient's medical or surgical workup and treatment must be complete.
  VIII. If a patient has nutritional, pain, or wound issues, they must be manageable and not interfere with the therapies.
2. The patient must meet the criteria of at least two of the three (physiotherapy, occupational therapy, and speech-language therapy) major therapy areas.
3. The patient must have the endurance to tolerate at least three to four hours of therapy over the day.

Source: KSMC policy on Intensive Rehabilitation Joint Program, IPP-KSMC-015-V1

Before discharge home, a patient had to be able to: (1) execute self-care activities such as feeding, grooming, dressing, and toileting; (2) move from bed to chair/wheelchair/shower chair independently; (3) securely handle household appliances; and (4) walk with or without support inside the ward [13]. These criteria remained the same in pre-AITR and AITR era.

Data collection

The data of selected TBI patients who were referred for possible rehabilitation care were collected from the PM&R department and trauma unit records. Then for these selected patients, the data of patient demographics, mechanism of injuries,

baseline admission characteristics (on presentation to ED), length of stay, and discharge destination in terms of home or rehabilitation center were extracted from the KSMC trauma registry. Discharge destination and time to discharge from hospital were the primary outcome variables.

Statistical analysis

The data were analyzed using SPSS 25.0 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) and R (RStudio Team 2020). The data were subgrouped into the two periods before and after the implementation of AITR. Demographic, mechanism of injury, and baseline injury characteristics (on presentation to ED) were compared to assess equivalence between the two subgroups. The continuous and normally distributed data (e.g., age, respiratory rate, heart rate, systolic blood pressure, international normalized ratio, base excess, P^H, abbreviated injury scale [AIS] head, and length of stay) were summarized using mean (standard deviation [SD]) and compared using Student's t-test. Skewed and ordinal data (e.g., Glasgow Coma Scale) were summarized using the median (inter-quartile range [IQR]) and compared using the nonparametric Mann-Whitney U-test. Count data (e.g., male sex, mechanism, trauma team activation, blood transfusion in ED, injury-severity score, and discharge destination) were summarized using proportions and compared using the nonparametric chi-square test. A p-value of < 0.05 was considered significant.

Ethics statement

The study was approved by King Saud Medical City institutional review board (IRB) with a reference number of H1RI-03-Oct18-02. The IRB committee approved a waiver of the requirement to seek informed consent from the participants for a retrospective review of their data.

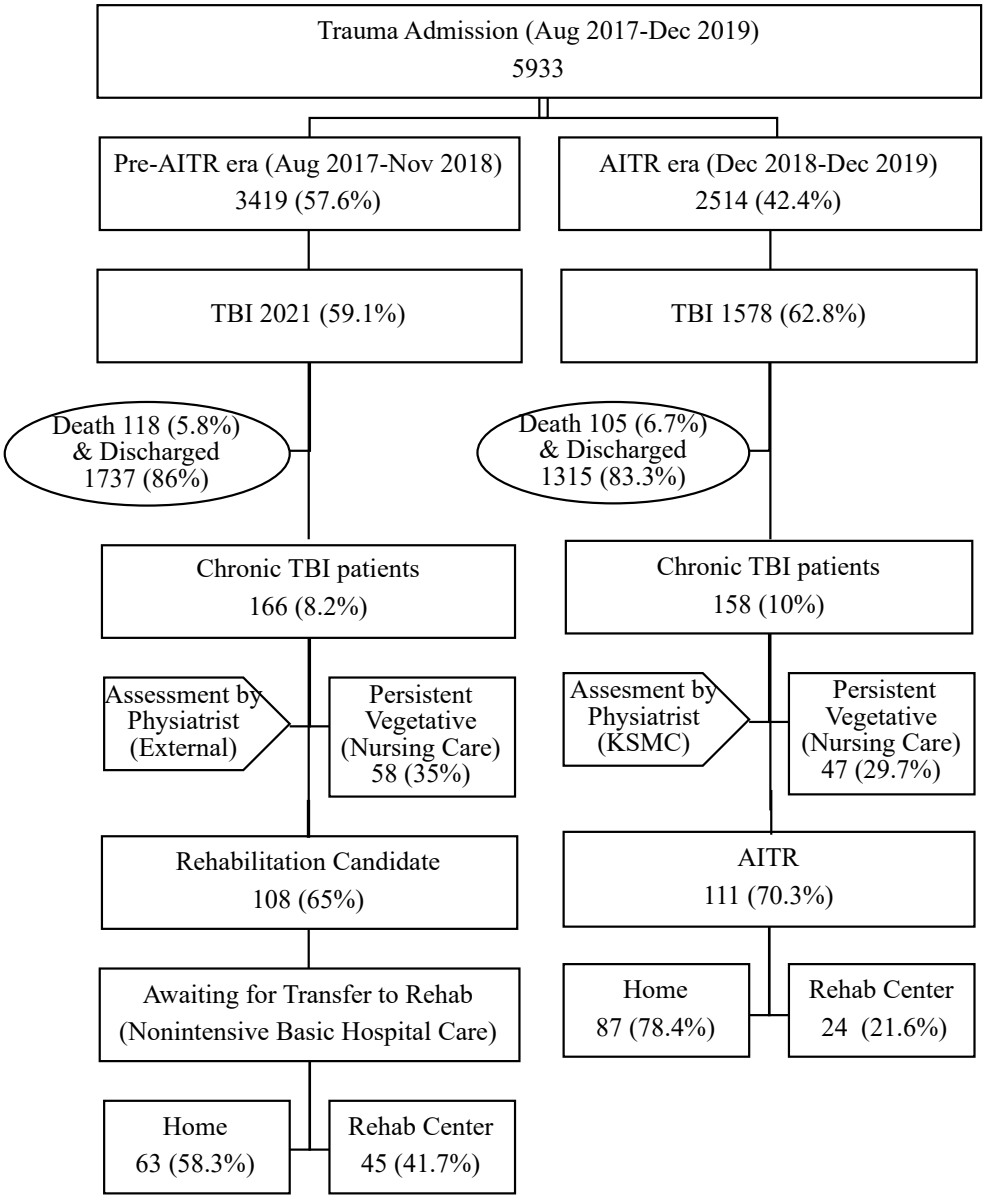

Fig 1: Sample selection

Results

A total of 5,933 trauma patients were included in the KSMC registry between August 2017 and December 2019. Of these, 3,419 (57.6%) patients were admitted pre-AITR era and 2,514 (42.4%) patients were admitted after the introduction of AITR. During the pre-AITR period, 2,021 (59.1%) patients sustained TBI, of which 118 (5.8%) died, 1,737 (86%) were discharged after rapid and good recovery that did not require rehabilitation, and 166 (8.2%) became chronic TBI patients (who required rehabilitation care or were persistent vegetative patients). Among the chronic TBI patients, 108 (65%) were selected for the rehabilitation care, and the remaining persistent vegetative patients were selected for nursing care. On the other hand, during the AITR era, 1,578 (62.8%) patients sustained TBI, of which 105 (6.7%) died, 1,315 (83.3%) were discharged after rapid and good recovery that did not require rehabilitation, and 158 (10%) became chronic TBI patients. Among the chronic TBI patients, 111 (70.3%) were selected for AITR, and the remaining persistent vegetative patients were selected for nursing care (Fig 1).

