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Dedication

In dedicating the inaugural issue of Sri Lanka Journal of Trauma, we honor the resilience, dedication and collaborative spirit of all those who tirelessly work to advance the field of trauma care and trauma system development.

This journal is dedicated to healthcare professionals, researchers, policymakers, advocates, trauma survivors, and their families, as well as pioneers in trauma care in Sri Lanka. We acknowledge their unwavering dedication, commitment to innovation, advocacy, resilience, and contributions to trauma care, prevention and system development.

As we embark on this journey with the launch of Sri Lanka Journal of Trauma, we acknowledge the collective effort and collaboration required to address the complex challenges of trauma. May this journal serve as a platform for sharing knowledge, fostering innovation, and promoting collaboration in the pursuit of excellence in trauma care locally and globally.

With gratitude and dedication,

Chair & Members of National Trauma Secretariat ,Sri Lanka
and
Editorial Board- Sri Lanka Journal of Trauma

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The content on this journal is intended for healthcare professionals.

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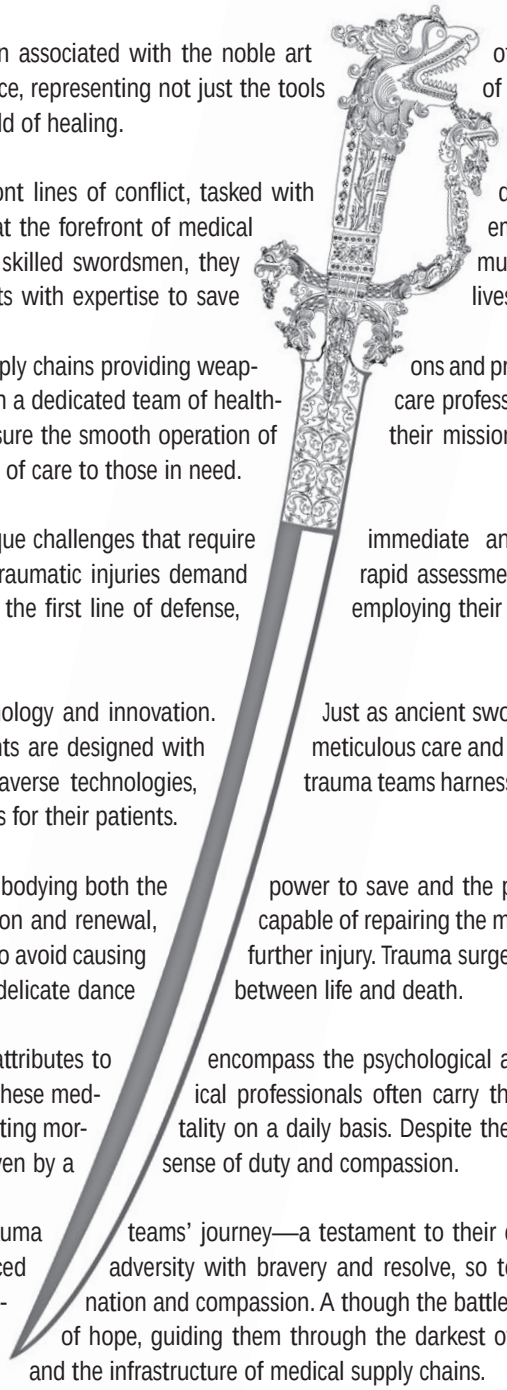
Cover Story

The Sword as a Symbol of Trauma: Navigating the Battlefield of Healing



In the realm of medicine, the symbol of sword has long been associated with the noble art of medicine. For trauma care professionals, this emblem takes on a profound significance, representing not just the tools of their trade, but also the courage, skill, and dedication required to navigate the battlefield of healing.

In ancient times, swords were wielded by warriors on the front lines of conflict, tasked with defending and protecting their communities. Similarly, trauma care professionals stand at the forefront of medical emergencies, confronting life-threatening injuries with precision and decisiveness. Like skilled swordsmen, they must swiftly assess the situation, make split-second decisions, and wield their instruments with expertise to save lives.

Yet, behind every warrior stood a network of support, from supply chains providing weapons and provisions to fellow soldiers offering aid and camaraderie. Likewise, trauma surgeons rely on a dedicated team of healthcare professionals—from nurses and anesthesiologists to radiologists etc. and support staff—to ensure the smooth operation of their missions. Together, they form a cohesive unit, working tirelessly to deliver the highest standard of care to those in need.

Trauma, often referred to as a "surgical disease," presents unique challenges that require immediate and decisive intervention. Whether caused by accidents, violence, or natural disasters, traumatic injuries demand rapid assessment and treatment to prevent further harm. In this regard, trauma care teams serve as the first line of defense, employing their skills to stabilize patients and mitigate the effects of injury.

The sword also symbolizes the cutting edge of medical technology and innovation. Just as ancient swords were forged with the finest materials and craftsmanship, modern surgical instruments are designed with meticulous care and precision. From advanced imaging techniques to minimally invasive procedures to metaverse technologies, trauma teams harness the latest advancements in science and technology to ensure the best possible outcomes for their patients.

Moreover, the sword represents the dual nature of healing, embodying both the power to save and the potential for harm. In the hands of an expert professional, it becomes a tool of restoration and renewal, capable of repairing the most grievous wounds. Yet, like any instrument, it must be wielded with care and precision to avoid causing further injury. Trauma surgeons must balance the urgency of intervention with the need for caution, navigating a delicate dance between life and death.

Yet, the symbolism of the sword extends beyond its physical attributes to encompass the psychological and emotional challenges faced by trauma surgeons. Like warriors returning from battle, these medical professionals often carry the weight of trauma and loss. They witness the raw brutality of injury and illness, confronting mortality on a daily basis. Despite the toll it may take on their own well-being, they steadfastly remain on the front lines, driven by a sense of duty and compassion.

In essence, the sword serves as a powerful symbol of the trauma teams' journey—a testament to their courage, skill, and unwavering commitment to healing. Just as the ancient warrior faced adversity with bravery and resolve, so too do these modern-day heroes confront the challenges of their profession with determination and compassion. A though the battlefield may be fraught with uncertainty and danger, the sword remains a steadfast symbol of hope, guiding them through the darkest of times towards the light of healing and renewal, supported by their dedicated team and the infrastructure of medical supply chains.

Concept ; Dr Gayan Ekanayake, Dr A I Jagoda & Dr Nanadana Kumara. **Written by** Dr Gayan Ekanayake & Dr A I Jagoda. (Generative artificial intelligence (AI) and AI-assisted technologies used to enhance readability and language of this narrative. Authors reviewed and edited the AI generated content.)

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Editorial

Commercial Determinants of Health and its influence on trauma care

Asela Gunawardena[1] MBBS, MSc, MA,MBA, DPBS, FCMA

Commercial determinants of health (CDoH) are the private sector activities that affect people's health, directly or indirectly, positively or negatively. The private sector influences the social, physical, and cultural environments through business actions and societal engagements. CDoH includes all products and services provided by private entities to gain a financial profit, market strategies, research funding, working conditions, production externalities, and political activities, such as misinformation, lobbying, and donations. Some parts of the private sector also use instrumental, structural, and discursive power to undermine public health policies that threaten profits. Therefore, CDoH impact a wide range of health outcomes, such as non-communicable diseases, communicable diseases and epidemics, injuries on roads and from weapons, violence, and mental health conditions[1,2]

"Many of the most significant risk factors for disease and injury – tobacco, alcohol and unhealthy diet – are major industries and profit-drivers for some of the world's biggest companies."-wrote WHO Director-General Dr Tedros Adhanom Ghebreyesus in his commentary in the Lancet Series on Commercial Determinants of Health [3]. It was found that four industry sectors (ie, tobacco, ultra-processed food, fossil fuel, and alcohol) already account for at least a third of global deaths[4].

In recent years, the landscape of trauma has evolved beyond the traditional boundaries of physical injury and psychological distress. We find a complex interplay of factors, where the commercial determinants wield significant influence on trauma. As the term "commercial determinants of health" has gained traction in public health discourse, acknowledging the profound impact of commercial entities on health outcomes. Similarly, we propose the concept of "commercial determinants of trauma," recognizing the multifaceted ways in which commercial interests intersect with the experience and management of trauma , both positively and negatively

From road traffic accidents fueled by aggressive marketing of automobiles to workplace injuries exacerbated by profit-driven production targets, the influence of commercial forces on trauma is undeniable. Moreover, the proliferation of harmful use of alcohol, tobacco (and substance abuse) contributes significantly to the burden of trauma through accidents, violence etc.

Furthermore, industry's marketing strategies shape the trajectory of trauma care, often prioritizing profit over people and planet. This commodification not only influences treatment modalities but also creates stigma and inequities in access to care.

Commercial determinants even have an impact on accessing and sharing knowledge. The study published by LaGrone et al examines the financial barriers faced by low/middle-income countries (LMICs) in the form of article processing charges (APCs) to publish into, and pay walls to read and access, major surgical journals. According to the study , the mean APC for a fully open access surgical journal was US$1574 and for a hybrid surgical journal was US$3338. The average costs for a 1-year subscription in a hybrid surgical journal were US$434 and US$1878 for an individual and institution, respectively. The subscription fee may be a barrier to access and share latest knowledge in trauma care.[5,6] Simultaneously, the private sector is an indispensable partner for development by, for example, creating vaccines, medicines and assistive products, financing research & development, building infrastructure and delivering health services towards Universal Health Coverage [1].

Some of the safety measures used today are from the private sector. The modern three-point safety belt was perfected by Volvo engineer Nils Bohlin in 1959 and its patent given for free to the world. The invention has been credited with saving at least a million lives worldwide [7]. The continuous competition to produce safer and greener vehicles has contributed to save people and the planet while fostering innovation and increasing profits. There are many other examples.

In Sri Lanka, as in many other countries, the commercial determinants of trauma intersect with broader social, economic, and political dynamics. Understanding these intersections is crucial for developing comprehensive strategies to prevent and address trauma effectively.

For scholars and practitioners in the field of trauma, it is important to critically examine and confront the commercial determinants that shape trauma care. This requires interdisciplinary collaboration, rigorous research, and advocacy efforts aimed at challenging the status quo and promoting health equity.

To advance the trauma care in Sri Lanka , it is important to recognize and address its commercial determinants with the urgency and diligence it demand. Only then can

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we truly fulfill our commitment to alleviating suffering and promoting resilience in our communities.

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Towards a mature trauma system in Sri Lanka

Editorial

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Indika Jagoda[3] MBBS, MSc, MD, MBA, DDM

The publication of the Sri Lanka Journal of Trauma (SLJT) marks a significant milestone in the field of medical research and trauma care development in Sri Lanka. SLJT is an open access, peer- reviewed multidisciplinary publication committed to advancing the frontiers of trauma care. Published quarterly, this is the official Journal of National Trauma Secretariat of Sri Lanka (NTSSL). As a premier platform backed by the NTSSL, this journal is dedicated to fostering innovation, knowledge exchange, and the dissemination of cutting-edge research in injury prevention, trauma management and system development. We sincerely hope that these will contribute to the enhancement of current scientific knowledge and practices. We are following the best possible editorial process and practices to ensure quality and accuracy of scientific writing.

The recent history of organized trauma care in Sri Lanka can be traced back to the year 1965/66 with the establishment of the dedicated trauma center (Accident Service) at the Colombo General Hospital (currently National Hospital of Sri Lanka - NHSL). Since then trauma care has evolved rapidly in Sri Lanka. We have passed the initial stage and now looking forward towards a mature trauma care system which is on par with the best practices.

To evaluate a trauma system in a country, the World Health Organization (WHO) has published a maturity index (Table 1)[1]. It has several defined domains. One of the most important domains is the prehospital trauma care. Sri Lanka is in a constant mechanism to upgrade itself in this area over several decades. [2]

One of the key areas in pre hospital care is the safe transfer of patients. To address the issue of safe pre hospital transport of patients, in the year 2007 , the first pre hospital ambulance service was initiated in Sri Lanka with the introduction of toll free call number 110. This was by the Colombo Fire Department which is under the Colombo Municipal Council (CMC). It was a collaborative effort between CMC, Accident Service of NHSL and the Trauma Secretariat. However services were restricted to the CMC area. The turning point was the establishment of island wide, toll free pre hospital ambulance service "Suwasariya" in 2016 with the initial support from the government of India. It started with 88 ambulances and now expanded to 687 ambulances . Service is available island wide with an average response time of 8-12 minutes. There are few private ambulance operators also.

Table 1 ([1])

Prehospital Trauma Care	
Level I	•No mapping of prehospital resources •No formal EMS, unavailability or duplication of prehospital services •No defined communication system
Level II	•Prehospital resources are identifiable •No coordination between public and private providers of prehospital care •No universal access number, weak links of communication
Level III	•Formal EMS present •Universal Access Number available •Coordination seen between various agencies for prehospital care delivery •Well defined communication
Level IV	•Formal EMS controlled by a lead agency •National universal access number •Legislative mechanism in place to govern EMS and allow universal coverage

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However the primary transfer of trauma patients, weather it is major-trauma or minor trauma, majority is by private vehicles , most commonly by three wheelers which are ubiquitous in Sri Lanka. This was confirmed by two studies done in Nothern province in Sri Lanka and in Galle district in Southern part of Sri Lanka. These studies showed that 52.6% and 52.8% of trauma victims respectively were transferred by three whelers. However, the major trauma and minor trauma transfer contribution by three wheelers is unclear. This calls for further studies on different modes of primary transfers including how the community utilizes the free ambulance service in trauma transfer.

Most of the times, trauma patients are transferred to the nearest health care facility irrespective of the level of care needed. After initial stabilization and care, secondary transfers occur to the to the next level of institution or sometimes to a centre where definitive care can be provide All these inter hospital transfers (in the government sector in Sri Lanka) require a transfer form (health form) to be completed. Despite having one of the simplest transfer forms, studies have indicated incomplete documentations are common[8]. The form being one of the basic documents in the health sector needs improvements.

In trauma care, initial stabilization and timely transfer of patients to a trauma center where appropriate level of care can be provided is crucial to improve outcomes. In Sri Lanka, as majority of trauma victims are bought to the hospital by private vehicles, it is important to have community education and training programmes on first response by public. The other is to develop and implement major trauma destination policy which ensure right patient is transferred to the right level of care facility at the right time. Real time tracking of ambulances by using GPS technologies will not only enable to develop hospital alert system but also will ensure efficient management of resources. This will facilitate central coordination of ambulance transfers. Further use of augmented reality and virtual reality technologies will enable to have a "connected ambulance "which further enhance the care of the injured and critically ill. These steps can help Sri Lanka to move to next level in the maturity index.

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Raising the bar on trauma standards in Sri Lanka

Guest Editorial

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It is a great honor to write an invited Guest Editorial for the inaugural issue of the Sri Lankan Journal of Trauma. This initiative undertaken through the Sri Lankan National Trauma Secretariat will provide a valuable platform for the entire trauma team to showcase their research and academic efforts. Having recently seen some of the results of trauma patients cared for within the Sri Lankan health care system, it is abundantly clear there is already excellent clinical care being provided to trauma patients at the National Hospital, in collaboration with regional hospitals across Sri Lanka. It is exciting to see the Sri Lankan surgical community take this next step forward toward supporting scholarly efforts and research productivity in surgeons and others interested in elevating the academic and clinical standards of trauma surgery. Establishing trauma as a distinct academic surgical specialty will encourage those currently in training - the next generation of surgeons – to view trauma as a fruitful area of specialty focus; one that is clearly necessary and beneficial to a large number of patients across the country. Perhaps even more importantly, launching a journal synergizes with attempts to develop a comprehensive coordinated national trauma system, which is an essential step toward reducing the burden of injury in any country.

Trauma is the number one killer of children and young adults worldwide, including in the United States where I live and practice. Despite this statistic remaining unchanged for many decades, trauma research remains extremely poorly funded compared to cancer research, for example. The reasons for this disparity are multifactorial: a lack of awareness by the general public of the higher prevalence of injury compared to heart disease and cancer, lack of recognition that research can lead to better treatment and prevention, and trauma surgeons being too busy simply taking care of the many patients arriving at our door to have time to engage in public education and advocacy!

As one example of the discrepancy between the scope of the problem and the investment in solution: the US is the only country in the world where – outside of active war – gunshots are the leading cause of death in children, surpassing even motor vehicle accidents. This statistic is a great cause for embarrassment to myself and my fellow trauma surgeons in the US; yet despite much effort from the surgical community, we have remained unable to convince legislators to take significant action on restricting civilian access to weapons of war, or investing in research on firearm injury prevention. I share this anecdote as a reminder that while we as a trauma surgeon community spend much of our time focusing on improving our surgical practice and clinical outcomes, followed by performance improvement in our trauma care delivery system, prevention remains the ultimate goal of our profession – essentially, we want to put ourselves out of business. As the Sri Lankan trauma system evolves, it will be important to remember that all aspects: research, education, performance improvement, system development and prevention will need to be included in order to reach the ultimate goal of improving outcomes for all injured patients.