In the combined group of chronic TBI patients selected for rehabilitation care (n = 219), the demographics were mainly young males (195, 89%) with a mean age of 28.2 (SD 14.2) years. The age distribution is presented in the violin plot (Fig 2).

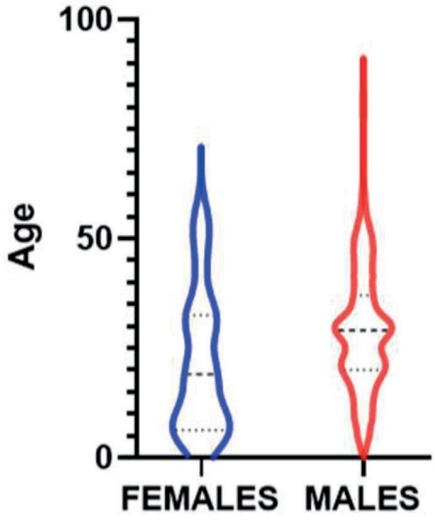

Fig 2: Age distribution of patients

The commonest mechanism of injury was motor vehicle crashes (192, 87.7%) followed by falls (22, 10%) and assaults (5, 2.3%). Eighty-four (38.4%) patients had trauma team activation (TTA) by the ED, and 27 (12.3%) patients received a blood transfusion in the ED. Ninety-three (42.5%) patients had an injury severity score (ISS) between 16 and 25, followed by 81 (37%) patients less than 16 and 45 (20.5%) patients above 26. The average length of ICU and hospital stay were 18 (SD 10.2) and 45.5 (SD 27.8) days, respectively.

The comparison of selected TBI patients' demographics, mechanisms of injury, baseline (on presentation to ED) characteristics, and outcomes between pre-AITR and AITR are described below (Table 2). There was no significant difference in the AIS for the head between the groups (p = 0.437).

In the pre-intervention period, there were 63 (58.3%) patients discharged to home, compared to 87 (78.4%) after the intervention (p = 0.001; chi-squared 10.2). Time to discharge from hospital pre-intervention was 52.4 (SD 30.4) days, which improved to 38.7 (SD 23.1) days after the introduction of the new AITR program (p < 0.001; 95% CI 6.6–20.9) (Table 2).

Table 2. Comparison of selected TBI patients' demographics, mechanisms of injury, baseline (on presentation to ED) characteristics, and outcomes between pre-AITR and AITR.

Characteristics	Total (n=219)	Pre-AITR (n = 108)	AITR (n = 111)	p-value
Age (mean years [SD])	28.2 (14.2)	26.9 (14.1)	29.4 (14.3)	0.202
Male sex (%)	195 (89%)	100 (92.6%)	95 (85.8%)	0.097
Mechanism				
- Motor Vehicle Collision (%)	192 (87.7%)	95 (88%)	97 (87.4%)	0.893
- Fall (%)	22 (10%)	10 (9.2%)	12 (10.8%)	0.694
- Assault (%)	5 (2.3%)	3 (2.8%)	2 (1.8%)	0.622
Trauma team activation (%)	84 (38.4%)	51 (47.2%)	33 (29.7%)	0.007*
Blood transfusion in ED (%)	27 (12.3%)	18 (16.7%)	9 (8.1%)	0.054
Respiratory rate (mean breath/ min [SD])	21.1 (8.2)	21.4 (8.2)	20.8 (8.2)	0.603

Heart rate (mean beat/min [SD])	102.7 (25.7)	108.7 (25.2)	96.9 (24.9)	0.001*
Systolic blood pressure (mean mm Hg [SD])	125.7 (25.3)	125.9 (28.1)	125.5 (22.2)	0.906
Glasgow Coma Scale (median [IQR])	7 (5-7)	7 (5–7)	7 (4–7)	0.447
International normalized ratio (mean [SD])	1.2 (0.3)	1.2 (0.3)	1.1 (0.2)	0.004*
Base excess (mean [SD])	-3.4 (4.1)	-3.6 (4.3)	-3.2 (3.8)	0.542
PH (mean [SD])	7.32 (0.1)	7.33 (0.1)	7.31 (0.1)	0.204
AIS-head (mean [SD])	3.08 (0.76)	3.05 (0.75)	3.13 (0.76)	0.437
Injury severity score (ISS) **1–15 (%)** **16–25 (%)** **> 25 (%)**	 81(37%) 93 (42.5%) 45 (20.5%)	 50 (46.3%) 42 (38.9%) 16 (14.8%)	 31 (28.0%) 51 (45.9%) 29 (26.1%)	0.002* 0.005* 0.296 0.039*
Length of ICU stay (mean days [SD])	18 (10.2)	19.2 (10.8)	16.9 (9.4)	0.086
Length of hospital stay (mean days [SD])	45.5 (27.8)	52.4 (30.4)	38.7 (23.1)	< 0.001* (95% CI 6.6–20.9)
Discharge destination **Home (%)** **Rehab Center (%)**	150 (68.5%) 69 (31.5%)	63 (58.3%) 45 (41.7%)	87 (78.4%) 24 (21.6%)	0.001* 0.001*

*Statistically significant at 5% level.

The comparison of length of hospital stay between pre-AITR and AITR is presented in the violin plot (Fig 3).

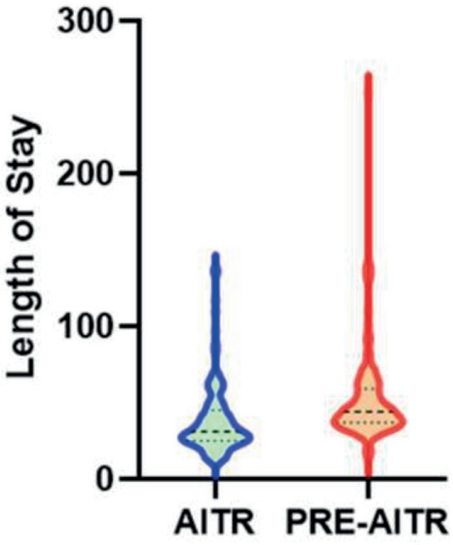

Fig 3: Comparison of length of hospital stay between pre-AITR and AITR

Discussion

We compared two similar groups (head injury) and an almost equal number of patients with two different rehabilitation strategies—AITR vs. non-intensive or minimal in-hospital rehabilitation (pre-AITR)—in two different periods (pre-AITR: Aug 2017–Nov 2018; AITR: Dec 2018–Dec 2019). This study demonstrated that integrating an intensive rehabilitation program with acute trauma care was associated with a significantly higher proportion of patients being discharged home and after a shorter length of stay in the hospital. As a result, the waiting list of rehabilitation candidates and the load on the only rehabilitation center in Riyadh, KFMC, are decreased.

In our cohort, the heart rate (108.7 bpm vs. 96.9 bpm; p = 0.001) at presentation to ED was significantly higher in the pre-AITR than AITR group. As the systolic blood pressure did not change in both groups (125.9 mm Hg vs. 125.5 mm Hg; p = 0.906), the difference in shock status was not significant. Moreover, the weak difference of blood transfusion requirement (16.7% vs. 8.1%; p = 0.054) in ED supports against significant difference in shock status between the two groups.