In 2016, the National Academies of Science, Engineering and Medicine (NASEM) in the United States set forth the ambitious goal of Mission Zero: achieving zero preventable trauma deaths[1]. This effort was initiated based on the realization that even in the richest country in the world, where many states (such as Texas, where I live) have had a comprehensive, well-developed and robust trauma system for decades, one-third of seriously injured patients are not taken directly to a high-level trauma center, and 2 out of 5 patients who were alive when emergency services first arrived on scene (a marker of survivability) subsequently died in hospital. NASEM estimated that in 2016, one in five trauma deaths in the US were potentially preventable with optimal care, and thus the number of lives that could potentially be saved warranted a significant investment of effort and energy on the part of experts in the field. The five broad categories they identified as targets for this effort: Emergency medical services/ambulance system infrastructure and trauma system organization, research and research funding, data and data linkage, work force education and training, and political advocacy as an overarching umbrella. Despite differences in social and cultural background, financial resources, insurance structure and existing trauma system infrastructure, I believe this multipronged effort highlights useful areas of focus for any trauma system in the world seeking to reduce the toll of preventable deaths from injury to a minimum.

As surgeons, we tend to focus on advances in surgical technique and equipment, and certainly there have been notable advances in trauma as well. The use of percutaneous catheters to replace large chest tubes for hemothorax and pneumothorax,[2] along with surgical rib fixation of flail chest and multiple rib fractures has reduced ventilator days, expedited discharge from hospital and reduced short- and long-term pain scores in many patients, including the growing population of elderly patients who sustain rib fractures after ground-level fall [3]. The use of REBOA remains controversial, however there are undoubtedly cases in which occluding the aorta without resorting to thoracotomy has saved lives and allowed time for definitive surgical hemorrhage control[4]. However, in my career as a trauma surgeon the greatest improvements in patient

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outcome have not come from the purchase of a new, fancy device; rather, they have been the result of painstaking improvements in the system that have required the participation of the entire multi-disciplinary team. One example is the "fly-by" direct-to-OR protocol that I developed at my own trauma center at University Medical Center in Lubbock, Texas in 2016. The FlyBy refers to a system where a patient who has a high chance of requiring immediate surgical bleeding control is taken directly to the operating room from the ambulance bay, essentially bypassing all Emergency Room assessment. This initiative was spurred by a case where I received a 14year old boy with a trans-abdominal gunshot wound from a town 2 hours away. Blood transfusion had been started at the outside hospital, and from the description of bullet wounds it was clear there was almost certainly major abdominal injury. That night, we tested the premise by having the ambulance flight crew roll the patient's stretcher directly to the operating room; after a quick Xray to delineate missile trajectory we started operating, and were able to have a very successful outcome in a patient with significant liver, pancreas and spleen injury. The patient arrived hypotensive and likely on the verge of cardiac arrest; by having the room prepared and blood products already available, we minimized any delay in bleeding control – the number one step in saving a trauma patient's life. Although this violation of usual procedure certainly triggered initial anxiety and a few complaints from staff, it was clear this unstable patient was better off being taken immediately to the OR than anywhere else. While this is intuitive to all trauma surgeons, literature has been subsequently published validating that time to bleeding control is the primary indicator of survival in trauma patients with major bleeding[4].

Having proven that a direct-to-OR method was feasible, we then met with operating room directors and nurses, anesthesiologists, ER physicians and staff, and created the protocol that would subsequently be deployed smoothly and regularly. During this phase we addressed all the problems that had been noticed in the initial "proof of concept" case: who would enter the patient into the hospital electronic system? How would Xrays be obtained? How would the OR and anesthesiologist be notified? How much lead time notice was required for blood to be already available in the room when the patient rolled in? Who would make the decision to activate the fly-by system, when, and how would this be communicated to the entire team? Once an initial protocol had been developed, we then practiced several times with simulation and drills, to ensure any further kinks were identified and corrected. Since massive bleeding requiring surgery remains a relatively small proportion of all injured patients, it was important that any system developed for these patients be practiced outside of patient care, since there would not be frequent enough use of the protocol to ensure all staff remained familiar. Since that first case, we have treated many patients using this protocol, and it is now a firmly established tool in our toolbox that has allowed us to reduce time to bleeding control and save lives in many patients.

Trauma surgery (including burn surgery) is the surgical specialty that has the closest ties between civilian and military surgeons. In fact, the history of trauma surgery is the history of advancements first recognized on various battlefields around the world, and then extrapolated into civilian practice – massive transfusion, acute respiratory distress syndrome, damage control laparotomy, torniquet use, and extracorporeal membrane oxygenation are all techniques first deployed in military conflict zones prior to routine incorporation in the care of critically injured civilian patients. Current hot topics include the use of whole blood for massive bleeding rather than components such as packed red blood cells, to prevent the inevitable coagulopathy these patients quickly develop that is often life-threatening. Ironically, the use of whole blood for injures soldiers was commonplace in World War II, before the techniques to fractionate blood had even been invented! Thus, what is old becomes new again, and lessons learned from military surgeons help inform civilian practice, and vice versa. Sri Lanka has already developed robust military-civilian partnerships, stemming from the prolonged experience of facing terrorism and civil war for over 30 years, and continues to utilize the breadth of expertise available in the military sector to inform trauma care in the civilian setting. This natural synergy is an excellent platform from which to continue to grow collaboration and develop ever more robust trauma systems, protocols, guidelines and practice standards for every level of facility throughout the country.

As the journal develops I look forward to seeing high-quality articles spanning the spectrum of trauma care, from case series of complex patients to reviews of infrastructure and performance improvement processes, to allow Sri Lankan surgeons to educate each other and contribute to the knowledge base of trauma care across the world.

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TRAUMA SECRETARIAT SRI LANKA

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Original Article:

Resilience in terror and disaster medicine through consolidation of institutional memory - National Hospital Sri Lanka Easter Sunday 2019 experience

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Keywords - terror medicine, suicide blast, blast injury, mass-casualty management, trauma systems, National Hospital Sri Lanka, institutional memory

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Background

Suicide bombing generates a significantly larger number of casualties per attack than other uses of force by terrorist groups. Acts of terrorism are evolving and becoming more complex. Health emergency trauma care systems should advance and be resilient to withstand shocks of terror mass casualty event while catering routine community care. Easter Sunday emergency and trauma care response at the Accident Services National Hospital Sri Lanka (AC-NHSL) accrued invaluable lessons to be learned and shared with global emergency care fraternity.

Method

Sri Lanka lacks a mature trauma network and fully scaled emergency medical services (EMS) facing a terror attack following nine years of peace after ending three decades of civil war prompted our research team, Easter Sunday Attack Research Consortium (ESARC) to analyze the perspective of challenges encountered and strategies used in terror mass casualty incident (MCI) to improve on.

Findings

Qualitative research into the 2019 MCI highlighted the wealth of experience NHSL staff gained facing multiple MCIs in the past. Prompt activation of disaster management plan drilled just two weeks prior to the incident, better fleet of prehospital ambulance service (1990- SUWASERIYA), overwhelming staff response, commitment and volunteerism, leadership contribution by experienced consultants well versed with past mass casualty incidents, communication and coordination with media and foreign embassies were the positive aspects of the Easter response.

AC-NHSL was developed at the height of the Sri Lankan Civil War after multiple terror-related MCIs and maintained indelible institutional memory despite the years of ensuing peace. In The 2019 Easter MCI highlighted issues outside human and material resources as the greater challenges: communication, security, and coordination with other agencies.

Conclusion

Terror mass casualty events are complex, evolving, and infrequent. Lessons learned rapidly dissipate and forgotten if not carefully accrued and integrated into institutional memory.

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Introduction

Terrorism inflicts society in many forms, including armed assaults, hijackings, hostage-taking, drone attacks and varying types of bombings including suicide bombings. Prominent weapon in the armamentarium of violent nonstate actors, suicide bombing generates a significantly larger number of casualties per attack than other uses of force by terrorist groups. The ability of the suicide bomber to deliver a relatively large explosive load accompanied by heavy shrapnel to the proximity of targeted victims has caused devastating effects[1].

Terrorist targets can also vary and can be aimed at civilians, state actors, or public infrastructure including health care institutes. According to the global terror index 2021 (GTI) report, 7,142 deaths from terrorism recorded. The number of countries experiencing a least one death from terrorism in 2021 was 44. South Asia remains the region with the worst average GTI score in 2021, with the region recording 1,829 deaths from terrorism in 2021. In 2020, 97.6 percent of deaths from terrorism occurred in conflict affected countries. Terrorist attacks in conflict countries are more than six times deadlier than attacks in peaceful countries[2].

Terrorist attacks pose a challenge to even mature trauma systems in the global north. The culprits manage to infiltrate the modern defense mechanisms and inflict the deadly blow in the most unexpected moment. The number of victims and their injuries vary depending on the context of the target incident. The survival of the injured will depends on seamless continuum of care from scene of injury to trauma center; triage to identify most critically injured, the efficient transport of survivable victims by emergency medical services (EMS) and the capabilities of the medical facilities and personnel therein to distribute and perform critical life and limb saving procedures without exhausting available resources[3,4].

In an aftermath of a terror event, trauma network function as such that the individual patient receives the best possible treatment but also that individual hospitals are not overwhelmed by patients. This means that available prehospital decision-making and treatment algorithms as well as network structures can be used not only for the management of single injured patients but

also for the tailored and coordinated distribution of multiple patients in a mass-casualty situation[5].

Sri Lanka lacks a mature trauma network and fully scaled emergency medical services (EMS) facing a terror attack following nine years of peace after ending three decades of civil war prompted our research team, Easter Sunday Attack Research Consortium (ESARC) to analyze the perspective of challenges encountered and strategies used in terror mass casualty incident to improve on[6,8].

Background

The health care Institutes in the capital Colombo, Colombo suburbs and borderline towns in the warzone were inflicted by multiple terror events during the 30-year-old civil conflict; these attacks were part of civilian life till the year 2009. Since then, the country has seen peace, and such incidents were not heard of till the easter Sunday of 2019 when multiple bombs were exploded in the Colombo city as well as outside.

Accident Services of the National hospital Sri Lanka (AS-NHSL) the apex trauma center (compatible with American College of Surgeons level 1) of the Island nation. AS-NHSL treats about 100,000 patients per annum of which almost one third are given in- house care. It is a purpose-built trauma institution with a separate building and entrance of its own. It has a well demarcated triage, resuscitation areas and space allocated for Priority 2 and Priority 3 patients. It has two dedicated acute trauma wards and two intensive care units with a capacity of 10 ventilator beds. The most remarkable feature of the institution is the three dedicated trauma theaters which function 24/7 handling trauma victims with inhouse consultant surgeon. AS-NHSL is fortified with adjoining robust neuro-trauma and orthopedic units.

The Orthopedic department of the accident service consists of four units with bed strength of four hundred and thirty which functions under direct supervision of four senior consultant Orthopedic surgeons[9].

The Neuro-trauma center is equipped with an Emergency Treatment Unit, eight operation theaters, six ICU units inclusive of 66 beds, a High Dependency Unit and Wards with 228 beds to provide a better service for head injury patients. A Helipad is also built to facilitate transfer of critical patients by helicopters in case of an emergency[9].

Easter Sunday blast was the first ever large-scale mass casualty event responded by Sri Lanka's first ever Island wide free ambulance service; SUWASERIYA established by Act of Parliament in 2016, with a fleet of 88 ambulances, a generous grant from the government of India and functions under Primary Health Care, Epidemics and COVID Disease Control State Ministry. 1990 Suwasariya provides island-wide, free pre-hospital emergency care to all Sri Lankans, with an average response time of 15:32 minutes. 297 SUWASERIYA ambulances are strategically located in police stations across the island and are connected to fast and efficient call centers that operate 24/7 to ensure medical emergencies. Victims receive the immediate attention it requires. Suwasariya currently, served by a 1390+ member passionate team. After initial training of EMTs in India, now the organization has shifted the training to a specifically designed Diploma in Paramedical Sciences for EMTs conducted by the Faculty of Medicine, University of Kelaniya[10,11].

Institutional memory

The eight storied Accident and Orthopedic services building was constructed and equipped under the General Hospital, Colombo, rehabilitation project which was funded by the Finland government and declared open in 1991.The unit since its inception has catered for many natural and manmade disasters including the Indian ocean tsunami in 2004 and multiple (more than fifty) terrorist bombings during the civil war (1980-2009) has made the AS- NHSL well adapted and resilient in dealing with large scale incidents. The worst-case scenario was the central bank bomb blast in 1996, by a 440-pound high explosive mounted lorry accompanied by an attack with semi-automatic rifles and rocket-propelled grenade launchers at the prime financial hub in Colombo. NHSL received 1300 victims in less than one hour with a recorded 76 deaths. But since the end of civil war in 2009 the incidents were far sparse in frequency and in volume. But NHSL accident Services 'institutional memory, which has been well established over the years, was instrumental in bouncing back to a resilient state catering to the Easter Sunday disaster victims[7,9,12].

Incident Description

On 21st of April 2019 between 8 25 am and 9 20 am, 6 bombs were exploded. Four in Colombo, out of which 3 were in five-star hotels and one in a St Anthony's Catholic Church. Another two blasts occurred in St Sebastian Church Negombo and in Zion church, Batticaloa, 20 km north of Colombo and in 300 km east of Colombo, respectively.

Almost all patients from the Colombo blasts were directly admitted to AS-NHSL. Some of the severely injured patients from the Negombo blasts were transferred secondarily to Colombo NHSL for further specialized care[13,14].

A total of 259 patients died in the blasts and over 500 were injured. The national hospital received 251 admissions out of which 50 were dead on arrival. First patient received by the trauma unit was at 9.05 am approximately 20 minutes after the first explosion. Out of the victims, 208 were found to be Sri Lankans and rest of the 43 were foreigners. Majority of the patients were in the 3rd to 5th decades of life depicting the normal distribution of the general population. Out of the live admissions, 17% (34) were categorized as severe injuries (Priority 1) and 23% (46) were found to be moderate injuries (Priority 2) while 60% (121) were categorized as walk-in casualties (Priority 3).The victims had a remarkable number of head injuries. This is presumably due to most of the victims being in the seated position inside the church while the terrorist being in standing position[7].

Surgical interventions and outcomes

135 operative procedures were performed in the first 24 hours consisting of 8 laparotomies, 21 craniotomies, 4 vascular procedures, 30 orthopedic procedures, 56 wound debridement and 16 burn patients.

Easter response had more lifesaving neurosurgeries performed in comparison to similar events in the past. The NHSL Department of Neurosurgery communicated with peripheral hospitals to direct management of neurotrauma.

Out of the 201 live admissions there were 5 deaths during subsequent institutional care.

There were 35 consultants and 50 medical officers involved in the MCI response at NHSL. Accident and emergency, general surgery, neurotrauma, orthopedic, vascular, reconstructive, anesthesia critical care and radiology services were the main disciplines contributed in patient management during the Ester response[7,8].

Lessons learned

Mass casualty incidents (MCIs) are diverse, unpredictable, and increasing in frequency, but preparation is possible and necessary. Mass casualty preparedness is a complex, iterative process that requires an integrated, multidisciplinary, and tiered approach. Through effective

preparedness planning, trauma systems should be well-placed to deliver an optimal response when faced with MCI[5].

Qualitative research into the 2019 MCI highlighted the wealth of experience NHSL staff gained facing multiple MCIs in the past. After nine years of peace, the immediate response was intuitive. The initial flood of patients arrived within 15 to 30 min of the bombings, before activation of the MCI plan, which resulted in initial chaos. The first wave consisted of 50 critically injured patients loaded on a bus by security forces with no medical triage or treatment initiated. Experienced consultants and senior staff took on the challenge of triaging, while another team established surge capacity by vacating ICUs and wards. Three anesthetists, who faced similar prior events, expedited preparing the operating theaters with staff.and equipment to receive the first surgical cases. Prompt activation of disaster management plan drilled just two weeks prior to the incident, better fleet of prehospital ambulance service (1990- SUWASERIYA), overwhelming staff response, commitment and volunteerism, leadership contribution by experienced consultants well versed with past mass casualty incidents, communication and coordination with media and foreign embassies were the positive aspects of the Easter response.

AC-NHSL was developed at the height of the Sri Lankan Civil War and therefore maintained adequate staff and resources despite the years of ensuing peace. In The 2019 Easter MCI highlighted issues outside human and material resources as the greater challenges: communication, security, and coordination with other agencies[4,9].

Conclusion

Twenty first century geopolitical environment made terrorist attacks become more frequent and lethal with the rise of religious ideological movements, necessitating resilient health care system to counteract complex emergency surgical care needs. Number and complexity of the wounded consistently challenged emergency and trauma care system continuum and terrorist tactics are evolving. National Hospital Sri Lanka is well resourced, and decades long war experiences left indelible mark of institutional memory. Being a robust, well-resourced accident and emergency care center in a developing nation, institutional memory of the Accident Services - National Hospital Sri Lanka is invaluable knowledge to share with global emergency and trauma care fraternity.

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Announcement:

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Sri Lanka Journal of Trauma

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Original Article:

Fasciotomy done for vascular trauma at a tertiary care centre in Sri Lanka.