The international normalized ratio (1.2 vs. 1.1; p = 0.004) was significantly higher in the pre-AITR group. Higher blood transfusion requirements in this group should have corrected the coagulopathy. Moreover, trauma system development in Saudi Arabia is recent, and defects in pre-hospital patient transfer could contribute to the difference in both groups. However, as these parameters are corrected with resuscitation measures immediately in our ED, these should not directly affect the selection of patients or outcomes in both groups.

The TTA rate in the pre-AITR cohort was significantly higher (47.2% vs. 29.7%; p = 0.007). However, ISS was comparatively lower (p = 0.002) in the pre-AITR group, which seems inconsistent as more severe injuries should get more activation. Although TTA is based on specific criteria, it is subjective (at emergency physician discretion) and may have information bias due to over- or under-triage and should not affect outcomes directly.

In our study, ISS in the AITR group was significantly higher (p = 0.002). However, the AIS-head did not show a statistically significant difference (p = 0.437) between the groups, which means we dealt with similar groups of head-injury patients in both rehab strategies. With comparable AIS, the higher ISS in the AITR group indicates more polytrauma [14–16]. On the other hand, with more polytrauma, the AITR group had a significantly lower length of hospital stay (38.7 days vs. 52.4 days; p < 0.001), which favored the success of the AITR program.

Rehabilitation service is an essential pillar of the trauma system and plays a vital role in trauma patients' outcomes. In our situation, it is a challenge to transfer a trauma patient to a rehabilitation center due to a long waiting list. Delay in transfer causes increases in the length of hospital stay and cost. Long waits for rehabilitation have a negative impact on the functional and cognitive recovery of severely injured patients [17].

Identifying factors that contribute to the prediction of discharge disposition is crucial for efficient resource utilization and reducing cost. Several factors may influence discharge location after hospitalization [18]. Functional status due to early and advanced professional rehabilitation can affect the discharge destination. Nursing home management for all ages has demonstrated a significantly lower quality of life across multiple domains as compared with those

living elsewhere [19, 20]. Return to living at home is an important patient-reported outcome following a traumatic injury. Receiving specialized acute rehabilitation is a significant and robust predictor of return to home. Specialized acute intensive rehabilitation helps patients with severe trauma maximize function and independence and return to home. Improving access to specialized acute intensive rehabilitation could potentially reduce discharges to nursing homes or other non-home destinations [21].

The introduction of a multidisciplinary AITR program was a challenge at KSMC. Bringing various allied health-care services under one umbrella was a difficult administrative decision. The PM&R department is understaffed; a dedicated ward with all relevant resources such as a gymnasium is not available to date.

This study is limited to being a retrospective cohort and only a moderate sample of patients. However, it includes consecutive patients during 29 months from the most active trauma center in the country. With only 111 cases of AITR, we attempted to develop a model to improve the trauma patient's outcomes. The study did not analyze in depth the cognitive and functional recovery, bladder and bowel control, etc. An analysis of the Functional Independence Measure (FIM) and the Neurobehavioral Cognitive Status Examination (NCSE) in both groups would have given more strength to the study. A national trauma registry with a systematic collection of data on patient outcomes would be invaluable to assess such a program.

Conclusions

The implementation and early integration of AITR significantly reduced the percentage of patients referred to another rehabilitation or long-term facility. It also reduced the length of stay in the hospital. Continuation and expansion of the program to other trauma services with ongoing surveillance are indicated. We also emphasize the importance of PM&R specialists as the coordinators of structured, comprehensive, and holistic rehabilitation programs delivered by the multi-professional team, working in an interdisciplinary way [22]. The leadership and coordination of a PM&R physician are likely to be effective, especially for those with severe disabilities after brain injury.

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CHAPTER 19

Summary, Discussion, and Future Perspectives

This thesis delves into virtually every aspect of trauma systems development strategies in developing countries. Chapter 1 presents an overview of the thesis, emphasizing trauma as a worldwide burden, the definition of a trauma system, trauma as a disease burden on the health systems of two emerging nations—South Africa and Saudi Arabia—and, lastly, an outline of the various parts of the thesis.

In Part 1, Chapter 2, the discussion centered on the history and current state of trauma systems in two emerging nations: South Africa, a middle-income country, and Saudi Arabia, a high-income country, with a focus on prehospital, in-hospital, rehabilitation, trauma quality assurance, and research and development. The chapter concluded that, while both countries' current trauma systems have some strengths, such as personnel education and training, several critical components are missing that would enable them to achieve a superior outcome.

Chapter 3 discussed the new model of care (MOC) developed in response to the recent transformation of Saudi healthcare under the Kingdom's Vision 2030. The MOC concept began by examining the current state and the collection of lessons learned. It is organized around six systems of care (SOCs): staying well, planned procedure, women and children, urgent problems, chronic conditions, and the last phase of life [1]. The SOC spans multiple service layers to help people stay healthy and quickly rehabilitate them when they require care. The new MOC describes forty-two interventions, twenty-seven of which are divided among the six SOC, and the remaining 15, which span multiple SOCs [1]. By implementing all MOC interventions, the Saudi healthcare system will be streamlined to align with the Kingdom's Vision 2030. This initiative for healthcare transformation aided in developing the Saudi trauma system, which is discussed in Chapter 4.

A national clinical advisory group (CAG) for trauma was formed to develop the Saudi Arabian trauma system, with CAG members analyzing and collating internationally recognized trauma systems and guidelines [2–4]. The applicability of the guidelines in the Kingdom was discussed and reviewed, and an interactive document was created to aid in socialization and implementation. The CAG team members agreed on the trauma pathway's guiding principles, identified obstacles, and finalized the new system design. Additionally, they developed a trauma care standard document to assist and guide the Kingdom's rollout of new

trauma networks. Members of the CAG and other stakeholders are leading the charge in implementing the trauma system throughout the Riyadh region. Recent trauma system development in Saudi Arabia is the first step toward improving national trauma care. It may serve as a model for development in other areas and countries to improve outcomes.

Part 2 focuses on the prehospital aspect of the trauma system. Chapter 5 investigated the effectiveness of EMS in transporting trauma patients to the Groote Schuur Hospital Trauma Center (GSHTC) in Cape Town, South Africa. During the study, 48 index laparotomies were performed, of which 13 patients developed postoperative complications. After contact, the median response time of the EMS was 53 minutes for patients who developed complications. It was significantly longer, 21 minutes ($p < 0.01$), than those without complications. The median time from injury to laparotomy was 10.3 hours for patients with postoperative complications and 7.5 hours for those without complications. The time interval between injury and admission to the operating room was also a significant predictor of the development of complications ($p = 0.02$). The study concluded that EMS response time increased the likelihood of complications. It is well established that when a trauma patient is transported to a designated trauma center within an hour of injury—the "golden hour"—the outcome improves [5]. Prehospital time reduction is highly dependent on the efficiency of the EMS system, particularly response time. Rapid response by the EMS is expected in the event of a life-threatening condition, and it is used to determine the effectiveness of a prehospital system [6]. As a result, the EMS's rapid response to trauma patient transfers must be enhanced.

Chapter 6 examined how quickly a trauma patient arrives at a hospital following injury in a low- or middle-income country, such as South Africa, for safe and effective tranexamic acid administration for hemorrhage control, according to the landmark CRASH-2 trial [7]. Fifty consecutive patients admitted to GSHTC were included in a prospective cohort study using the CRASH-2 criteria. Thirteen (26%) patients presented early enough (within about three hours of injury) to receive tranexamic acid. Only three patients were seen within the first hour. Eleven patients had an injury that occurred more than three hours prior to presentation. Most bleeding trauma patients (74%) did not present within the timeframe necessary for effective tranexamic therapy administration. Of those who did, the majority would have

benefited from initiating therapy even sooner. This suggests that if tranexamic acid is carefully integrated into prehospital rather than in-hospital protocols in a lower-middle-income country with an underdeveloped prehospital system, it may be more effective at the population level. Effective trauma management in the emergency department is critical for any successful trauma system.

In Part 3, Chapter 7 investigated the improvement in knowledge after trauma resuscitation training for healthcare professionals. The study used pre- and posttraining test to evaluate the effects of a trauma training program on the participants' knowledge. A total of 128 nurses participated in 16 courses conducted during the study period. This study found a significant improvement in nurses' knowledge after the training (pre- and postraining test scores 5 [4–6] vs. 9 [8–9], $p < 0.001$). There was no significant difference in pretraining test scores between the participants with previous trauma training and those without training (test scores 5 [4–6] vs. 4 [4–5], $p = 0.751$). The study concluded that trauma resuscitation training affects nurses' knowledge improvement, emphasizing the need for training trauma care professionals to provide adequate care.

Chapter 8 aimed primarily to evaluate the association between the initial shock index (SI ≥ 1.0) and blood transfusion requirements in the ED after acute trauma. The study's secondary aim was to look at the outcomes regarding patients' disposition from the ED, ICU, and hospital in terms of length of stay and deaths. Of 6667 patients, 908 (13.6%) had SI ≥ 1.0. With SI ≥1.0, there was a significantly higher incidence of blood transfusion in the ED compared to SI < 1.0 (8.9% vs. 2.4%, $p < 0.001$). In addition, SI ≥ 1.0 was associated with significant ICU admission (26.4% vs. 12.3%, $p < 0.001$), emergency surgical intervention (8.5% vs. 2.8%, $p < 0.001$), longer ICU stay (5.0 ± 0.36 days, $p < 0.001$), longer hospital stays (14.8 ± 0.61 days, $p < 0.001$), and higher number of deaths (8.4% vs. 2.8%, $p < 0.001$) compared to patients with SI < 1.0. In our cohort, an SI ≥ 1.0 at presentation in the ED carried significantly worse outcomes. Traditionally, hypovolemic shock has been classified based on the percentage of circulatory blood loss [8]. Practically, accurate quantification of blood loss is not possible. Base deficit testing, a more accurate physiological parameter, may not be available everywhere [9–11]. The SI calculation is more practical and can be performed quickly in trauma patients with available vitals. This may be used as a screening tool and thus incorporated into protocols for the initial assessment of trauma patients.

In-hospital treatment strategies influence the outcomes and, ultimately, the success of a trauma system. **Part 4** of the thesis examined and described various treatment strategies. Although nonoperative management (NOM) has become more popular for abdominal trauma in recent years, it is rarely used for gunshot liver injuries (GLI) [12–15]. Chapter 9 evaluated the safety of the selective NOM of GLI. During the 52-month study period at GSHTC, 54 (28.3%) of 191 GLI patients were chosen for NOM of hemodynamic stability, the absence of peritonism, and CT imaging. The mean injury severity score (ISS) was 25 (4–50). Twenty-one (39%) patients had simple (grades I and II) liver injuries, while 33 (61%) patients had complex (grades III to V) liver injuries. There were 12 (22.2%) associated kidney injuries, 43 (79.6%) diaphragm injuries, 20 (37.0%) pulmonary contusions, 38 (70.4%) hemothoraces, and 24 (44.4%) rib fractures. Three patients required delayed laparotomy, resulting in a 94.5% NOM success rate. There were the following complications: liver abscess (1), biliary fistula (5), intrahepatic A-V fistula (1), and hospital-acquired pneumonia (3). Overall, the median length of stay in the hospital was 6 (IQR 4–11) days, with no deaths. NOM was found to be safe and associated with a low rate of morbidity in carefully selected patients with GLI.

Chapter 10 looked at hemodynamically stable patients with left-sided thoracoabdominal (TA) stab wounds who did not require abdominal operation with regard to whether they needed to go for mandatory diagnostic laparoscopy (Group A) or could be safely treated with clinical and chest X-ray follow-up (Group B) in a prospective, randomized control study conducted at GSHTC, a level 1 trauma center in Cape Town, South Africa. Twenty-seven patients were randomized to Group A (N = 27) and 31 to Group B (N = 31). The incidence of occult diaphragm injury in Group A was 29%. All diaphragm injuries found at laparoscopy were repaired. The mean hospital stay for the patients in Group A was 5 (SD 1.3) days, compared to 2.9 (SD 1.5) days in Group B ($p < 0.001$) patients. All patients in Group B had normal chest X-rays at their last visit. The mean follow-up time was 24 months (median 24, IQR 1–40 months). There was no morbidity or mortality in Group B. Clinical and radiological follow-up were feasible and appeared to be safe in the short term in patients who harbor occult diaphragm injuries after left TA stab wounds. Until studies showing the natural history of diaphragm injury in humans are available, laparoscopy should remain the gold standard in treatment.

Chapter 11 discussed the treatment options for penetrating mediastinal vessel injuries. Penetrating trauma accounts for more than 90% of thoracic great vessel injuries [16]. Increased civilian penetrating chest trauma (stab and low-velocity gunshot wounds) and improved EMS have resulted in an increasing number of seriously injured but potentially salvageable patients presenting to trauma centers. Mediastinal vascular injuries that penetrate the mediastinum are associated with a high mortality rate. Unstable patients pose diagnostic and surgical difficulties for surgeons, necessitating damage control resuscitation (DCR) and prompt surgery. DCR begins with restrictive fluid administration, permissive hypotension, and early blood product therapy, which may include the initiation of a massive transfusion protocol, balloon tamponade, tube thoracostomy, and/or resuscitative thoracotomy. Stable patients can undergo a rapid and aggressive workup that includes screening computerized tomographic angiography (CTA), catheter angiography for unclear CTA findings, and endovascular intervention when possible [17].

In Saudi Arabia, blunt neck trauma is common because of high-speed motor vehicle accidents and falls. Chapter 12 discussed the incidence, nature, screening, diagnosis, and management of blunt cerebrovascular injury, particularly blunt vertebral artery injury (VAI) caused by severe cervicocephalic trauma. This was a retrospective observational study of all polytrauma patients admitted to the KSMC trauma unit who underwent CT neck angiography for the purpose of diagnosing blunt VAI using modified Denver criteria. A total of 1025 (94.6%) out of 1084 admitted polytrauma patients sustained blunt trauma. Of these, 120 (11.7%) underwent CT neck angiography screening. VAI was detected in 10 patients (8.3%; 95% CI 4.1–14.8). Three patients sustained Grade I injuries, two sustained Grade II injuries, and five sustained Grade IV injuries. The incidence of diagnosed VAI was 0.9% (95% CI 0.5–1.8) of all trauma admissions. There was no univariable association between VAI and C-spine fracture in patients suspected of VAI: odds ratio 4.2 (95% CI 0.51–34.4; p = 0.18). Two (20%) deaths were attributed to VAI. To avoid missed injuries, a high index of suspicion and liberal screening with CT angiography should be considered in cases where VAI is possible.