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Keywords - Fasciotomy, delay, Sri Lanka, National Hospital of Sri Lanka, compartment syndrome, compartments of leg

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ABSTRACT

Introduction Compartment syndrome is a major factor contributing to limb loss and poor outcome following lower limb vascular injuries.

Method

This is a retrospective study done on patients with vascular injuries and undergone fasciotomy at the accident service operation theatre (ASOT) at the national hospital of Sri Lanka (NHSL), during a period of one year. Cases with Incomplete documentation were excluded. Data on patient demographics, time of injury, and time of fasciotomy, associated fractures, muscle viability and outcome were collected.

Results

A total of 30 cases were included. 26 (86%) were males. Nine (30%) were upper limb and 21(70%) were lower limb fasciotomy. The cause for limb injuries were road traffic accidents (RTA) in 18 (58.1%), trap gun injury in five (16.1%). All the fasciotomy were done prior to revascularization. 19 (63.3%) had fractures (12 (63%) were open and seven (36%) closed). six (20%) fasciotomy were done for compartment syndrome, 24 (80%) were done prophylactically. Three patients with compartment syndrome had open fractures (50%) and three had closed fractures (50%).

On fasciotomy, in four cases all four leg compartment muscles were non-viable, two had non-viable three compartments and one patient had non-viable two compartments. The mean delay in patients who had all compartments viable was 3.7 hours (2-6.5) and the mean delay in patients with three or four non-viable compartments was 12.2hours (7-24). This difference was statistically significant (p-0.0001). The fasciotomy delay was also significant (p-0.0001) between the patients who had an amputation and limb salvage. Overall amputation rate was 20% in this series. Mean time of delay from admission to NHSL to the time of fasciotomy was 1.8 hours (1-3.5). Mean time of injury to time of fasciotomy was 5.42 hours (2-24).

Discussion

Number of non-viable compartments is significantly associated with the duration between time of injury to time of fasciotomy(P-0.0001). Therefore we suggest early fasciotomy before transfer.

Introduction

Compartment syndrome is increased intra compartmental pressure resulting in reduced tissue perfusion within the compartment. Compartment syndrome is a major problem contributing to muscle death and poor outcome following lower limb injuries. The percentage of patients developing compartment syndrome and needing fasciotomy varies between 28% to 62% [1,2]. Following limb trauma, fasciotomy is performed for the following purposes, i.e. Therapeutic, prophylactic and diagnostic purposes.

Therapeutic fasciotomy is done when the patient already has an established compartment syndrome. Prophylactic fasciotomy is done on a patient who has a high risk of developing compartment syndrome. Whereas the diagnostic fasciotomy is done when there is a need to assess the viability of the compartments. Delay in fasciotomy results in death of the muscles and finally the limb. There are many patients who presents with compartment syndrome at the accident service at the national hospital of Sri Lanka (NHSL). Data on such patients are lacking. Therefore this study was done to assess the existing practices related to the compartment syndrome following limb trauma.

Method

This is a retrospective study done on patients with vascular injuries and underwent fasciotomy at the accident service operation theatre (ASOT) at NHSL, during a period of one year. Data were collected from the admission records, the theatre register and the operation notes. Data on patient demography, time of injury, and time of fasciotomy, associated fractures, muscle viability and outcome were collected. Cases with Incomplete documentation were excluded.

Results

A total of 30 cases were included. 26 (86%) were males and four (13%) were females. Nine (30%) were upper limb fasciotomy and 21(70%) were lower limb fasciotomy. The cause for limb injuries were road traffic accidents (RTA) in 18 (58.1%), trap gun injury in five (16.1%). All the fasciotomy were done prior to revascularization. 19 (63.3%) had fractures, out of them 12 (63%) were open and seven (36%) were closed fractures.

Six (20%) fasciotomy were done for compartment syndrome and 24 (80%) were done prophylactically. Three patients with compartment syndrome had open fractures (50%) and three had closed fractures (50%).

On fasciotomy, in four cases all four leg compartment muscles were non-viable, two had non-viable three compartments and one patient had non-viable two compartments. The mean delay in patients who had all compartments viable was 3.7 hours (2-6.5) and the mean delay in patients with three or four non-viable compartments was 12.2 hours (7-24). This difference was statistically significant (p-0.0001). The fasciotomy delay was also significant (p-0.0001) between the patients who had an amputation and limb salvage. Overall amputation rate was 20% in this series. Trap gun injuries resulted in higher rate of amputation (66.6%) than penetrating trauma (33.3%). 22 fasciotomy (73%) were performed within 6 hours of injury. 60% patients presented to accident service within 2 hours of the injury. Mean time of delay from admission to NHSL to the time of fasciotomy was 1.8 hours (1-3.5). Mean time of injury to time of fasciotomy was 5.42 hours (2-24).

Discussion

Number of non-viable compartments is significantly associated with the duration between times of injury to time of fasciotomy. (P <0.0001).The risk of amputation is also directly associated with the delay. Closed fractures were associated with more completely non-viable limbs (1/10vs3/12).

Leg is a common site of vascular trauma and compartment syndrome. It has four compartments; namely the anterior compartment, Lateral compartment, deep posterior compartment and superficial posterior compartment (Figure 1).

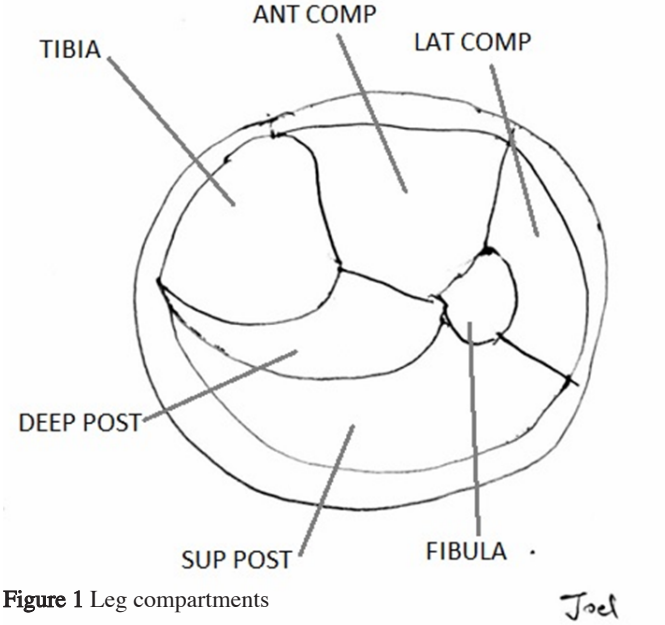

Figure 1 Leg compartments

Fasciotomy in the leg can be done through two methods i.e. Single incision fasciotomy, Double incision fasciotomy. Single-incision fasciotomy is done through an incision on the lateral aspect of the leg. The double incision fasciotomy is done through two incisions on medial and lateral aspects of the leg. The disadvantages of double incision fasciotomy in case of trauma include; Additional length of wounds for the patient and the medial incision on the leg it may cause problems with popliteal arterial exploration and closure of the wound .Therefore single incision fasciotomy can be performed with minimal discomfort to the patient exposing all the compartments adequately (Figure 2).

Studies have found that development of compartment syndrome results in poor limb salvage [3] and there are no reliable factors to predict the development of compartment syndrome. This can happen especially during long transfers of the patients. Studies have also demonstrated that the development of compartment syndrome also results in increased mortality [4]. Therefore early prophylactic fasciotomy is advisable. Some studies have found that the risk of developing compartment syndrome is more with combined arterial and venous injuries, with increased blood loss, open fractures and joint dislocations [5,6]. These studies suggest to do fasciotomy in patients with risk factors for development of compartment syndrome.

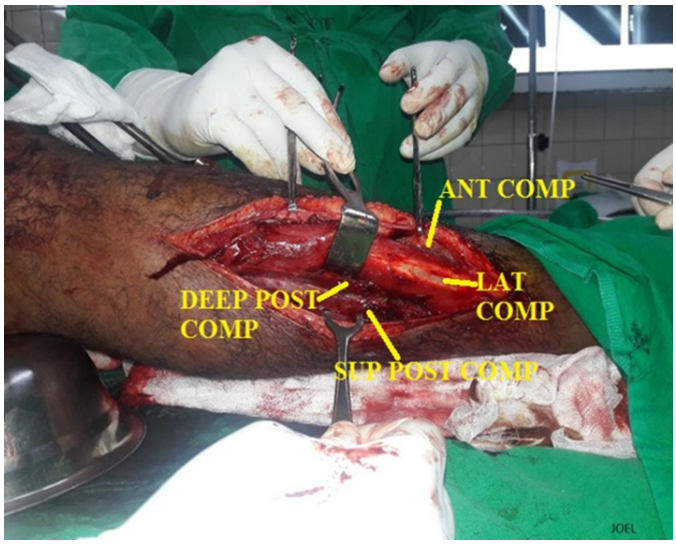

Figure 2 Single-incision fasciotomy

Conclusion

The compartment syndrome results in increased limb loss and increased mortality. This study has shown that the delay in performing fasciotomy is significantly associated with limb loss. Therefore single incision prophylactic fasciotomy should be done under local anaesthesia early and before the transfer of the patients to the vascular trauma centres. In future the steps should be taken to minimise the delays in performing the fasciotomy.

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National Trauma Conference 2024

Encouraged by the success of first National Trauma Conference 2023, we are pleased to announce the Second National Trauma Conference, to be held in Colombo, Sri Lanka, in November, hosted by National Trauma Secretariat in collaboration with the World Health Organization (WHO) Country Office Sri Lanka. As the only conference fully dedicated for trauma care in Sri Lanka, this conference aims to bring together healthcare professionals, policymakers, researchers, and other stakeholders to address the critical challenges and opportunities in trauma care and prevention.

Conference Objectives:

1. Knowledge Exchange: Facilitate interdisciplinary dialogue and collaboration among healthcare professionals involved in trauma care.
2. Research Dissemination: Disseminate the latest research findings, innovations, and evidence-based practices in trauma management.
3. Capacity Building:Enhance the capacity of healthcare providers in the assessment, treatment, and rehabilitation of trauma patients.
4. Injury Prevention: Raise awareness about the importance of injury prevention and promote safety measures in various settings.
5. Advocacy: Advocate for policy changes and investments to strengthen the trauma care system and improve outcomes for trauma patients.
6. Trauma care quality improvement: to prevent preventable deaths and disabilities.

Key Conference Features:

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- Panel Discussions on Current Challenges and Best Practices
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Sri Lanka Journal of Trauma

Journal homepage: www.traumaseclanka.health.gov.lk/sljt

Original Article:

Vascular injury pattern and workload; A tertiary care center experience from Sri Lanka

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Keywords - Vascular injury, incidence, Sri Lanka, National Hospi¬tal Sri Lanka (NHSL), Vascular repair, Causes of vascular injuries, Time duration, Admission times,Delay from admission

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Introduction
Vascular injuries can lead to life-threatening haemorrhage and limb-threatening ischemia if not addressed promptly. In Sri Lanka the number of limb vascular injuries are increasing due to the increase in road traffic accidents (RTA). This study describes the characteristics of patients who were operated on following vascular injuries at the Accident and Emergency department theatre of the National Hospital Sri Lanka (NHSL) from 2023 January to 2023 December.

Methods
This study was a retrospective study done at the Accidents and Emergency department theatre of the National Hospital Sri Lanka (NHSL). Patient information was collected from the theatre registry. The data on age, gender, mode of admission, mechanism of injury, associated injuries, type of vascular repair done, type of skeletal fixation done, duration of the surgery and time duration from admission to theatre were collected. Patients with incomplete records were excluded.

Results
There were 64,274 admissions to NHSL, Accident and Emergency (A & E) department from January to December of 2023. 14,616 (22.74%) of patients underwent surgeries at the A & E theatre complex. 103 of the admissions had vascular injuries, which needed surgical interventions. Therefore, vascular interventions account for 0.7 % of the total number of major surgeries. 90 cases were males (n = 90, 87.38%). The mean age was 37.13 years (15 to 73). The commonest cause for vascular injuries is RTA (n=46, 44.66%).50.47% had lower limb vascular injuries (n=54). 52.83% (n=56) were managed with the reversed saphenous vein (RSVG) interposition graft.

Conclusions
According to the results of this study, 0.16% of A & E admissions required vascular surgical interventions. 0.7% of surgeries were vascular surgeries. The commonest cause for vascular injuries was RTA (n=46, 44.66%). The majority, 52.83% (n=56) of the vascular repairs were done using RSVG. The outcome details are not presented in this study. This is a main drawback. Future countrywide study is needed to come to further conclusions.

Introduction
Unintentional or violence-related trauma causes 4.4 million deaths around the world and it accounts for 8% of all deaths. Road traffic accidents (RTA), homicides, and suicides are the three leading causes of mortality in ages 5 to 29[1]. 0.4 to 1.6 % of all trauma patients sustain vascular injuries worldwide[2]. However vascular injuries are responsible for 20% of all deaths related to trauma[3]. Vascular injuries can lead to life-threatening hemorrhage and limb-threatening ischemia if not addressed promptly.

Vascular injuries occur due to penetrating and blunt trauma. Trauma can show a spectrum of patterns of injuries like laceration, transection, pseudoaneurysm, contusion, intimal flaps, intimal disruption, and external compression .

The first urgent vascular repair was done in 1759 by Dr. Hallowell after being encouraged by his colleague Dr. Richard Lambert. Before that, vascular injuries were managed with ligation only and led to high morbidity and mortality. To minimize the consequences of ligation of injured vessels, various types of methods are used to restore blood flow. Primary anastomosis, synthetic and autologous vascular grafts, temporary intravascular shunts (TIVS), and endovascular techniques are some of the methods of vascular restoration . Vascular injuries are very common in third-world countries like Sri Lanka due to the increasing number of road traffic accidents (RTA), industrial trauma, and interpersonal violence. Out of all causes, RTA is the leading cause[4].

Methodology
This study was a retrospective analysis of all patients who were operated on following vascular injuries at the Accident and Emergency department theatre of the National Hospital Sri Lanka (NHSL) from 2023 January to 2023 December. Patient information was collected from the theatre registry. The data on age, gender, mode of admission, mechanism of injury, associated injuries, type of vascular repair done, type of skeletal fixation done, duration of the surgery and time duration from admission to theatre were collected. Patients with incomplete records were excluded. Data were analyzed with computer software.

Results
There were 64,274 admissions to NHSL, Accident and Emergency (A & E) Department from January to December of 2023. 14,616 (22.74%) of patients underwent surgeries at the A & E theatre complex. 1772 (2.76%) and 12844 (19.99%) of them were major and minor surgeries respectively. 103 of the admissions had vascular injuries, which needed surgical interventions.

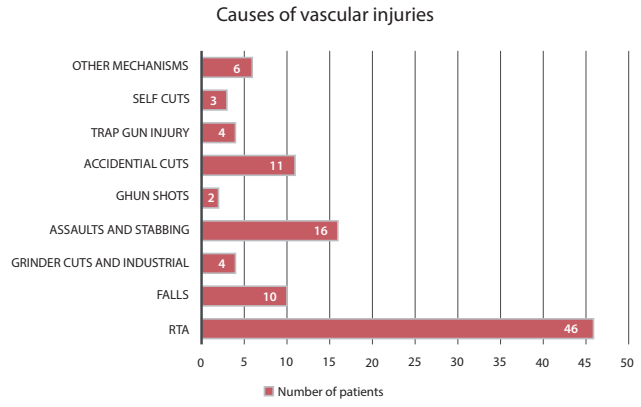
Therefore, vascular interventions account for 0.7 % of the total number of major surgeries done at the A & E theatre complex, NHSL. Number of the patients in the study was 103. The majority of them were males (n = 90, 87.38%). The mean age was 37.13 years (15 to 73). The age and gender distribution of the study group is presented in Table 1.

Table 1 Age and gender distribution

AGE	MALE	FEMALE	TOTAL	%
10-19	12		12	11.65
20-29	22	3	25	24.27
30-39	23	5	28	27.18
40-49	18	1	19	18.44
50-59	6	2	8	7.77
60-69	6	2	8	7.77
70-79	3		3	2.91
TOTAL	90	13	103	

The commonest cause for vascular injuries is RTA (n=46, 44.66%) and it is followed by interpersonal violent activities like assaults with sharp weapons and stabbing. Etiological distribution is presented in Graph 1.

Graph 1 Causes of vascular injuries



50.47% of all vascular trauma involved lower limb vessels (n=54). The distribution of the anatomical location of the vascular injuries is shown in Graph 2 and Table 2.