Complications **(Part 5)** and outcomes **(Part 6)** are the key performance indicators (KPIs) of a trauma center. Monitoring such KPIs on a regular basis is critical for quality improvement purposes. The incidence of surgical site infection (SSI)

following trauma laparotomy was determined in Chapter 13 of **Part 5**. The data analysis included a retrospective cohort study of 70 patients who underwent laparotomy. Nine patients (12.9%; 95% CI: 6.9–22.7%) developed SSI, including five with bowel injury (small bowel; n = 3, colonic injuries; n = 2). Most cases were identified after seven days in the hospital. Each patient developed a superficial incisional SSI (involving the skin and subcutaneous tissue). There was no statistically significant association between the development of SSI and any predetermined variables, including bowel injury (p = 0.08) or surgery duration (p = 0.09). The rates of SSI following trauma laparotomy were comparable to those previously reported by other centers [18].

Chapter 14 of **Part 5** determined the incidence and nature of the development of venous thromboembolism (VTE) in polytrauma patients taking prophylaxis. This prospective observational study enrolled 169 patients aged 18 years or older who presented directly from the scene with polytrauma and underwent extremity Doppler ultrasound to detect deep vein thrombosis (DVT). Among these, 69 (40.8%) patients were classified as having a high risk of developing VTE. On admission, 115 (68%) patients received pharmacologic agents for VTE prophylaxis, while 54 (32%) patients received intermittent pneumatic compression. Despite prophylaxis, three (1.8%) patients developed DVT, and four (2.4%) patients developed pulmonary embolism (PE) during the index presentation, diagnosed between days 3 and 13 following injury. There was no evidence of early DVT in any of the patients diagnosed with PE. PE is difficult to predict in trauma and is not associated with established risk factors. According to previous studies, patients who sustain trauma and develop PE may not exhibit evidence of lower extremity thrombosis [19–23]. Nine (5.33%) died overall, but there were no in-hospital deaths associated with DVT and/or PE. In our small series, the incidence of DVT in polytrauma patients remained low, possibly due to the mandatory VTE risk assessment for all hospitalized patients and the early initiation of prophylaxis.

At GSH, the emergency surgery triage (EST) system, based on the Cape Triaging Score (CTS), is used to triage emergency surgical cases, including trauma cases. Chapter 15 of **Part 6** is a prospective study that examined the effect of delay in surgery in terms of postoperative complications and death following scheduling using the EST system. During the study period, 106 patients underwent surgery. Of these, 92 (96.2%) of the cases involved penetrating trauma (stab wounds 71 [67%],

gunshot wounds 31 [29.2%]). Of these 106 patients, 6, 47, 40, and 13 were classified as red (immediate, <1 hr), orange (expedited, 1-2 hr), yellow (urgent, <6 hr), and green (emergent, <24 hr), respectively. The median delay for the green, yellow, and orange cases was within the expected time. The red patients took unexpectedly longer (median delay 48 min, IQR 35–60 min). Thirty-one (29.3%) patients developed postoperative complications. Among the booked red, orange, yellow, and green cases, postoperative complications developed in 3, 18, 9, and 1 cases, respectively. Only two (1.9%) postoperative deaths were documented during the study period. There was no statistically significant association between operative triage and postoperative complications ($p = 0.074$). Inadequate triage results in increased waiting times, poor clinical risk assessment, and management, all of which contribute to increased morbidity and mortality [24]. The study concluded that the categorization of surgical cases has been demonstrated to be effective in prioritizing emergency trauma surgical cases in a resource-constrained, high-volume trauma center.

Chapter 16 evaluated the outcomes of damage control laparotomies (DCL) performed following abdominal organ injury, resulting in severe metabolic failure. During the 52-month study period, 25 patients underwent DCL, and 55 patients underwent definitive surgery (DS). DCL patients were more frequently hemodynamically unstable ($p = 0.02$), required more blood units ($p < 0.001$), and required intubation to secure the airway ($p < 0.001$). Metabolic failure developed more rapidly in these patients than in the DS group. The mean base deficits were 7.0 and 3.8 ($p = 0.003$), respectively. In the DCL group, abdominal vascular ($p = 0.001$) and major liver injuries ($p = 0.006$) were more frequently diagnosed. Patients with DCL also had a higher rate of mortality, complications ($p < 0.001$), prolonged hospitalization ($p < 0.001$), and ICU stay ($p < 0.009$). In severely injured patients with an intricate pattern of injuries, 31% required a DCL, with a 92% survival rate. Severe metabolic failure because of significant liver and abdominal vascular injuries necessitated the use of DCL and improved outcomes. Despite reports of increased survival following the implementation of DCL in the field of emergency surgery, some authors have concluded that evidence supporting the safety and efficacy of damage control is limited [25–27]. While there has been an increase in the number of patients undergoing DCL, we should be aware of the increase in morbidity among patients who undergo DCL unnecessarily.

Chapter 17 sought to provide an overview of trauma epidemiology by examining the first calendar year of data collection for the newly established KSMC registry. We conducted risk-adjusted analyses to compare our outcomes to those of a major Australian trauma center in Melbourne. This was an observational study using records from both hospitals' registries with injury dates in 2018. Demographics, processes, and outcomes, as well as baseline characteristics, were extracted. Inpatient mortality and length of stay were the risk-adjusted endpoints. The Riyadh and Melbourne databases contained a total of 2436 and 4069 records, respectively. The Saudi cohort contained a greater proportion of men than the Australian cohort (86% vs. 69%). The Saudi cohort was younger, with a median age of 36 years compared to 50 years, and road traffic accidents accounted for 51% of injuries. At the Melbourne hospital, the risk-adjusted length of stay was 4.4 days shorter (95% CI: 3.95 to 4.86 days, $p < 0.001$). The odds of dying in hospital were also lower (OR 0.25; 95% CI 0.15 to 0.43, $p < 0.001$). This was the Kingdom's first hospital-based trauma study to compare itself to an individual international center. Although the comparisons have limitations, the findings establish a baseline for measuring continuous improvement in KSA trauma service outcomes.

Early integration of rehabilitation services for trauma patients is expected to improve clinical outcomes and overall quality of life. Chapter 18 of **Part 7** compared the outcomes of selected traumatic brain injury (TBI) patients in terms of discharge destination and length of hospital stay before and after the implementation of an acute intensive trauma rehabilitation (AITR) program at KSMC. A total of 108 and 111 patients, respectively, were managed prior to and following the implementation of the AITR program. Of these, 63 (58.3%) patients were discharged prior to AITR, compared to 87 (78.4%) patients following AITR ($p = 0.001$). The time to discharge from hospital was 52.4 (SD 30.4) days in the pre-AITR group but improved to 38.7 (SD 23.2) days in the AITR group ($p = 0.001$; 95% CI 6.6–20.9). Early integration of AITR resulted in a significant decrease in the percentage of patients referred to another rehabilitation or long-term care facility. Identifying the factors that influence discharge disposition prediction is critical for efficient resource utilization and cost reduction. Numerous factors may influence the location of discharge following hospitalization. The discharge destination may be affected by functional status as a result of early and advanced professional rehabilitation [28].