Graph 2 :Anatomical location of the vascular injuries

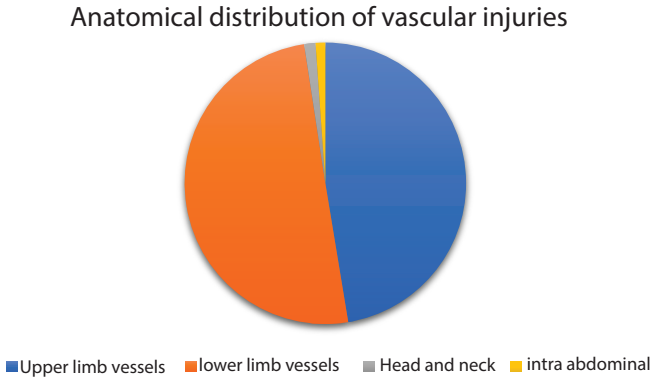
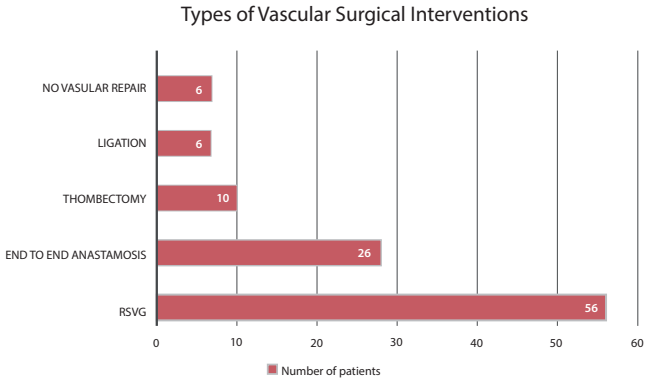


Table 2: Anatomical Distribution of Vascular Injuries

	Blood vessel damaged	Number of injuries	%
Upper Limb	Subclavian, Axillary Artery	2	1.89
	Brachial Artery	27	25.47
	Ulnar Artery	13	12.26
	Radial Artery	9	8.49
Lower Limb	Femoral Artery (Superficial and Common)	13	12.26
	Femoral Vein	4	3.77
	Profunda Femoris Artery	1	0.94
	Popliteal Artery	30	28.3
	Anterior tibial Artery	2	1.89
	Posterior Tibial Artery	2	1.89
	Peroneal Artery	1	0.94
	Dorsalis Pedis Artery	1	0.94
Head and Neck	External Jugular Vein	1	0.94
	TOTAL	**106**	

The modality of the vascular surgical intervention depended on the anatomical site of the injury, type of the injury, duration from the time of injury to the hospital admission, and associated other injuries. 52.83% (n=56) was managed with an interposition graft with the reversed saphenous vein (RSVG). Very small segment contusions, where the intimal injury is minimal were managed with thrombectomy alone (n=10, 9.43%). The types of vascular intervention for injuries are presented in Graph 3.



Graph 3: Types of Vascular Surgical Interventions

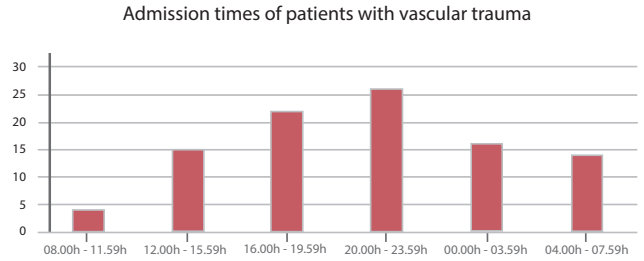
Mode of admissions

49.51% (n=51) of admissions were transferred from local hospitals and the rest were direct admissions.

Graph 4 Mode of admissions

patients with vascular injuries were admitted to the NHSL between 20:00h to 00:00h (n=26). Minimum admissions reported from 0800h to 1200h.

Admission times of patients with vascular trauma are shown in Gragh 5.

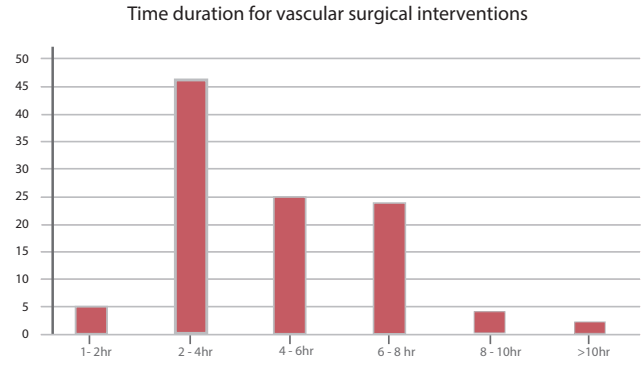


Graph 5 Times of admissions of patients with vascular trauma

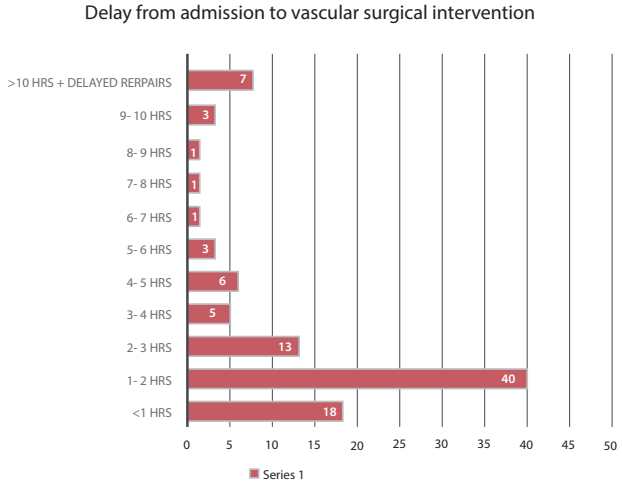
Surgical interventions for vascular injuries are carried out by the vascular surgical team with the liaison of orthopedic and plastic surgical teams most of the time. 44.66% (n=46) surgeries took 2 to 4 hours. The mean time is 4.4 hours for surgery. Time durations for surgical interventions are shown in Graph 6.

A total of 440 hours within a year were spent on vascular surgeries.

Graph 6: Time duration for vascular surgical interventions



Most of the admissions with vascular injuries underwent appropriate surgical intervention within 1 to 2 hours after admission (n=40). The mean delay is 2.6 hours. Delay from the admission to the theatre was analyzed and shown in Graph 7.



Graph 7 : Delay from the admission to the theatre

Discussion and conclusions

According to the results of this study, 0.16% of A & E admissions required vascular surgical interventions. 0.7% of surgeries were vascular surgeries and some of them were combined surgeries with orthopedic, plastic, or general surgical teams.

Male preponderance is an observed fact in the context of vascular injuries and 80% to 99% of vascular injuries occur in males in most studies[5], our data is also consistent with these data, 87.38% of vascular trauma occurs in males.

In our study, the commonest cause for vascular injuries was RTA (n=46, 44.66%). When comparing this with data from other parts of the world, gunshots, stabs, and assaults are the predominant causes in some studies[6]. Some studies show RTA is the predominant cause

50.47% (n=54) of vascular trauma involves the lower extremity vessels and popliteal artery injury is the commonest injury in the lower limb(n=30) Brachial artery injury is the commonest upper limb vessel injury and accounts for 25.47% of the population. There are similar studies some are showing lower limb injuries than upper limb[7], and others vice versa. The common vessels injured in the upper and lower limbs in our study are consistent with other studies.

The majority, 52.83% (n=56) of the vascular repairs were done using RSVG. Usually vascular trauma due to blunt trauma comes with long-segment contusions, and crush injuries in RTA. It requires tension-free repair after removing the damaged part of the vessel. This is consistent with studies done in other places.

59.8% (n=58) of vascular trauma admissions reach the theatre within the first two hours of admissions. The mean delay from admission to the theatre for vascular surgical intervention is 2 hours and 36 minutes. The timing from the admission to the theatre depends on the severity of the vascular trauma, degree of extremity ischemia, pre-hospital delay following the trauma, and associated other injuries.

A total of 440 hours of theatre time were spent from 2023 January to 2023 December for vascular trauma and the mean time for surgery is 4 hours and 24 minutes.

Our study has limitations. This study only includes the data of patients who underwent vascular surgical intervention by vascular surgeons at the A & E theatre complex for 2023 year. This data does not include on-arrival deaths due to vascular trauma, and vascular trauma where vascular surgical intervention was not needed like unsalvageable limbs. Since this is a retrospective study, only the patients with complete data were included in the study. The number of patients in the study is not adequate to get the exact prevalence and pattern of vascular injuries in the population. In addition the outcome details are not presented in this study. This is a main drawback. Future country-wide study is needed to come to further conclusions.

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TRAUMA SECRETARIAT SRI LANKA

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Case Series:

Salvaging mangled upper limbs with early soft tissue cover with flaps

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Key words: upper limb injuries, limb salvage, soft tissue reconstruction, free tissue transfer, case series.

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Summary

Mutilating upper limb injuries present complex challenges to both patients and surgeons, necessitating prompt and effective management strategies to achieve favorable outcomes. This retrospective study examines the cases of five consecutive patients with mangled upper limbs resulting from blunt trauma, evaluating demographics, injury mechanisms, injury patterns, and 60-day limb salvage outcomes. Among 2128 admissions between January and December 2022, five patients were identified with mangled upper limbs and open fractures, with an average age of 40.2 years and a notable male predominance (80%). The dominant hand was affected in 60% of cases, primarily due to blunt high-velocity road traffic accidents. The mean Mangled Extremity Severity Score (MESS) was 7.2, and the Ganga Hospital Open Injury Score averaged 16, indicating substantial injury severity without limb ischemia or compartment syndrome. All patients underwent definitive surgery within 48 hours, with various soft tissue reconstruction techniques employed, including free flaps, pedicle flaps, and local muscle mobilization, along with nerve grafting procedures. At the 60-day follow-up, successful limb salvage was achieved in all cases, with no instances of surgical site infection and excellent acceptance of skin grafted areas exceeding 95%. The findings underscore the importance of timely surgical intervention and comprehensive soft tissue coverage in achieving successful limb salvage outcomes in patients with mutilating upper limb injuries, emphasizing the critical role of early intervention and multidisciplinary collaboration.

Introduction

Mutilating upper limb injuries are a major impact of patient as well as a challenge to the operating surgeon. Loss of function leads to loss of productive contribution to society. The ability to restore structure and function depends on the facilities and the expertise of the center of concern. Here we describe two mutilating upper limb injuries which we managed to get a good functional outcome.

Case details

Among 2128 admissions between January and December 2022, 5 patients were presented with severely injured upper limbs characterized by open fractures (Table 1). These individuals had an average age of 40.2 years, ranging from 28 to 54, with a male predominance (4 males, 80%). The dominant hand was affected in 60% of cases, and all injuries were attributed to blunt high-velocity road traffic accidents. (Table 1)

Patient demographics, Mangled Extremity Severity Scores (MESS), and Ganga Hospital Open Injury Scores (GHOIS) and type of soft tissue cover used.

Abbreviations-ALT flaps; antero-lateral thigh flap, LD flap; Latissimus dorsi flap

Patient No	Age(years), Gender	MESS	GHOIS	Soft tissue cover
1	34 (Male)	7	16	Free ALT Flap
2	28 (Male)	7	17	Free ALT Flap
3	54 (Female)	8	15	Pedicle LD Flap
4	39 (Male)	7	15	Skin graft
5	46 (Male)	7	17	Free ALT Flap

Upon evaluation, the mean Mangled Extremity Severity Score (MESS) was 7.2, with a range of 7 to 8, indicating non salvageable limb injury. The Ganga Hospital Open Injury Score averaged 16, ranging from 15 to 17, reflecting the extent of tissue damage without evidence of limb ischemia or compartment syndrome. Within a critical window of 48 hours, all patients underwent definitive surgical interventions to address their injuries. The surgical approach varied among the patients, with three individuals requiring free flap procedures, specifically antero-lateral thigh (ALT) flaps, while one patient received a pedicle latissimus dorsi flap (Figure 3), and another underwent local muscle mobilization and skin grafting for soft tissue coverage. Additionally, two patients underwent nerve grafting, with an average graft length of 9.5 cm.

After a 60-day follow-up period, all patients demonstrated successful limb salvage outcomes, characterized by the absence of surgical site infections and excellent acceptance rates exceeding 95% for skin grafted areas. These findings underscore the effectiveness of timely and comprehensive surgical management in achieving favorable outcomes in cases of severe upper limb trauma.

Apart from free ALT flap, patient 1 underwent a free toe transfer from 2nd toe to right thumb reconstruction and after 1 year, he has regained 3 types of grips of the hand (Figure 1). Patient 2 had an open elbow joint where reconstruction of capsule and ulnar collateral ligament repair was performed with tensor fascia lata graft.

Figure 1- Patient 1a. severely contaminated upper limb,1b. appearance after wound debridement, 1c. after soft tissue cover with Free ALT flap and skin grafting, 1d. 6 months post-op after free flap and 2nd toe to thumb transfer

Discussion

The threshold for limb salvage in an upper limb is low compared to lower limb due to many reasons. The main function of the upper limb in terms of grip and prehension is far superior compared to prosthesis. The Cost, durability, and less maintenance are important factors to consider in a country like Sri Lanka. The decision to limb salvage is aided by MESS (Mangled extremity severity score) and Ganga hospital open injury score (GHOIS)[1,2]. If salvageable, the management should be in concordance with standards for the management of open fractures by British association of plastic reconstructive and aesthetic surgeons (BAPRAS) and the British Orthopaedic Association (BOA)[3]. According to this evidence-based approach, proper initial assessment, antibiotics, methodical wound debridement, early soft tissue cover and rehabilitation are key aspects in patient management. The scoring systems for limb salvage can be used as an initial guide for the management but the decision should be carefully evaluated according to the expertise available in the center of management. The reported patients had a MES score of 7 and GHOI score of 16 (Grey zone) respectively. But according to the local expertise, we proceeded for limb salvage option to maximize the structural and functional outcome of the patient. The likely concern for limb salvage in this type of mangled limb is the soft tissue cover. In this type of extreme soft tissue loss, free tissue transfer by means of free flap is the key in management. Free tissue transfer should cover the non-skin graftable areas (bear bone, implants) as well as functionally important joints to maximize the range of motion.

A proper wound debridement can convert a grossly contaminated wound to a clean wound which is suitable for early internal fixation and soft tissue reconstruction without increased risk of surgical site infections. The technique of wound excision should be utilized for removal of contaminated particles rather than relying on wound irrigation alone. All the reported patients had gross contamination (Figure 1a) and clean wound beds were achieved by the debridement (Figure 1b). This facilitated the early tissue cover in patient 1(Within 48 hrs.) and early internal fixation and soft tissue cover in patient 2. None of the patients developed any surgical site infection. (Figure 2)

Figure 2- Patient 2a. Pre-op upper limb with dislocated elbow, 2b. post-debridement, 2c. after soft tissue cover with Free ALT flap and skin grafting, 2d. 3 months post-op

Patient 3 is an example of vascular compromised mangled limb saved with brachial artery repair with venous graft and soft tissue cover achieved by pedicle latissimus dorsi flap.

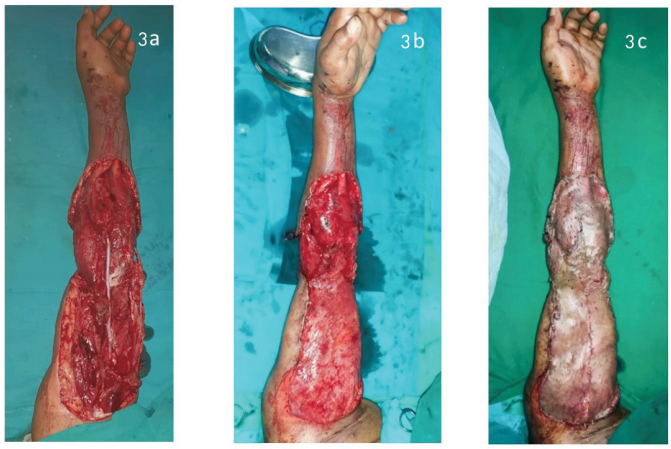

Figure 3- Patient 3a. exposed venous graft of brachial artery segmental defect, 3b. soft tissue coverage achieved with pedicle latissimus dorsi flap, 3c. post-op after the skin grafting

Since the thumb accounts for 40% of the function of the hand, Patient 1 underwent a free 2nd toe transfer to reconstruct the right thumb. Power grip was restored with some element of opposition (Figure 1 d). He is awaiting a tenolysis to improve the range of motion of the thumb. Free tissue transfer by means of toe transfer is useful in maximizing the functional outcome of mutilated hand[4].

Recent systematic review has shown that the decision of limb salvage vs. amputation depends on many factors and most scoring systems are based on lower limb trauma[5]. Until robust evidence emerges, the knowledge and the experience of the reconstructive specialist should be sought in case-by-case basis.

Conclusion.

The management of mutilating upper limb injuries poses significant challenges for all involved healthcare providers. However, it is important to prioritize upper limb salvage in patients following the stabilization of life-threatening injuries. Key steps in successful management include thorough assessment, methodical wound debridement, and prompt provision of early soft tissue coverage. Consulting with local experts is essential before considering upper limb amputation, as their insights can provide valuable guidance in decision-making processes. Furthermore, superior structural and functional outcomes are achievable through the expertise of reconstructive specialists, particularly with the use of free tissue transfers using microsurgical techniques. By adhering to these principles and engaging in collaborative decision-making, healthcare professionals can optimize patient outcomes and enhance the quality of care for individuals with mutilating upper limb injuries.