Future perspectives

Providing immediate care to injured patients is vital for minimizing mortality and promoting long-term recovery [29,30]. Major trauma patients are currently transported to the nearest large hospital in both South Africa and Saudi Arabia, regardless of travel time to the major trauma centers. However, there is considerable coherence in South Africa's prehospital system due to national standardization. Nevertheless, other practical components must be expanded, including interservice communication and collaboration, particularly among private services, and a change away from transferring patients to the closest institution to the most appropriate facility. The establishment of quality assurance methods and clinical audits for paramedic treatment is proceeding at a reasonable pace in both countries. This part of the system has room for improvement in Saudi Arabia through the development of a clear prehospital transportation procedure with trauma triage tools to identify significant trauma patients.

Second, in-hospital trauma services are excellent or near-excellent in both nations owing to the presence of highly competent medical and nursing personnel; however, they are occasionally hampered in South Africa by a resource-constrained situation. The initial phase of trauma resuscitation in the ED requires coordinated, well-equipped, and trained healthcare professionals to make critical, prudent, and urgent management decisions [31]. Our study's findings accentuated the critical nature of ongoing trauma resuscitation training for nursing personnel. Additional research is required to ascertain the effect of trauma resuscitation training on practitioners' knowledge, skills, and ability to practice. More importantly, organizations must identify cost-effective alternatives, implement trauma education methods that are inclusive and accessible to a broad audience across all units, and maximize the benefits of such training while simultaneously improving the quality of trauma treatment. While SI is a useful tool for predicting blood transfusion requirements and outcomes in trauma patients in the ED, careful selection and addition of additional variables in our trauma registry, along with systematic collection of data on patients' presentation and calculation of delta-SI, modified-SI, or age-SI, would be invaluable in the future.

Third, regarding treatment strategies, the NOM for blunt abdominal trauma is widely accepted and regarded as the gold standard. The selective NOM of penetrating abdominal trauma is gradually being accepted by the trauma community. Although a selective NOM for stab wounds already exists, a NOM for gunshot wounds to the abdomen is gaining traction in the context of concurrent CT scanning in patients who do not have peritonism or sustained hypotension. Additionally, interventional radiology or minimally invasive surgery can be used to manage potential complications. In the future, emerging radiological techniques will bolster the conservative approach to abdominal trauma. Occult diaphragm injury is common in left-sided TA stab wounds. The optimal duration of follow-up for conservative approaches is still unknown and could not be established reliably in our trial due to the slow rate of patient accrual, the high rate of patients lost to follow-up, and the brief duration of follow-up. Due to the trial's limitations, a larger multicenter randomized trial is recommended to confirm these findings and to demonstrate the long-term safety of clinical and radiological follow-up. Mediastinal vessel injury can be obvious or subtle after penetrating chest trauma. Many factors influence it, including mechanism, weapon type, patient distance from weapon, and vessel involvement. A transmediastinal gunshot wound or a wound at the root of the neck should alert the physician to the possibility of mediastinal vascular injury. Stroke is the most feared VAI complication, occurring in 10–13% of patients. As a result, early screening of patients with VAI may help to reduce the risk of stroke [32]. Even in cases where antiplatelet agents are contraindicated due to concurrent injuries, screening for BCVI at the time of presentation facilitates treatment planning and close follow-up and possibly avoids delayed presentation with ischemic posterior circulation events.

Fourth, while we reported on in-hospital complications, such as the incidence and nature of SSI and DVT, as well as the outcomes of emergency surgery case triaging, DCL, and a comparison of two major trauma services, future research should focus on survivors' mortality, functional status, and long-term functional outcomes. Cameron asserted that accurate benchmarking requires standardization of variables and comparison of "like with like" [33]. As more data become available, a robust model of risk-adjusted comparisons for processes and outcomes will be developed. A national trauma registry with systematic data collection on patient outcomes would be invaluable for assessing clinically significant injuries, complications, and outcomes.

Fifth, both countries frequently overlook trauma rehabilitation. Advanced rehabilitation services have become critical for enhancing a patient's functional health status following significant trauma. Early intensive rehabilitation significantly decreases dependency, thereby decreasing the need for ongoing community care [34]. The AITR program should be continued and expanded to other trauma services with ongoing surveillance. A physiatrist's leadership and coordination are likely to be effective, particularly for those with severe disabilities following brain injury [35].

In conclusion, for a trauma system to be successful, both countries must address this subject according to local needs. Each region in both countries should have its own infrastructure that is compatible with the national trauma system but tailored to the region's resources and needs to offer care for the injured from prehospital to rehabilitation [36]. There is room for development in this area by reviewing and improving present hospital capabilities prior to establishing a hierarchy among these facilities in relation to trauma services. Additionally, a national registry managed by qualified personnel would help standardize the fields and approach to data collection and entry, thereby improving the completeness of data for both countries. To improve people's health, safety, and well-being, trauma quality assurance and research and development are critical. Although South Africa is a leader in trauma research and development, Saudi Arabia, as an affluent country, should place greater emphasis on this area.

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CHAPTER 20

Summary in Dutch (Nederlandse Samenvatting)

Trauma of lichamelijk letsel is de belangrijkste oorzaak van overlijden en invaliditeit, en het heeft een aanzienlijke impact op het leven van mensen en legt een druk op de gezondheidszorgsystemen over de hele wereld. Traumasystemen, die een georganiseerde benadering bieden voor acuut gewonde patiënten binnen een bepaald geografisch gebied, van eerstelijnszorg tot geavanceerde zorg, hebben in talrijke onderzoeken aangetoond dat ze de resultaten verbeteren. Het doel van het proefschrift is om te kijken naar verschillende aspecten van traumasystemen in twee opkomende landen: Saoedi-Arabië, een land met een hoog inkomen, en Zuid-Afrika, een land met een gemiddeld inkomen, met name op het gebied van preklinische, ziekenhuis- en revalidatie. Hoofdstuk 1 geeft een overzicht van het proefschrift, waarbij de nadruk ligt op trauma als een wereldwijde last, de definitie van een traumasysteem, trauma als een ziektelast voor de gezondheidssystemen van twee opkomende landen – Zuid-Afrika en Saoedi-Arabië – en tot slot een overzicht van de verschillende onderdelen van het proefschrift. In deel 1, hoofdstuk 2, concentreerde de discussie zich op de geschiedenis en de huidige staat van traumasystemen in twee opkomende landen: Zuid-Afrika en Saoedi-Arabië. Het hoofdstuk concludeerde dat, hoewel de huidige traumasystemen van beide landen een aantal sterke punten hebben, zoals opleiding en training van personeel, er verschillende essentiële componenten ontbreken die hen in staat zouden stellen een superieur resultaat te bereiken. Hoofdstuk 3 besprak het nieuwe zorgmodel (MOC) dat is ontwikkeld als reactie op de recente transformatie van de Saoedische gezondheidszorg in het kader van de Kingdom's Vision 2030. Door alle MOC-interventies te implementeren, zal het Saoedische gezondheidszorgsysteem worden gestroomlijnd om af te stemmen op de Kingdom's Vision 2030. Dit initiatief voor transformatie van de gezondheidszorg is geholpen bij de ontwikkeling van het Saoedische traumasysteem, dat werd besproken in hoofdstuk 4. De recente ontwikkeling van het traumasysteem in Saoedi-Arabië is de eerste stap naar verbetering van de nationale traumazorg. Het kan als model dienen voor ontwikkeling in andere gebieden en landen om de resultaten te verbeteren. Deel 2 richt zich op het preklinische aspect van het traumasysteem. Hoofdstuk 5 onderzocht de effectiviteit van het pre-klinische Emergency Medical System bij het vervoeren van traumapatiënten naar het Groote Schuur Hospital Trauma Centre (GSHTC) in Kaapstad, Zuid-Afrika. Tijdens de studie werden 48 index-laparotomieën uitgevoerd, waarvan 13 patiënten postoperatieve complicaties ontwikkelden. Na het eerste contact was de mediane responstijd van de EMS 53 minuten voor