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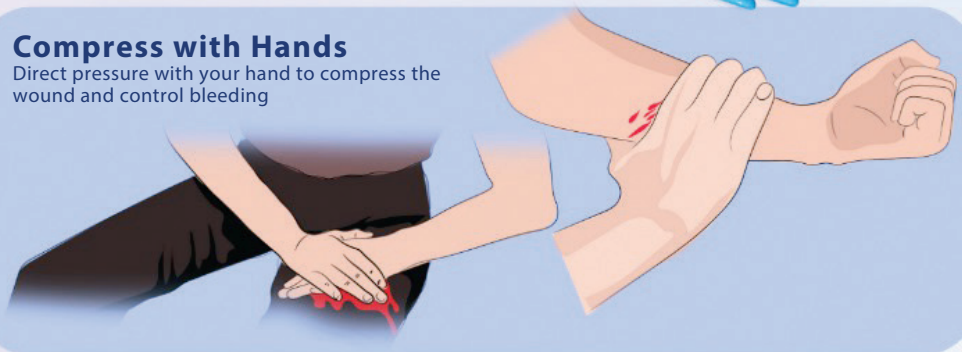
Act Fast, Save a Life

How to STOP Bleeding

Gloves
For your personal protection

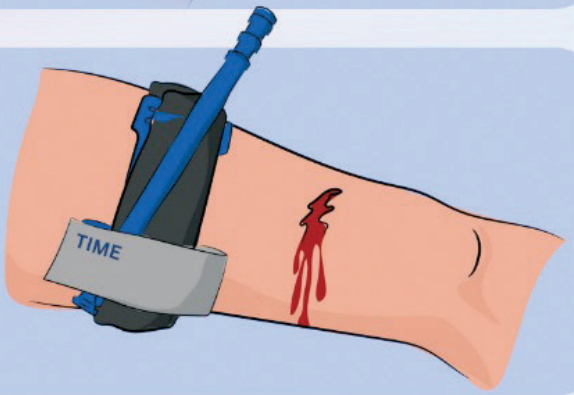
Compress with Hands
Direct pressure with your hand to compress the wound and control bleeding



Apply Dressing and Pressure
Place a clean dressing on the wound and apply firm pressure to control bleeding

Apply Turniquet

- Use only arms and legs
- Apply at 2-3 inches above the wound
- Do not apply on a joint



Stop BLEED

Only second to traumatic brain injury, some 40% of all trauma deaths are the result of blood loss. Reducing death from severe bleeding requires training in the recognition and treatment of life-threatening bleeding, as well as programs to ensure immediate access to bleeding control resources.

The Stop BLEED (Stop **B**lood **L**oss with **E**mergency **E**quipment & **D**evices) initiative seeks to educate and empower people to be immediate responders and provide control of life-threatening bleeding until emergency medical services arrive/definitive treatment initiaed

For details please visit: https://traumaseclanka.health.gov.lk/stop-bleed

Another initiative from TRAUMA SECRETARIAT

TRAUMA SECRETARIAT SRI LANKA

Sri Lanka Journal of Trauma

Journal homepage: www.traumaseclanka.health.gov.lk/sljt

Case series

Severe liver injuries; a case series and review of the literature

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Abstract

Introduction

Severe hepatic injuries are associated with high morbidity and mortality. Liver injuries occur frequently. In a series of 48 patients who underwent laparotomy at the national hospital of Sri Lanka, Colombo (NHSL), there were 11 (22.9%) liver injuries. Severe liver injuries may require resection as management. This study reports the outcome of liver resection following severe liver injuries.

Methods

This is a retrospective study of liver resections following abdominal trauma. Data on Basic demographics, surgical procedures, and the outcomes were collected and analysed. American Association for the Surgery of Trauma (AAST) classification was used to classify the liver injuries.

Results

Six patients were included. All were males. Median age was 40.0 years (7-87). Four (66.7%) were following road traffic accidents. Three (50%) had AAST grade V and two (33.3%) had AAST grade III injuries. Three (50.0%) underwent staged right hepatectomy. Two (33.3%) patients died as a result of the effects of haemorrhage in the early post-operative period. At a median follow-up of 32.9 months, others have recovered and are well.

Discussions and Conclusions

At present the management of the patient with liver trauma depends on the hemodynamic stability, associated injuries and the evidence of bleeding from the liver on. If the patient is haemodynamically stable and if there are no other indications for laparotomy the patient can be managed conservatively. When there are injuries to the hepatic artery, portal vein, hepatic veins and major branches, with severe bleeding and if the patient remains unstable these should be ligated. The patient is resuscitated for about 24 to 48 hours and the infarcted area of the liver can be resected later (staged liver resection). In this way the mortality of undergoing primary liver resection can be reduced.

Introduction

Severe hepatic injuries are associated with high morbidity and mortality (30%) and are challenging to manage[1]. Liver injuries occur frequently following abdominal trauma. For example in a series of 48 patients who underwent laparotomy following trauma at the national hospital of Sri Lanka, Colombo (NHSL), 11 patients had liver injuries (22.9%). Most of the liver injuries can be managed non operatively. In case of surgical management the focus is on damage control, packing, and vascular ligation and resection. Interventional radiological modalities are also used in the management (e.g. embolisation of the bleeding vessels). This report is on the outcome of patients who underwent liver resection following severe liver injuries.

Methods

This is a retrospective analysis of the patients who underwent liver resections following abdominal trauma for severe liver injuries. The study was done from March 2017 to march 2023. Data on patients, who underwent liver resection following liver injuries at the NHSL, were collected retrospectively. Basic demographics, surgical procedures, and the outcomes were analyzed. To classify liver damage, the AAST hepatic Injury Scale was used. Patients who were lost to follow up and incomplete records were excluded.

Results

Six patients who underwent liver resection after trauma were included. All patients were males. Median age was 40.0 years (7-87). 4 (66.7%) were following road traffic accidents and two (33.3%) were after a fall from a height. Three (50%) had AAST grade V liver injury and two (33.3%) had AAST grade III and one (16.7%) had AAST grade IV liver injury. The indication for laparotomy in all 6 patients was haemodynamic instability. One patient (16.7%) who had near total separation of the left lobe, underwent primary left hepatectomy, three (50.0%) underwent staged right hepatectomy. In patients who underwent staged hepatectomy, a primary resuscitative laparotomy was done first. At the time of the initial laparotomy, selective portal vein and hepatic artery branch ligation to control the bleeding was done. Following this the patients were sent to the intensive care unit for resuscitation for 24 to 48 hours. This was followed by a relaparotomy and hepatectomy. At a median follow-up of 32.9 months, two (33.3%) patients died as a result of the effects of haemorrhage in the early post-operative period others have recovered and are well.

Discussion and conclusions

Liver is one of the commonly injured abdominal organs following abdominal trauma[2]. Liver injury is encountered at a rate of 22.9% among abdominal trauma patients undergoing emergency laparotomy at the NHSL (NHSL, unpublished data). According to the severity of the liver injury, it can result in increased mortality and can result in complications in the late recovery phases of the patient. Liver injuries are graded according to the

Table 1 AAST grading scale

Grade I	Sub-capsular haematoma involving less than 10% of the surface area Capsular laceration involving less than 1 cm depth
Grade II	Sub-capsular haematoma involving 10% -50% surface area or Intra-parenchymal less than 10 cm diameter Laceration - capsular laceration involving 1 cm -3 cm parenchymal depth and less than 10 cm length
Grade III	Subscapular hematoma involving greater than 50% of the surface area or enlarging Intra-parenchymal haematoma of greater than 10 cm or enlarging Laceration involving more than 3 cm of parenchymal depth
Grade IV	Parenchymal laceration involving 25% -75% of the hepatic lobe
Grade V	Laceration involving more than 75% of the hepatic lobe Retro hepatic vena caval or major central hepatic venous injuries
Grade VI	Hepatic vascular avulsion (not compatible with life. These patients do not reach the hospital).

size of the haematoma, the degree of laceration, presence of bleeding into the peritoneum and the presence of hepatic venous injuries[3].

Computerised tomographic scan (CT) of the abdomen and pelvis is the gold standard investigation in patients with suspected liver injuries. This allows grading of the liver injuries and also helps in identifying the associated injuries.

Based on the CT findings the liver trauma is classified into 6 grades according to the American Association for the Surgery of Trauma (AAST) grading scale[4] (Table 1).

World Society of Emergency Surgery (WSES) classification grades liver injuries incorporating the AAST classification and the haemodynamic status [4] (Table 2).

Table 2 WSES liver trauma classification

Minor	WSES grade I	AAST I–II	Stable
Moderate	WSES grade II	AAST III	Stable
Severe	WSES grade III	AAST IV–V	Stable
	WSES grade IV	I–VI	Unstable

The concept of management of liver injuries has changed over time. Initially all patients with liver injuries underwent exploratory laparotomy[5]. At present the management of the patient with liver trauma depends on the hemodynamic stability, associated injuries and the evidence of bleeding in the liver on imaging (blushing in contrast enhanced CT scan). Liver injuries can be associated with other abdominal injuries. In a series of 11 patients with liver injury at the NHSL, 3 (27.27%) patients had bowel injury, 2 (18.18%) had diaphragmatic injury and one (9.09%) had mesenteric tear. Grading of the liver injury according to the CT scan can be used to plan the operative management.

Haemodynamic stability is defined as follows. A haemodynamically unstable patient is defined as a patient with the systolic blood pressure of less than 90 mmHg with other features of shock i.e. poor peripheral circulation, reduced urine output and altered level of consciousness (3). Some patients who maintain the systolic blood pressure above 90 mmHg with inotrope infusion or fluid infusions or blood transfusions of more than four units in the first 8 hours are also considered haemodynamically unstable.

A patient is categorised as transient responder if the blood pressure rises following initial resuscitation and then subsequently the patient develops features of hemodynamic instability[3].

If the patient is haemodynamically stable and if there are no other indications for laparotomy, the minor (WSES I/ AAST I–II), moderate (WSES II /AAST III) and severe (WSES III / AAST IV–V) injuries can be managed non-operatively (NOM). However these patients should be carefully monitored at the Intensive Care Unit with preparedness for intervention if the clinical situation of the patient deteriorates. In addition serial investigations should be done to detect complications. If there is any deterioration in the clinical status or haemodynamic stability of the patient, he or she should be revaluated and sent to the theatre for emergency resuscitative laparotomy[3].

In patients managed non-operatively and are haemodynamically stable, if there are evidence of active bleeding on CT images i.e. blush, urgent angiography and embolisation should be offered.

During laparotomy, a midline incision is done first. An initial assessment of the peritoneal cavity and the retroperitoneal area is done. In case of bleeding from the liver, the following methods can be used to stop bleeding. Initial manual compression on both sides of the laceration is applied. This will reduce the bleeding by approximating the damaged edges. Bleeding is also stopped by application of gauze packs around the liver to compress the lacerated edges together. More severe bleeding can be stopped compressing the hepatoduodenal ligament (Pringle manoeuvre).

After controlling the bleeding from the liver, the damage to the liver and the bleeding site is assessed. For superficial parenchymal injuries packing, diathermy cauterisation, parenchymal suturing is often adequate to stop bleeding.
One study reported among 804 liver injuries that were treated with peri hepatic packing, the mortality was between 14% to 30%. However the re-bleeding rates were higher when the packs were removed before 36 hours (21% vs. 4% / P less than 0.001) [6].

In severe liver injuries with unstable patient (WSES IV), inspect for major bleeders. The injured hepatic artery, portal vein and hepatic veins can be repaired. However if the patient remains unstable these should be ligated. The patient is sent to the intensive care unit (ICU) for further resuscitation. During this period, revaluation is done with CT scan. Subsequent re laparotomy can be done in 28 to 48 hours and the infarcted hepatic segment or the lobe can be resected (staged liver resection). However liver resections following liver injuries are associated with high mortality. In one series of 216 patients, the mortality following liver resection was 30.0% compared to the overall mortality of 17.8%[1].

If the bleeding remains uncontrolled despite the above mentioned methods, total hepatic vascular exclusion should be done followed by inspection of the hepato caval junction or retro hepatic inferior vena cava (IVC). These should be repaired. For irreparable retro hepatic IVC injuries, various temporary cava to atrial shunt techniques are used.

If there is a near total laceration of the hepatic segments or the lobe is found on initial laparotomy, that segment can be excised.

Therefore in conclusion, hepatic injuries are associated with high mortality. Presence of major vascular injuries Increases the mortality further. Non operative management can be offered in most patients provided the patient is haemodynamically stable and has no other indications for laparotomy. However, these patients should observed in an intensive unit with readiness to intervene if the patient deteriorates. Further data (countrywide and institutional) on liver injuries is needed to arrive at further conclusions and to plan the system improvement.

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Current Opinion

Forging alliances: examining civil-military partnerships and their impact on war-time casualty care in Sri Lanka

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Keywords - civil military health partnerships, combat casualty care, trauma system development, national trauma care system, civil military health system integration.

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ABSTRACT

Over the course of the 26-year civil war in Sri Lanka between the Liberation Tigers of Tamil Eelam (LTTE) and the government forces, LTTE's 'military' capacity and strategy evolved from guerrilla-type ambushes using landmines to semi-conventional warfare with light arms and eventually to heavy artillery and improvised explosive devices. This evolution required both military and civil surgeons to enhance their knowledge and skills in managing high-energy war wounds to handle the large number of casualties admitted to health institutions. The Sri Lanka Medical Corps (SLMC) had been meticulously organized into echelons of care with graded capacity and capability to medivac battle injured personnel from point of injury to definitive care facilities. All injured personnel eventually found their way to Colombo Army Hospital and Ragama Rehabilitation Hospital for comprehensive rehabilitation. The civil war in Sri Lanka presented a significant influx of war-related injuries, demanding the creation of a comprehensive system seamlessly integrating both military and civilian elements. With a decade of peace, accompanied by shifts in injury epidemiology, the evolving landscape has mandated the exploration of innovative strategies to sustain and enhance the surgical skill-base for both military and civilian casualty care.

Introduction

Context of the war

Over the course of the 26-year civil war in Sri Lanka between government forces and the Liberation Tigers of Tamil Eelam (LTTE), four main phases occurred, interspersed with periods of reduced activity, particularly during internationally brokered ceasefires. During these lulls, the LTTE regrouped to counter government forces' territorial advances[1,3] (Table 1)

TABLE 1. The timeline of the Eelam war

Eelam war	Period
Eelam war 1	1983 - 1987
Eelam war 2	1990 - 1995
Eelam war 3	1995 - 2002
Eelam war 4	2006 - 2009

The LTTE gained infamy as one of the world's most ruthless and sophisticated terrorist organizations, employing terrorist, guerrilla, and conventional tactics through its semi-conventional fighting force. Starting as a small armed cadre, the LTTE evolved into a battle-hardened force of around 30,000 cadres, comprising military, sea tiger, air, and black tiger wings. The latter was a special unit dedicated to suicide attacks against security forces and terrorist attacks on civilians in Sri Lanka[4,5].

The conflict zone encompassed diverse vegetation, including semiarid flat lands with tropical thorn forests, dry evergreen jungles, and bush-type vegetation. The terrain was further complicated by seasonal North-Eastern monsoon rains from December to February, leading to waterlogged conditions that posed significant challenges for casualty evacuation[4].

Nature of injuries

In contemporary warfare, musculoskeletal injuries predominated, caused by blast munition fragments and automatic assault rifle bullets. A published report from Eelam War 3 revealed that 65% of injuries resulted from exploding ordnance, while 35% were gunshot wounds. Explosive wounds were largely inflicted by mortars, landmines, grenades, and artillery shells. In the urban and suburban terrains where close-range fighting occurred, injuries were predominantly due to small arms fire by T 56 and AK 47 automatic assault rifles. Additionally, there were burns and blunt injuries in the minority, specifically in armored corps personnel. There were reported incidents of drowning during a Kalmadukulam Tank bund blast by the LTTE in January, 2009. Extremities were the predominant region to be injured in battle. Torso, head and neck contributed a minor percentage in personnel surviving to reach medical care[6].

During active conflict, the LTTE engaged in conventional war with a defined front line, using a variety of arms, ammunition, and equipment that resulted in an estimated death of around 30,000 government soldiers[7]. (Table 2).

TABLE 2. Types of weapons used by the LTTE (verified by Lt Col. (Dr) Bandula Nishshanka RSP USP psc Phd.

Category of weapons	Weapons used by LTTE
Light arms	Type 56 Chinese assault rifle AK 47 assault rifle Type 69 RPG M2 browning 12.7mm Mines used

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TABLE 2. (*Continued*)

machine gun	Jony 95 (a small wooden box mine) Jony 99 (with motion sensor) Rangan 99 (with anti-handling features) SN 96 (Claymore-type mine) Amman 2000 (anti-vehicle mine) MK1 and MK2 (anti-vehicle mines) Claymore mine
Heavy weapons	152 mm towed gun-howitzer 130 mm towed field gun 122 mm howitzer 85 mm Gun T-56 Improvised 106 mm Artillery Indigenously produced long-range artillery 107 mm Indigenous Single BRL (1-barrel) 140 mm Mortar 120 mm Mortar 82 mm Mortar 81 mm Mortar 60 mm Mortar

Mines and amputations

The no man's land was seeded with improvised anti-personnel mines (IAPM) aimed at maiming soldiers rather than killing them. Unique to the LTTE were improvised devices connecting multiple blast components to cause severe injuries to multiple victims simultaneously. Anti-personnel mines (APM) led to numerous amputations, with approximately 6,000 post-war amputees in the Sri Lankan Army. Anti- personnel mines improvised by the terrorists referred to as "Jony mines" were triggered by victims stepping on them, causing extensive damage and posing a high risk of infection and sepsis[2,4].

Evolution of LTTE military strategy

Over decades, the LTTE's military capacity and strategy evolved from guerrilla-type ambushes using landmines to semi-conventional warfare with light arms and eventually to heavy artillery and improvised explosive devices. This evolution required both military and civil surgeons to enhance their knowledge and skills in managing high-energy war wounds to handle the large number of casualties admitted to health institutions. Workshops in military surgery conducted by the College of Surgeons of Sri Lanka together with the surgeons of the International Committee of the Red Cross and the College of Military Medicine helped in updating the knowledge of the surgeons treating the battle wounded[4,5,8].

Evolution of military medical system in Sri Lanka

The inception of the medical corps traces back to 29th July 1881, with the establishment of the stretcher bearer (Medical) company as an integral part of the Ceylon Light Infantry (Volunteers). Major (Surgeon) J. Tothill, a retired regular medical officer, assumed command during its formation.

Following Ceylon's independence in 1948, the Ceylon Army was established, and in 1950, the 1st Battalion of the Ceylon Army Medical Corps emerged as a regular force within the army. Over the ensuing years, the medical corps has undergone significant evolution, currently comprising four regular units and one

TABLE 3. Landmarks events of evolution of SriLanka Army Medical Corps (SLAMC)

Event	Year
The first stretcher bearer (Medical) company was raised as a part of the Ceylon Light Infantry (Volunteers). This was commanded by Major (Surgeon) J. Tothill, a retired regular Medical Officer.	29th July 1881
Formation of Ceylon Medical Corps (Volunteer)	1911
1st Battalion of Ceylon Army Medical Corps was created as a regular force in Ceylon Army.	1950
The former British Military Hospital of the Royal Army Medical Corps in Colombo was opened as a medical reception station with 10 beds. Very soon this was upgraded to a 30 bed service hospital.	-
Medical Reception Station (MRS) was opened in Diyathalawa Garrison, later upgraded to a Base Hospital.	-
A medical reception station in Palaly, Jaffna was made an Army Base Hospital as did the MRS at Panagoda Cantonment.	1983
Military Hospital Colombo was expanded with a new wing. Soon followed the building of rehabilitation institute 'Ranaviru Sevana' at Ragama.	1988
Regimental Centre SLAMC was established at Army Headquarters premises	15th January 1990
Military Hospital, Anuradhapura was established to treat soldiers in Vanni Sector	1997
3rd Battalion of Sri Lanka Army Medical Corps was formed	1999
Army Nurses Training School was established at Anuradhapura.	2001
4th Battalion of Sri Lanka Army Medical Corps was formed	November 2007
5th Battalion of Sri Lanka Army Medical Corps was formed	Decmber 2010
He largest ever military hospital in Sri Lanka, Army Hospital Colombo, with 1,024 beds commissioned. It has 21 wards, 12 dental surgery units and nine operation theaters	May 2014

volunteer unit. The operational landscape includes two army hospitals, seven army base hospitals, and four field hospitals strategically positioned and operational nationwide[9,10] (Table 3)

The Sri Lanka Army Medical Corps was a relatively small Division and by 2006 there were only 118 officers and 3200 men of which only a small proportion were deployed in the field. In response to the demanding casualty care requirements during high-intensity conflict in North and East Sri Lanka, a group of infantrymen from each regiment were trained as nursing assistants in the combat life support training course. This extended to all special force personnel, commandos and young medical officers. Further, since 1995, the Sri Lanka Medical Corps (SLMC) had been meticulously organized into echelons of care with graded capacity and capability to medivac battle injured personnel from point of injury to definitive care facilities. Over the years of high Intensity war, operation of echelons matured into a formidable integrated system of casualty care with a combination of both military and civilian health care assets. Currently, the medical corps boasts a workforce of more than 4000 personnel including 363 skilled medical officers, 908 staff nurses, 1133 medical assistance [10,11].

The initial tier of care is strategically positioned in close proximity to the front line, providing essential casualty care immediately following injury. This primary care encompasses vital interventions such as control of bleeding, pain relief, and fracture immobilization. Notably, a range of tourniquet techniques were employed, ranging from improvised military tourniquets comprising belts and buckles to simple twined cloth adaptations. It's worth noting that, during the civil war in Sri Lanka, commercial tourniquets were unavailable and not advocated due to extended average evacuation times[4,11].

The second tier of medical care comprised Advanced Dressing Stations (ADS), Main Dressing Stations (MDS), and field hospitals. ADS facilities strategically positioned around 400 to 5000 meters behind the front line served as pivotal points equidistant from three forward regimental aid points. These stations were staffed by a medical officer, two nurses, and three nurse assistants, all proficient in emergency combat resuscitation, including advanced procedures such as intubation, chest-drain insertion, bleeding control, securing intravenous access and intravenous fluid infusion[4].

A singular MDS, situated behind three ADSs, possessed the capability to stabilize casualties and facilitate their airlift to definitive care facilities. MDS units were manned by a senior medical officer, four nurses, six nurse assistants, and other support personnel. All support staff including the ambulance drivers were trained as nursing assistants. The procedures performed at the MDS included transfusing of un- cross matched group O blood when necessary, essential life-saving surgical interventions, including tracheostomies, emergency amputations, fasciotomy, and wound exploration to achieve hemostasis. All army doctors were trained in anesthesia to cater for field surgery. A blood store and portable ventilator were available for life-saving surgery undertaken at MDS. At each medivac station (ADS, MDS) casualties were triaged according to the priority of medical care needed. There was a good communication system in each dressing station, which helped to not only convey relevant information to higher headquarters but also to obtain relevant expert opinions from Colombo in difficult situations[4].

The third tier of care encompassed military base hospitals and general hospitals equipped to provide definitive surgical care through specialized services such as vascular, orthopedic, oral-maxillofacial, neurosurgical, and intensive care units. In 2008-2009, the military Base Hospital in Anuradhapura, located 180 kilometers away from the conflict zone, was repurposed as a center for definitive extremity vascular care. General surgeons trained in vascular surgery were deployed to minimize revascularization delays. The facility was well-equipped with two operating theaters, a three-bed intensive care unit, and an 80-bed ward[4].

TABLE 4. Field casualty care organization in Sri Lanka medical corps. (verified by Col. (Dr) RKP Pushpakumara MD.)

Military organization (Commands,Formations & units)	Military medical evacuation(MEDEVAC) chain	Capacity and capability	Distance from the frontline /mode of transport to next the level / average time after injury to reach medical post during last phase of Eelam war
Company / platoons (units)	Company Aid Post (CAP)	In the casualty parties, Infantry soldiers are trained in combat life saving and bringing injured personnel from Frontline to CAP. At the CAP, Nursing assistant or Infantryman trained in basic first aid course / apply field dressing & bleeding control	Less than 400m/ stretcher bearers/ depending upon tactical and ground situation
Battalion / Regiment (formation)	Regimental Aid Post (RAP)	Regimental nurse or nursing assistants capable of applying proper dressing, giving intravenous fluid and analgesics, and carrying out splinting of fractured limbs.	200 to 400 m from Frontline /stretcher bearers / depending upon tactical and ground situation
Brigade headquarter (formation)	Advanced Dressing Station (ADS)	Medical officer or Registered Medical Officer.(RMO) The responsibilities of the medical team at this point consisted of maintaining airway, breathing and circulation, continuation of antibiotics and IV fluids, giving tetanus toxoid, blood transfusion if required, stabilization of fractured bones, performing life-saving minor surgical procedures and stabilization of patients for transfer to MDS.	Advanced Dressing Stations are located about 400m – 4 km away from the frontlines /Ambulances, tractors, armored personnel carriers (APC) / usually within hour but can vary according to tactical and ground situation

TABLE 4. (Continued)

Division headquarter (formation)	Main Dressing Station (MDS)	manned by senior medical officers together with five nurses, PHI, storeman, lab technician, ambulance and driver and a clerk. A blood store and portable ventilator are available for life-saving surgery undertaken at MDS and from there patients are evacuated to Field Hospitals or Army Base Hospitals.	4 to 10 km from the frontline /Helicopters/ usually within 2 hours but can vary according to tactical and ground situation
Security Force Field command	Military Base Hospital (MBH)	Definitive care at the theater of war-manned by consultants, medical officers and other allied health, supportive and administration staff. Anuradhapura MBH was equipped with two operating theaters, a three-bed intensive care room, and an 80-bed ward	Victory (Anuradhapura Army Base Hospital) situated 180 km away from the conflict zone (Vanni theater of war- with 45 min helicopter flying time)/ Fixed wing air evacuation and by road ambulances to Colombo - 4 to 6 hours from Frontline to MBH
Sri Lanka Army	Army Hospital Colombo (AHC) / National Hospital Sri Lanka (NHSL- Ministry of Health)	Advanced surgical subspecialty care and rehabilitation	Situated 199 km from Anuradhapura (equivalent to 5 to 6 hours of traveling time by road)

For complex injuries requiring advanced neurosurgical, spinal, visceral, orthopedic, and reconstructive services, patients were transferred to the Colombo Army Hospital (CAH) and the National Hospital of Sri Lanka (NHSL), both situated 199 km from Anuradhapura (equivalent to 5-6 hours of travel time by road). All injured personnel eventually found their way to Colombo Army Hospital and Ragama Rehabilitation Hospital for comprehensive rehabilitation[4]. (Table 4)

Contribution of civilian health system in combat casualty care

The protracted nature and heightened intensity of the war, coupled with inherent limitations in human and physical infrastructure, underscored the inadequacy of relying solely on the Sri Lanka Medical Corps for managing the entire spectrum of combat casualty care—from the initial point of injury to rehabilitation at tertiary care centers. Recognizing this challenge, a pioneering solution emerged: the development of a distinctive hybrid approach that seamlessly integrated military and civilian health systems, orchestrated at the highest administrative level to achieve a shared objective [4,8,11,13].

The pivotal stages of resuscitation, stabilization, and evacuation from the battlefield were skillfully executed by field surgeons well-versed in the intricacies of managing war casualties. Meanwhile, the bulk of definitive care was shouldered by civilian surgeons and healthcare personnel stationed across multiple tertiary care centers. To fortify the healthcare infrastructure at the fringes of the conflict zone, selected Health Ministry General Hospitals were transformed into specialized facilities dedicated to the intricate management of battle trauma. These centers were meticulously equipped with the requisite materials and human resources. While General Hospital Anuradhapura primarily attended to the medical requirements of both armed forces personnel and civilians wounded in the Northern sector and adjacent regions, the Base Hospital at Polonnaruwa played a crucial role in providing care to those injured in the Eastern Province and Polonnaruwa District. In 1987, the introduction of a dedicated military ward at the Polonnaruwa Hospital, managed by civilian staff, significantly bolstered these efforts, underscoring the effective collaboration between the military and civilian sectors in addressing casualties during the conflict. This collaborative approach extended to other civilian hospitals, further emphasizing the synergistic relationship between military and civilian healthcare in these challenging circumstances [4,8,13].

In a commendable show of solidarity, Ministry of Health consultants, doctors, and nurses volunteered their expertise, converging at Army Base Hospitals to alleviate the strain on the military medical system caused by the overwhelming influx of casualties. This dynamic collaboration between military and civilian healthcare entities formed an integrated and effective hybrid system of care. Notably, this model drew inspiration from Israel's successful implementation of a similar approach, wherein the swift dissemination of knowledge acquired during wartime was seamlessly applied to enhance civilian trauma care [4,11]

Lessons learned for future national trauma systems

The civil war in Sri Lanka presented a significant influx of war-related injuries, demanding the creation of a comprehensive system seamlessly integrating both military and civilian elements. Operating in austere conditions necessitated the use of improvised techniques to preserve life and limb in frontline areas, followed by a transition to more sophisticated settings for damage control and definitive surgery. With a decade of peace, accompanied by shifts in injury epidemiology, the evolving landscape has mandated the exploration of innovative strategies to sustain and enhance the surgical skill-base for both military and civilian contexts [4,14,15].

Combined civil military medical alliances in natural and manmade disasters have already been evident in the peacetime. Further these alliances can be expanded to civilian trauma care, combating epidemics, medical education and research on the way towards a combined national trauma care system.

Legends for figures and tables

Table 1. The timeline of the Eelam war
Table 2. Types of weapons used by the LTTE (verified by Lt Col (Dr) Bandula Nishshanka RSP USP psc Phd.
Table 3. Landmarks events of evolution of SriLanka Army Medical Corps (SLAMC)

Table 4. Field casualty care organization in Sri Lanka medical corps. (verified by Col (Dr) RKP Pushpakumara MD.)

Acknowledgement : Lt Col (Dr) Bandula Nishshanka RSP USP psc Phd -Institute for Combinatorial Advanced Research & Education (KDU CARE), General Sir John Kotelawala Defence University, Sri Lanka, for verifying military related facts and figures.

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TRAUMA SECRETARIAT SRI LANKA

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Trauma Quality Improvement/ Mortality Case Reports:

A patient with penetrating cardiac trauma: A real time test of integrity of the trauma care system in Sri Lanka

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Keywords - penetrating cardiac trauma, trauma system, primary care, trauma care, thoracotomy

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Background

Management of penetrating cardiac trauma is a real time test of evaluating the integrity of a trauma care system.[1] They have a low incidence of 0.16% as indicated by the trauma data bank of American College of Surgeons.[2] Gunshot injuries, stab injuries and rarely accidental impalement are the main mechanisms of penetrating cardiac trauma. Knowledge and experience from high density trauma centers shows us that emergency transportation, quick response and proper diagnosis with urgent intervention is necessary to minimize fatalities.[3] We present this rare case highlighting major challenges trauma care system in Sri Lanka faced with to deliver optimal care

Case presentation

A teenage boy presented to a major trauma centre (MTC) after a fall from a tree of ten feet height. He was from a close by suburb and fallen directly on to a steel rod fixed to a concrete wall and it had penetrated the left side lower chest wall. He had removed the rod and was found collapsed at the scene by his elder brother. Without any further care at the scene, he was taken immediately to the close by divisional hospital which was 6km away by a trishaw (Tuk-Tuk).

The Divisional hospital has an emergency treatment unit (ETU) which caters for both trauma and non-trauma patients. It has patient monitoring facilities with a multimonitor and basic airway management devices including ambu bags, face masks and intubation facilities. Laryngeal mask airways are not available and there is no portable ventilator available. ETU is manned medical officers who are MBBS qualified. Some have undergone emergency care training and primary trauma care training.

Blood pressure was unrecordable on admission with a weak pulse and he went into cardiac arrest. With cardiac massage, ambu ventilation via face mask and one cycle of adrenaline he was resuscitated and was immediately transferred to a MTC with ambu ventilation via face mask and a Dobutamine infusion.

MTCreceived the patient approximately 40 minutes after the incident. This MTC has a separate out-patient department, trauma resuscitation bay and a short stay ward for initial assessment and observation manned by trained medical officers and nursing staff. An in-house consultant surgeon is available round the clock with or without a post graduate trainees in Surgery.

On admission, the patient was unconscious but was in sinus rhythm with a heart rate of 140 beats per minute and the blood pressure was 60/40mmHg. The patient was intubated and was connected to the portable mechanical ventilator. The puncture wound was just above the left costal margin 3cm from the left sternal edge overlying the 6th intercostal space. Bilateral air entry was equal and the heart sounds were audible with no evidence of distended neck veins.

Volume resuscitation with crystalloids and the first pint of non-crossmatched blood in the massive transfusion protocol improved the blood pressure to 100/60mmHg. An emergency focal assessment with sonography in trauma (eFAST) was performed by the radiology team at bedside using the ultrasound machine available in the MTC. .Assessment with the cardiac probe showed no evidence of cardiac tamponade and haemopneumothorax as there was malfunctioning of abdominal probe of ultrasound machine at that moment.

The radiology unit at MTC functions 24/7 under an on-call consultant radiologist with medical officers and radiographers facilitating ultrasound, X-rays and Computed Tomography (CT) scans.

Since the eFAST excluded major thoracic bleeding and there was a drop in blood pressure indicating ongoing bleeding, the bleeding was assumed to be into the peritoneal cavity with probable injury to the diaphragm. Hence, it was decided to perform an exploratory laparotomy.

Exploratory laparotomy revealed no blood in the peritoneal cavity and there was no evidence of bleeding from the diaphragm or other solid organs. As the diagnosis was in doubt, bilateral intercostal tubes were inserted and a pericardial window was created through the central tendon to exclude cardiac injury. Intercostal tubes revealed no drainage while the pericardial window revealed the presence of blood clots in the pericardial cavity.