patiënten die complicaties ontwikkelden. Het was significant langer, 21 minuten (p <0,01), dan die zonder complicaties. De studie concludeerde dat de responstijd van EMS de kans op complicaties verhoogde. Als gevolg hiervan moet de snelle reactie van de EMS op transfers van traumapatiënten worden verbeterd. Hoofdstuk 6 onderzocht hoe snel een traumapatiënt in een ziekenhuis arriveert na een verwonding in een land met een laag of middeninkomen, zoals Zuid-Afrika, voor veilige en effectieve toediening van tranexaminezuur voor bloedingscontrole, volgens de historische CRASH-2-studie. Vijftig opeenvolgende patiënten die waren opgenomen in GSHTC werden opgenomen in een prospectieve cohortstudie op basis van de CRASH-2-criteria. De meeste traumapatiënten met ernstige bloeding (74%) presenteerden zich niet binnen het tijdsbestek dat nodig is voor effectieve toediening van tranexaminezuur. Dit suggereert dat als tranexaminezuur beter wordt geïntegreerd in preklinische in plaats van in ziekenhuisprotocollen in een land met een lager middeninkomen met een onderontwikkeld preklinisch systeem, het effectiever kan zijn op populatieniveau. Effectieve traumaopvang op de afdeling spoedeisende hulp is van cruciaal belang voor elk succesvol traumasysteem. In Deel 3, Hoofdstuk 7 onderzochten we de verbetering in kennis na trauma reanimatie training voor zorgprofessionals. De studie maakte gebruik van pre- en post-trainingstesten om de effecten van een traumatrainingsprogramma op de kennis van de deelnemers te evalueren. Tijdens de onderzoeksperiode werden zestien cursussen gegeven en namen 128 verpleegkundigen deel aan het trainingsprogramma. Deze studie vond een significante verbetering in de kennis van de verpleegkundigen na de training (pre- en post-training testscores 5 [4-6] vs. 9 [8-9], p <0,001). De studie concludeerde dat traumatraining van invloed is op de kennisverbetering van verpleegkundigen, waarbij de noodzaak wordt benadrukt om traumazorgprofessionals op te leiden om adequate zorg te bieden. Hoofdstuk 8 was primair gericht op het evalueren van de associatie tussen de initiële shockindex (SI ≥ 1.0) en de behoefte aan bloedtransfusie op de SEH na acuut trauma. Het secundaire doel van de studie was om te kijken naar de uitkomsten met betrekking tot de dispositie van patiënten op de SEH, ICU en het ziekenhuis in termen van verblijfsduur en sterfte. In ons cohort had een SI ≥ 1,0 bij presentatie op de SEH significant hogere bloedtransfusievereisten en slechtere resultaten. De SI-berekening is praktischer en kan snel worden uitgevoerd bij traumapatiënten met beschikbare vitale functies. Dit kan worden gebruikt als screeningsinstrument en dus worden opgenomen in protocollen voor de eerste beoordeling van traumapatiënten. Behandelingsstrategieën in het ziekenhuis beïnvloeden de

resultaten en uiteindelijk het succes van een traumasysteem. Deel 4 van het proefschrift onderzocht en beschreef verschillende behandelstrategieën. Hoewel niet-operatieve behandeling (NOM) de laatste jaren populairder is geworden voor buiktrauma, wordt het zelden gebruikt voor schotverwondingen van de lever (GLI). Hoofdstuk 9 evalueerde de veiligheid van de selectieve NOM van GLI. Tijdens de studieperiode van 52 maanden bij GSHTC werden 54 (28,3%) van 191 GLI-patiënten gekozen voor NOM van hemodynamische stabiliteit, de afwezigheid van peritonisme en CT-beeldvorming. NOM bleek veilig te zijn en geassocieerd met een lage morbiditeit bij zorgvuldig geselecteerde patiënten met GLI. Hoofdstuk 10 bekeek hemodynamisch stabiele patiënten met linkszijdige thoracoabdominale (TA) steekwonden die geen buikoperatie nodig hadden met betrekking tot de vraag of ze verplichte diagnostische laparoscopie moesten ondergaan (Groep A) of veilig konden worden behandeld met klinische en thorax X- ray follow-up (Groep B) in een prospectieve, gerandomiseerde controlestudie uitgevoerd bij GSHTC, een niveau 1 traumacentrum in Kaapstad, Zuid-Afrika. Zevenentwintig patiënten werden gerandomiseerd naar Groep A (N = 27) en 31 naar Groep B (N = 31). De incidentie van occult diafragmaletsel in groep A was 29%. Alle diafragmaletsels gevonden bij laparoscopie werden hersteld. Alle patiënten in groep B hadden normale thoraxfoto's bij hun laatste bezoek. De gemiddelde follow-upduur was 24 maanden (mediaan 24, IQR 1-40 maanden). Er was geen morbiditeit of mortaliteit in Groep B. Klinische en radiologische follow-up was mogelijk en leek op korte termijn veilig te zijn bij patiënten met occult diafragmaletsel na linker TA-steekwonden. Totdat er studies beschikbaar zijn die het natuurlijke beloop van diafragmaletsel bij mensen aantonen, zou laparoscopie de gouden standaard in de behandeling moeten blijven. Hoofdstuk 11 besprak de behandelingsopties voor penetrerende mediastinale vaatletsels. Hoofdstuk 12 besprak de incidentie, aard, screening, diagnose en behandeling van stomp cerebrovasculair letsel, in het bijzonder stomp wervelslagaderletsel (VAI) veroorzaakt door ernstig cervicocephalisch trauma. Complicaties (deel 5) en uitkomsten (deel 6) zijn de key performance indicators (KPI's) van een traumacentrum. Het regelmatig monitoren van dergelijke KPI's is van cruciaal belang voor kwaliteitsverbetering. De incidentie van postoperatieve wondinfectie (POWI) na trauma-laparotomie werd bepaald in Hoofdstuk 13 van Deel 5. De frequenties van SSI na trauma-laparotomie waren vergelijkbaar met die eerder gerapporteerd door andere centra. Hoofdstuk 14 van deel 5 bepaalde de incidentie en aard van de ontwikkeling van veneuze trombo-embolie (VTE) bij