A Left anterolateral thoracotomy was performed to deal with pericardial tamponade. Bleeding from the left atrial penetrating wound was noted upon displacing pericardial blood clots. The bleeding was initially controlled with digital pressure until haemodynamic stability was achieved. The defect in the atrium was re-

paired using two 2-0 polypropylene stitches with pledgets. All blood clots in the pericardium were removed and pericardium was repaired using 2-0 polyglactin sutures. A pericardial drain through the pericardial window in the central tendon and a sub diaphragmatic abdominal drain was left in situ. This management was carried out by surgical and anaesthesia teams with inputs from consultant intensivist and consultant radiologist.

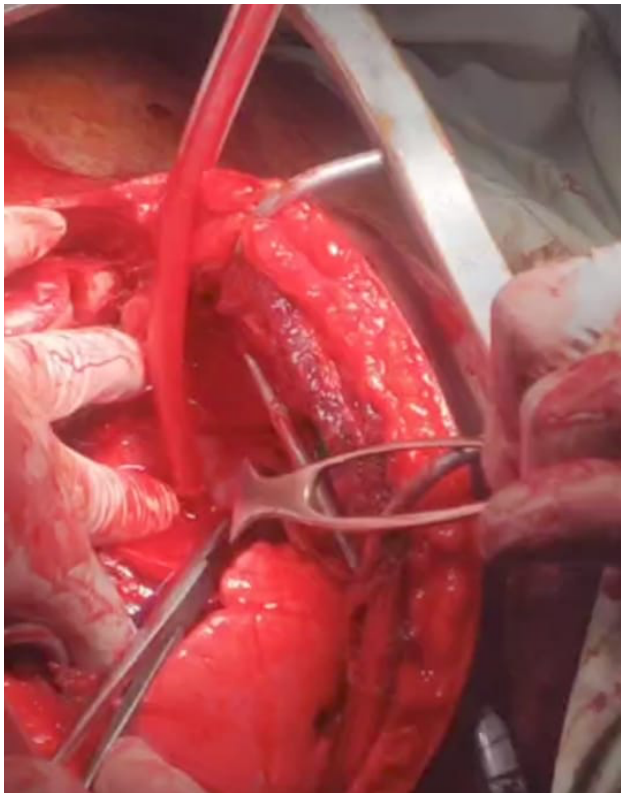

Figure 1: Bleeding from the defect in the atria controlled by digital pressure

Figure 2: After the repair with pledgeted sutures

Following surgery, the patient was admitted to General Intensive Care Unit (GICU) as the MTC does not have a dedicated trauma intensive care unit nor beds reserved for trauma patients. Post-operative 2D-echocardiography showed minimal pericardial effusion with no structural defects in the heart. Despite haemodynamic stability, his neurologic status was static and his al pupils were dilated to size 4 and non-reactive by post-operative day 4. Non-contrast computer tomography revealed cerebral oedema with evidence of global ischemia. With subsequent scans and electronic encephalogram (EEG), the diagnosis of hypoxic ischaemic encephalopathy was made. On top of this, patient developed right sided pneumonia and sepsis probably as a result of aspiration The patient expired on post-operative day 18.

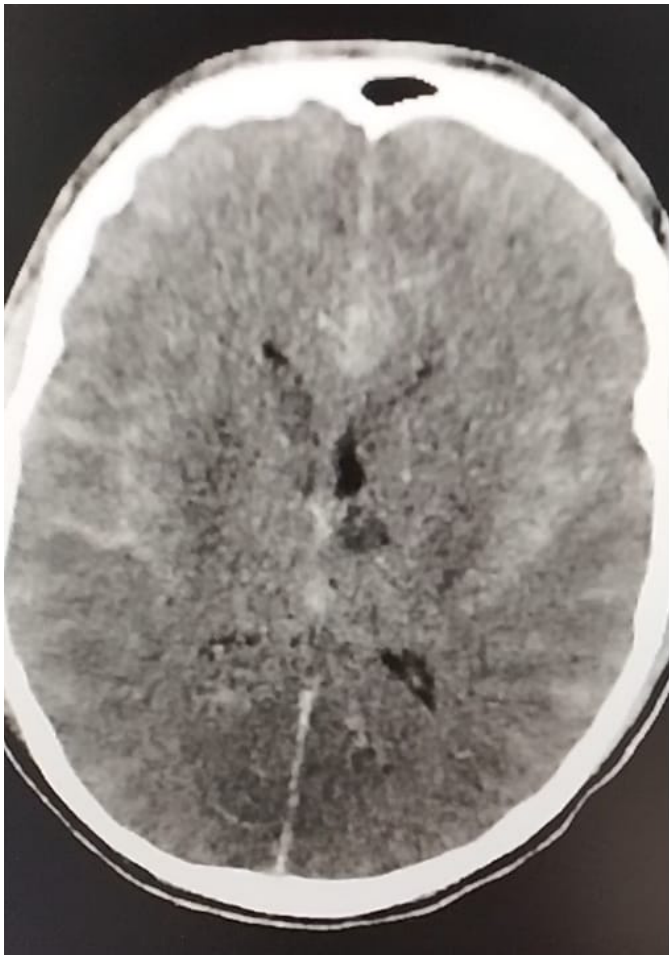

Figure 3: Non contrast computer tomography showing global infarction and cerebral oedema

Discussion

Penetrating cardiac injuries carry a high mortality even in world's best trauma care systems. 1 Improvement in pre-hospital care, operative management and intensive care with integrity in a trauma care system is a major factor in reducing fatalities. Management of such serious injuries gives us a good evaluation of the quality and integrity of our trauma care and an opportunity to improve the system[4,5].

Sri Lanka has a free ambulance service available round the clock with trained personnel which responds to the hotline 1990.6 But this patient was taken to the hospital in a trishaw which denied him of the opportunity for pre-hospital management of airway, breathing and circulation. This signifies the need for the improvement in community awareness regarding the importance of the ambulance service and its role in prehospital care which can improve patient outcomes.

Divisional hospitals in Sri Lanka are equivalent to level III trauma centres according to the classification of American College of Surgeons – Committee on Trauma (ACS-COT).7 They have basic facilities for initial care with no specialized care, no access to radiological investigations, transfusion of blood products and theatre facilities. Their main involvement is to stabilize the patient with primary survey and immediate transfer to a nearest hospital with higher level of care. This patient was admitted to the divisional hospital with a cardiac arrest with evidence of penetrating injury in the cardiac box. Cardiac box is the space bordered by bilateral midclavicular lines, costal margin and the clavicles in which a mediastinal injury is highly likely if there is evidence of trauma.1 An emergency room thoracotomy might have been considered at this presentation. But it was not performed in a place with bare minimum facilities and expertise.8 Thus, maintaining ventilation via a definitive airway and volume resuscitation is the maximum possible care he should have received prior to transfer going by the advanced trauma life support protocol.9 Inadequate ventilation and oxygen supply to the brain might have resulted in hypoxic injury which may have affected the final outcome.

Failure to maintain the airway was a major drawback in the initial care of this patient. To address these issues in primary trauma care, a system should be in place to constantly monitor the availability of infrastructure, resources and trained personnel. Peripheral units should be empowered to develop a trauma care using available facilities with inputs from National Trauma Secretariat. Training the staff involves getting them to follow workshops in trauma, basic life support and advance life support together with temporary attachment to higher level trauma centers. Conducting drills and refresher workshops at institutional level regularly will improve their performance in trauma care.

Communication between primary trauma care centers and field personnel with higher level centers is an important aspect of trauma care which has the capacity to improve outcomes.9 This gives the receiving centers adequate time to prepare and also an opportunity to advise on acute management. In penetrating cardiac injury, this integration of care can be an important factor in saving a life.[1]

This practice can be achieved simply by creating awareness among medical officers in peripheral units. Telephone communication is available island wide. Contact numbers of the personnel in higher level centers can be made available for peripheral units to be contacted in cases of emergency to inform regarding patients being transferred and to get instructions on initial management. Constructive feed back from the receiving institution regarding transferred patients and educating sending institutions without a blame culture will help to improve and maintain this practice.

A patient with a penetrating cardiac injury will present with an external entry point inside the cardiac box and haemodynamic instability. The classical triad of muffled heart sounds, hypotension and distended neck veins is rarely appreciated in the clinical setting. Options for diagnosis of a cardiac injury in an ideal setting are chest X-ray, eFAST, echocardiography and sub-xiphoid pericardial window. Subxiphoid pericardial window which was considered the gold standard earlier is now replaced by eFAST and echocardiography which has a high sensitivity and specificity.[4,10]

This patient arrived at resuscitation bay with haemodynamic instability with prior history of cardiac arrest. With initial resuscitation he was transiently stable to be taken to an operating theatre which avoided the option of emergency room thoracotomy. Only diagnostic option which was available at the bed side was the eFAST, that has a sensitivity and specificity comparable to echocardiography in identifying penetrating injury to heart and it is a crucial decision making tool in cardiac trauma algorithms around the world.[1,4] The MTC did not have an institutional level cardiac trauma algorithm in place. With no evidence of haemothorax clinically and radiologically, exclusion of cardiac tamponade by the eFAST gave a suspicions of a major abdominal bleeding in the background of inaccurate assessment of peritoneal bleeding with defective ultrasound probe. Laparotomy was performed with hope of excluding abdominal bleeding and performing pericardial window to look for further evidence of cardiac tamponade.

In patients with lower thoracic or upper abdominal penetrating trauma, injuries can be in both abdomen and thorax. When adjuncts did not reveal the cause of hypotension, next step is to surgical exploration usually abdomen first as it is the site of bleeding in most cases. In this patient blood has clotted in the pericardium which would have contributed to absence of typical appearance of pericardial effusion in eFAST scan to a certain extent. It also highlights the pitfalls of needle pericardiocentesis in this kind of situations as a preliminary measure. Left anterolateral approach, pericardiotomy, haemorrhage control using digital pressure and atrial repair using pledgeted sutures are acceptable evidence based practices in the management of cardiac trauma4. Post operative haemodynamic stability and the echocardiography findings gave evidence for the success of the cardiac repair in the initial part.

However, it was probable that significant hypoxic insult to brain had occurred during arrest and peri-arrest period of trauma care and had contributed so much to failure of attempt at saving this patient. Dependance for ventilator and predisposition to aspiration, pneumonia and sepsis are sequalae leading to death.

Penetrating cardiac injuries carry a high mortality even in world's best trauma care systems. Timely pre-hospital care, diagnostics and operative interventions carried out in an integrated manner is key to improve outcomes. This case highlights the importance of strengthening the trauma care system particularly related to prehospital care and diagnostics. It is also a case which demonstrates persistent clinical suspicion and logical intervention to exploration leads to achieve a correct diagnosis and treatment when investigation does not tally with clinical picture.

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Editor's notes: We, the editors, hope that this mortality case report/s will help in trauma quality improvement projects (TQIP) and make it easier to come to good patient care decisions. There is no doubt that understanding and rectifying the problems and systems issues presented in this case , will allow your future patients to have a better clinical outcome.

All patient & institution identifiable information removed/ changed from this article to protect privacy.

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TRAUMA SECRETARIAT SRI LANKA

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Photo Essay

Life threatening airway injury following blunt thoracic trauma.

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Keywords - Tracheobronchial Injury, Bronchial trauma, Blunt Thoracic Trauma.

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Summary

Blunt Thoracic trauma is one of the common presentations to accident and emergency departments in local settings. Life-threatening tracheobronchial injury is uncommon and carries high mortality and morbidity if left untreated. This article describes a case of major airway injury following blunt thoracic trauma in a young male.

Case

A 20-year-old male presented following a fall from a motorcycle and presented to the local hospital with shortness of breath. He was found to have a tension pneumothorax and an intercostal drain inserted into the right side. Subsequent Chest X-ray revealed persistent pneumothorax and continuous bubbling from the intercostal drain. He was transferred to National Hospital for Respiratory Disease for further management.

The patient had undergone a bronchoscopy which revealed a complete avulsion of the right main bronchus. Primary repair of the right main bronchus was done and the repair site was covered with an intercostal muscle flap. He had an uneventful recovery and was discharged home on postoperative day 5.

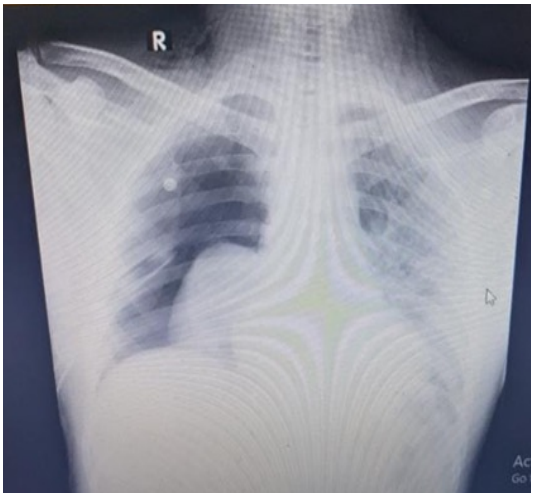


Figure 1: Chest X ray showing Persistent pneumothorax on right side.

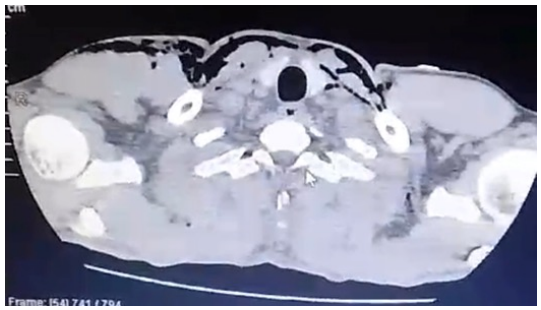


Figure 2: Surgical emphysema seen on CT chest.

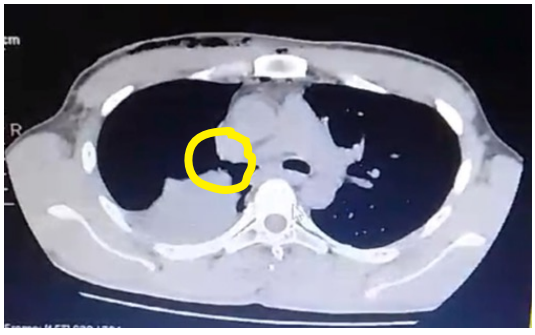
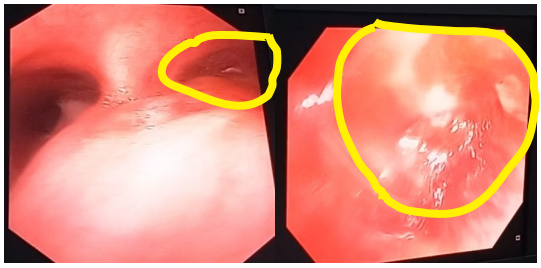


Figure 3: CT chest revealed collapsed right lung and Right Main bronchial Disruption.



a. b.

Figure 4: a. Bronchoscopy view at Carina. b. Obliterated Right Main bronchial orifice.

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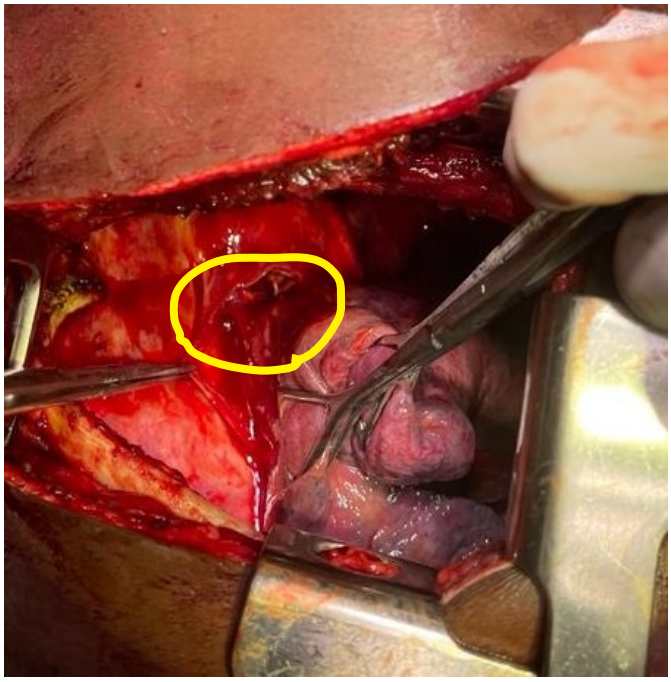

Figure 5: Right Main bronchial opening seen on Posterolateral Thoracotomy.

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TRAUMA SECRETARIAT SRI LANKA

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Review Article:

Traumatic elbow dislocations

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Keywords
Elbow, lateral ligament complex, elbow instability, simple dislocations, terrible triad

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Abstract

Elbow dislocations occur mostly in the young adult population and nearly 50% occur during sporting activities. Diagnosis and assessment of concentric reduction following manipulation are performed using plain radiography and fluoroscopy. Computed Tomography (CT) enable identifying subtle fractures that can otherwise lead to chronic instability. Simple dislocations by definition have no associated fractures and complex dislocations are associated with a variety of fractures, with the terrible triad injury and trans-humeral dislocations leading to surgical challenges.