polytraumapatiënten die profylaxe gebruiken. Ondanks profylaxe ontwikkelden drie (1,8%) patiënten DVT en vier (2,4%) patiënten ontwikkelden longembolie (PE) tijdens de indexpresentatie, gediagnosticeerd tussen dag 3 en 13 na het letsel. Er was geen bewijs van vroege DVT bij een van de patiënten met de diagnose PE. In onze kleine serie bleef de incidentie van DVT bij polytraumapatiënten laag, mogelijk als gevolg van de verplichte VTE-risicobeoordeling voor alle gehospitaliseerde patiënten en de vroege start van profylaxe. Bij GSH wordt het Emergency Surgery Triage (EST)-systeem, gebaseerd op de Cape Triaging Score (CTS), gebruikt om chirurgische spoedgevallen, waaronder trauma patiënten, te triageren. Hoofdstuk 15 van deel 6 is een prospectieve studie die het effect van uitstel van chirurgie onderzocht in termen van postoperatieve complicaties en overlijden na planning met behulp van het EST-systeem. De studie concludeerde dat is aangetoond dat de categorisering van chirurgische gevallen effectief is bij het prioriteren van chirurgische spoedgevallen in een traumacentrum met beperkte middelen en een groot volume. Hoofdstuk 16 evalueerde de uitkomsten van laparotomieën met damage control procedures (DCL) die werden uitgevoerd na een abdominaal orgaanletsel, resulterend in ernstig metabool falen. Tijdens de studieperiode van 52 maanden ondergingen 25 patiënten DCL en 55 patiënten ondergingen definitieve chirurgie (DS). Bij ernstig gewonde patiënten met een ingewikkeld patroon van verwondingen had 31% een DCL nodig, met een overlevingspercentage van 92%. Ernstig metabool falen vanwege significante lever- en abdominale vasculaire verwondingen maakte het gebruik van DCL noodzakelijk en verbeterde resultaten. Hoofdstuk 17 trachtte een overzicht te geven van trauma-epidemiologie door het eerste kalenderjaar van gegevensverzameling voor het nieuw opgerichte KSMC-register te onderzoeken. We hebben risicogecorrigeerde analyses uitgevoerd om onze uitkomsten te vergelijken met die van een groot Australisch traumacentrum in Melbourne. Het Saoedische cohort bevatte een groter aandeel mannen dan het Australische cohort (86% vs. 69%). Het Saoedische cohort was jonger, met een mediane leeftijd van 36 jaar in vergelijking met 50 jaar, en verkeersongevallen waren verantwoordelijk voor 51% van de verwondingen. In het ziekenhuis in Melbourne was de voor risico gecorrigeerde opnameduur 4,4 dagen korter (95% BI: 3,95 tot 4,86 dagen, $p < 0,001$). De kans om in het ziekenhuis te overlijden was ook lager (OR 0,25; 95% BI 0,15 tot 0,43, $p < 0,001$). Dit was de eerste vergelijkende traumastudie van een Saoedisch ziekenhuis met een gerenommeerd internationaal centrum. Hoewel de vergelijkingen beperkingen hebben, vormen

de bevindingen een basis voor het meten van continue verbetering van de resultaten van de KSA-traumaservice. Hoofdstuk 18 van deel 7 vergeleek de uitkomsten van geselecteerde patiënten met traumatisch hersenletsel (TBI) in termen van ontslagbestemming en duur van ziekenhuisopname voor en na de implementatie van een acuut intensief trauma revalidatieprogramma (AITR) bij KSMC. In totaal werden respectievelijk 108 en 111 patiënten behandeld vóór en na de implementatie van het AITR-programma. Hiervan werden 63 (58,3%) patiënten ontslagen vóór AITR, vergeleken met 87 (78,4%) patiënten na AITR (p = 0,001). De tijd tot ontslag uit het ziekenhuis was 52,4 (SD 30,4) dagen in de pre-AITR-groep, maar verbeterde tot 38,7 (SD 23,2) dagen in de AITR-groep (p = 0,001; 95% BI 6,6-20,9). Vroege integratie van AITR resulteerde in een significante daling van het percentage patiënten dat naar een andere revalidatie- of langdurige zorginstelling werd verwezen. Hoofdstuk 19 vat de bevindingen in dit proefschrift samen en presenteert een algemene discussie en toekomstperspectieven. Het toekomstperspectief richt zich op verbetering op bepaalde gebieden van traumasystemen in zowel Zuid-Afrika als Saoedi-Arabië, implementatie van een nationale traumadatabase, onderzoek en ontwikkeling, en verbetering van de traumakwaliteit in zorgprocessen en -uitkomsten.

APPENDICES

List of Publications

https://www.researchgate.net/profile/A_H_M_Sharfuddin_Mahmud_Chowdhury

https://scholar.google.com/citations?hl=en&user=BWbVi7kAAAAJ

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Author Biography

Sharfuddin Chowdhury is a trauma surgeon and the director of trauma center at King Saud Medical City (KSMC), Riyadh, Saudi Arabia. He obtained his basic medical degree, MBBS, in 2003, from Chittagong Medical College in Bangladesh. In 2006, Sharfuddin relocated to Cape Town, South Africa, for specialization, earning the FCS (SA) in General Surgery in 2012. He continued his training (fellowship) in Trauma Surgery and earned a MMed (Surgery) degree from the University of Cape Town (UCT) in South Africa in 2014. Sharfuddin decided to pursue a Ph.D. under Prof. Andrew Nicol at UCT in 2014 after identifying a gap in the trauma systems in Cape Town using the information he learned during his MMed and realizing the need for it. His doctoral research focused on an "In-depth analysis of the component of the trauma systems in Cape Town to improve outcomes". His move to Riyadh, Saudi Arabia, in 2016 caused a temporary interruption in his Ph.D. work. After consulting with Prof. Luke Leenen during his visit to KSMC, he resumed his work at Utrecht University and successfully developed the approach to assist hospitals and regions in establishing progressive trauma systems. Sharfuddin is involved in undergraduate, postgraduate, and fellowship teaching and clinical research in addition to his clinical practice. He has authored numerous publications in peer-reviewed journals and served as a reviewer for scientific journals. He is also a member of different national and international surgical societies, including the Eastern Association for the Surgery of Trauma (EAST), World Society of Emergency Surgery (WSES), the Upper Gastrointestinal Surgery (TUGS) global, the European Society of Coloproctology (ESCP), and a Fellow of the American College of Surgeons (FACS). Sharfuddin is the Trauma Services Development Lead at KSMC. He is also at the forefront of Trauma systems development in Saudi Arabia. He is a member of the trauma Clinical Advisory Group (CAG), Vision Realization Office, and Saudi Health Council at the Ministry of Health, Saudi Arabia. Sharfuddin is married to Rifat Jahan and is the proud father of Farwa Chowdhury.