Assessment of the direction and the mechanics of elbow dislocation enable identify the structures that have been injured. Posterior and posterolateral dislocations are the most common patterns, where the lateral ligament complex is often compromised. Most simple dislocations are amenable to reduction, immobilization, and gradual rehabilitation resulting in good functional outcome. Ongoing instability can occur in 10% of the patients. Complex dislocations pose a surgical challenge and lead to joint stiffness, pain and ongoing instability if not managed properly. Identifying the individual component of a complex dislocation such as radial head fractures, coronoid fractures, proximal ulnar fractures, and ligament injures is important for satisfactory outcome.

Introduction

The elbow is the second most common joint to dislocate in adults after the shoulder joint[1]. The reported incidence is 2.9 to 5.1 dislocations per 100,000 population per year [2]. Among children, the elbow is recognized as the most common joint to dislocate, with 45% of the dislocations occurring in the age group between 10 to 19 years. The incidence is higher among males[3] and the high energy mechanisms are the usual cause. Elderly females can present with low-velocity falls resulting in elbow dislocations. Approximately 50% of elbow dislocations occur due to athletic activities, specifically during competition rather than during practice [2]. Healthcare costs following elbow injury cannot be underestimated. The direct medical cost associated with elbow dislocations varies between populations. A study from Taiwan reported that the medical cost per patient with simple or complex dislocation is USD 508 per patient[4]. A study conducted by the National Health Service (NHS) United Kingdom reported an average cost of GBP 1088 per patient[5].

Figure 1 Simple elbow dislocation. From "The Assessment and Management of Simple Elbow Dislocations by Grazette AJ; Aquilina A. Open Orthop J. 2017 Nov 30; 11:1373-1379. [used under Creative Commons CC-BY license].

Applied anatomy

The elbow is stabilized by both static (osseous and soft tissue) and dynamic mechanisms[6]. The static mechanisms include the osseous congruity of the ulna-humeral joint and the medial and lateral ligament complexes. The elbow flexion angle affects the stability provided by these osseous and soft tissue structures [6]. Bony stability is maximum at <20°and >120° of flexion[7]. Soft tissue structures like static medial and lateral collateral ligament complexes are dynamically supported by muscular stabilizers; common flexor and extensor origins, the biceps brachii and triceps brachii. The anterior bundle of the medial collateral ligament (aMCL) is the primary stabilizer against valgus strain at 30°-110° of flexion. The anterior bundle is mainly active during extension and early flexion whereas the posterior bundle becomes the principal stabilizer from 60° to full flexion[6].

The lateral ligament complex resists excessive varus and external rotation forces on the elbow[8]. The lateral ligament complex consists of an annular ligament, lateral/ radial collateral ligament, and lateral ulnar collateral ligament (LUCL). LUCL originates at the lateral humeral epicondyle, partly blends with the annular ligament, and inserts at the supinator crest of the ulnar. About 30% of the population has an accessory lateral collateral ligament extending from the annular ligament to the supinator crest of the ulna[8].

Applied biomechanics

Falling on an outstretched hand during sporting events or high-velocity trauma is the most common mechanism that leads to elbow dislocation. The most com-

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mon directions of dislocation are posterior or posterolateral. O'Driscoll et al demonstrated simple elbow dislocations can be produced by sequential ligament failure from the lateral to the medial side, a concept termed "Horii circle"[9]. Schreiber reviewing 62 youtube.com video footage of elbow dislocation concluded that the elbow dislocates in a position of relative extension[10]. He stated that the sequence of disruption occurs from medial to lateral, disrupting the anterior bundle of the medial collateral ligament (aMCL) first. Evidence of MRI from further studies by Schreiber et al and Rhyou et al confirms this concept, the first study showing significant partial or complete medial ligament tears in all MRI scans following simple dislocations[11,12]. Other mechanisms can result in different sequences of osseous and soft tissue injury leading to elbow dislocation.

Definition and classifications

Dislocation of the elbow is defined as static loss of ulnohumeral and radiocapitellar joint congruency whereas instability is defined as dynamic disturbance to joint congruency with stress[13]. Elbow dislocations are primarily classified as simple, or complex based on the presence of concomitant fractures. Simple elbow dislocations are by definition not associated with fractures; however small osteochondral fractures may still be present in a dislocation classified as simple based on initial radiographs. The commonly associated fractures include the radial head and the neck, the olecranon and the proximal ulna, the coronoid process, the capitulum, and the distal humerus. Approximately 17% of the elbow dislocations are associated with fractures[14]. When elbow dislocations are compounded by radial head fractures and ulnar coronoid fractures, it is classified under "Terrible Triad Injury" which lead to poor outcomes if not treated properly[14]. Elbow dislocations can occur as open or compound injuries where the dislocation or the fractures are communicating with the exterior. Although rare, the median nerve, the radial nerve, the ulnar nerve, and the brachial artery are at risk of injury during elbow dislocation[15]. Therefore, neurovascular examination remains an important part of assessment following elbow dislocation. Elbow dissociations are also classified by the direction of the dislocation, with posterior and posterolateral dislocation accounting for 90%[16].

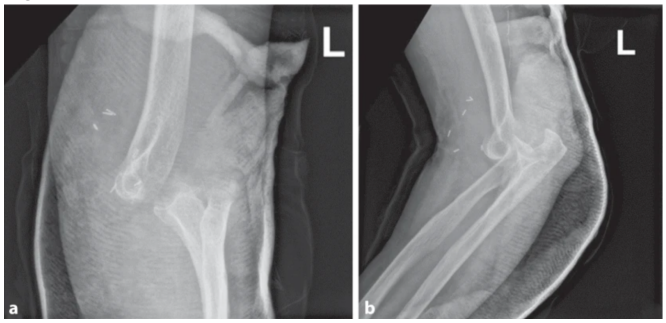

Figure 2 Complex elbow dislocation from Surgical management of a traumatic elbow dislocation with disruption of the brachial artery by Habarta, J., Jordan, M., Meffert, R. et al. Obere Extremität 17, 267–271 (2022). [used under Creative Commons CC-BY license].

Assessment

The importance of history, physical examination, and directed imaging to diagnose elbow dislocation cannot be overstated. The normal range of elbow flexion-extension prono-supination and varus and valgus stability can help rule out a dislocated elbow clinically. Palpation of anatomical landmarks in relation to each other also provides convincing evidence of an enlocated elbow. Plain anteroposterior and lateral radiographs are the mainstay in diagnosing a dislocated elbow.

The upper extremity is placed adjacent to the radiographic table with the entire posterior surface of the extremity contacting the cassette for the standard anteroposterior elbow radiograph. The beam is directed from anterior to posterior, perpendicular to the elbow. The hand is supinated, and the elbow is extended. Using the anteroposterior view the radiographic anatomy of the medial and lateral condyles, the radiocapitellar joint, the trochlea, the olecranon, the radial tuberosity, and the anteromedial facet of the coronoid can be delineated. The normal carrying angle of 5° to 20° valgus angle can also be appreciated.

The lateral view is obtained by flexing the elbow to 90° and placing it on the cassette. The entire upper extremity is maintained parallel to the floor and the forearm is maintained in the neutral position with the thumb pointed towards the ceiling. The X-ray beam is directed perpendicular to the elbow. Three concentric rings can be identified in a lateral radiograph of the elbow. From outside to inside, they represent the medial trochlear ridge, the capitellum, and the trochlear groove. Disruption of this concentric anatomy may indicate a pathology. Also, the anterior humeral line should intersect the capitellum in its middle third. If the radiocapitellar line that passes through the radial neck does not intersect the capitellum, the radial head dislocation or subluxation should be suspected.

In addition, the dislocation is associated with fractures and complex patterns the radiographs provide the initial assessment of the complex fracture patterns. In situations where the elbow is dislocated and relocated in the field, standard static X-ray imaging gives minimal details on instability which is a dynamic phenomenon. Standard anteroposterior and lateral X-rays may still reveal the presence of loose bodies, arthritis, coronoid dysplasia, and malalignments that occurred because of a paediatric fracture. Also following an acute dislocation, this may reveal, angulations in the radial neck, rim defects in the radial head, and impaction fractures of the capitellum.

Once the elbow is reduced assessment for physical signs of instability is important and is based on indirectly eliciting instability with stress testing. Thus, all involve axial loading with varus, valgus, or rotatory forces acting upon the elbow to demonstrate instability. This recreates the forces that disturb joint congruity, thereby indirectly observing features of instability like subluxation of the radial head, apprehension, and a palpable clunk. Eliciting subtle forms of instability clinically can be challenging, and findings can be equivocal in milder forms, in which ligament reconstruction is helpful.

While radiographs are helpful in most simple elbow dislocations, computed tomography (CT) is an important investigation to identify whether there are any fractures leading to long-term instability. Coronoid fractures are one such example. In complex dislocations, 3D CT scans are immensely helpful in assessing the fracture morphology in coronoid fractures, radial head fractures, and associated bone loss of the capitellum as in a 'Hill-Sach's lesion[17].

MRI Can help assess the extent of chondral injuries, ligament tears, chondral injuries, and joint subluxations. However, MRI is not a routine investigation in the acute setting. Dynamic imaging like ultra-sonography and fluoroscopy can demonstrate radial head subluxation or ulno-humeral widening. Ulno-humeral laxity of more than 4 mm is indicative of posterolateral rotatory instability (PLRI). Examination for the integrity of the nerves, specifically the ulnar nerve is mandatory. Associated injury to the forearm interosseous membrane can lead to longitudinal instability patterns such as Essex-Lopressti injury. The distal radioulnar joint must also be examined to identify any possibility of longitudinal instability[18].

Principles of management

Simple acute elbow dislocation rarely needs surgery, except for irreducible dislocations and the inability to maintain reduction. These occur in less than 10% of cases of acute simple elbow dislocations. Over 90% of the simple dislocations are managed with reduction and splinting. Pronation increases the stability of the elbow if lateral instability is the aetiology[19]. In isolated medial instability, the patient should be splinted in supination[20]. However, if both lateral and medial ligament complexes are compromised immobilization in the neutral position is recommended. At least for 4 weeks, unprotected shoulder abduction is not recommended. This is to prevent varus strain on the healing lateral ligament complex.

Some authors recommend examination under anaesthesia for simple dislocations if the mechanism of injury is of high energy, severe swelling and bruising all around the elbow, and if the patients are reluctant for active mobilization after 1-2 weeks of non-operative management[17]. This is due to the extent of soft tissue injury being more dramatic where the whole distal humerus can be stripped off the soft tissue. Ligament repair is recommended in the acute stage for unstable elbows <30°. The repair can also be attempted for early, less symptomatic chronic PLRI if soft tissues are favourable. For open surgery, the patient is positioned supine with the affected arm on a hand table. The use of a sterile tourniquet is helpful for adequate access during the procedure. The Kocher approach is used for isolated lateral access, but a posterior incision is an option in the presence of co-existing medial instability. In acute elbow dislocations, it is common to find a hematoma with a torn anterior capsule and brachialis muscle. Once the hematoma is cleared laxity of the lateral ligament complex and annular ligament can be observed. It is not uncommon to find the entire lateral ligament complex avulsed from the humeral origin and flipped into the radio-capitellar joint.

Once the avulsed proximal end is freed up, the footprint on the posterior aspect of the lateral humeral epicondyle can be identified. This is seen as a bare area directly lateral and slightly inferior to the centre of the olecranon fossa. After debriding the footprint, a trans osseous repair can be done with No 1 or 2 non-absorbable braided sutures. Sutures are tied at elbow flexion of 30°. Suture anchor repair is another option. A cast or brace is applied for the initial post-operative period which can be replaced by a removal splint/ brace at 10-14 days. The elbow is splinted at rest for 4 weeks, strictly avoiding shoulder abduction.

Complex elbow dislocations involving fractures are managed with anatomical reduction of the fracture fragments and stable fixation. The associated lateral collateral and medial collateral ligaments should be repaired either using suture anchors or trans-osseous sutures.

Outcome

The outcome following simple dislocations is generally satisfactory with only 10% reporting ongoing instability. Approximately 50% of the patients gain full range of motion, absent pain with good functional outcome. One-third of patients have less than 15 ° of loss of the range of motion, minimal pain, and good stability. With complex dislocations, associated fractures of the ulna, radial head and coronoid are the predictors of poor prognosis if not treated appropriately.

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Technology and Trauma

Metaverse: some of its applications for trauma care in Sri Lanka

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Keywords - meta verse, virtual reality, augmented reality, trauma care, mirror worlds, life logging

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Abstract

Metaverse technology has significant potential for improving trauma care. Its core components are Augmented reality (AR), Virtual Reality (VR), Lifelogging and Mirror worlds. Health 4.0 advancements presented by integration of AI (artificial intelligence) AR, VR and 5G networks will improve out comes for victims of trauma. However, adopting these technologies are not without challenges for low and middle income countries (LMIC) like Sri Lanka.

Introduction

Metaverse is a concept introduced three decades ago which simply means a shared real and virtual world or a universe. It refers to a virtual reality existing beyond the true reality. The science-fiction author Neal Stephenson coined the term metaverse in his novel "Snow Crash" published in 1992[1]. According to some broader definitions, the metaverse represents a futuristic virtual world in three-dimensions[2]. Since its beginning, the metaverse concepts have been applied in various industries such as education, entertainment, manufacturing, finance and in healthcare.

With regard to healthcare, metaverse technology has been used in many aspects such as remote patient management using immersive technologies there by reducing costs, improving accessibility and there by promoting universal health coverage[3]. In training and education virtual reality (VR)and augmented reality (AR) play a crucial part in developing training modules [4, 5] . Creating 'digital twins' (virtual replicas of patients) enables predictive healthcare[6].

Trauma care represents a complex interaction between humans and technology. Historically advancement in trauma care is linked to advancement in technology. With the increasing population demands metaverse has unique applications in enhancing trauma care. Virtually supporting the frontline workers in healthcare, by experts, training in simulated environments are some of its applications.

Metaverse-definitions and the roadmaps

Metaverse is recognized as convergence of Augmented Reality (AR) and Virtual Reality (VR), as its core the concepts. The Acceleration Studies Foundation (ASF), a representative metaverse research organization announced the metaverse roadmap in 2006 and defined 'Augmented reality', 'Virtual worlds', 'Lifelogging' and 'Mirror worlds' as four types of metaverse. In the ASF roadmap, two axes were presented to explain these four types of the metaverse. One is 'augmentation versus simulation', and the other is 'intimate versus external' (Figure 1)[2, 8].

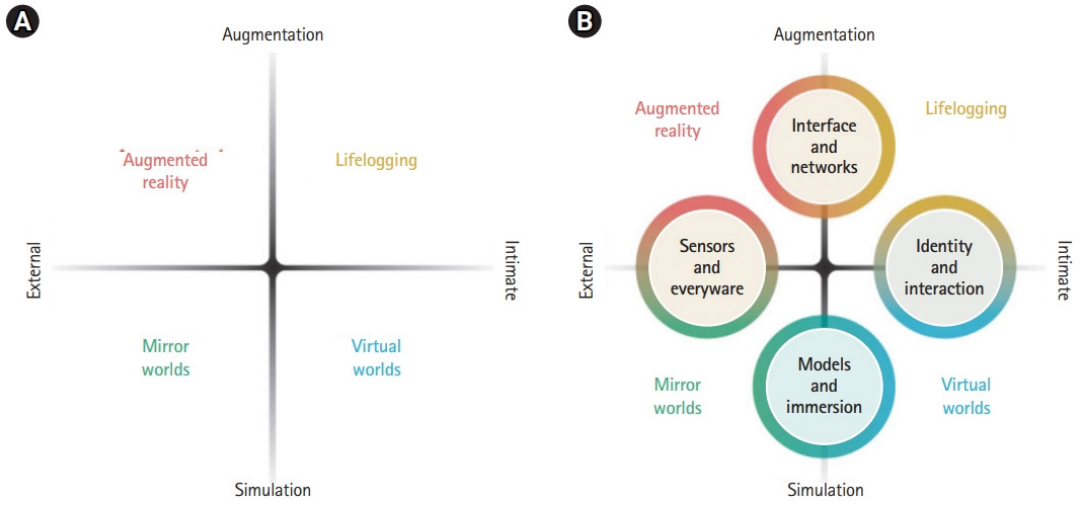

Figure 1 The two axes and the four types of metaverse. Reproduced from Kye B, Han N, Kim E, Park Y, Jo S. Educational applications of metaverse: possibilities and limitations. J Educ Eval Health Prof. Reproduced under the terms of the Creative Commons Attribution License

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Augmentation vs simulation: The first axis is augmentation versus simulation. Augmentation technology enhances human sensing or adds new functions to a real-world environment through stimuli. Simulation models the reality.

Intimate vs external: The second axis is intimate versus external. The intimate metaverse focuses on personal behavior and individual data. The external metaverse focuses on the surrounding world [2, 9, 10].
Thus, the four types of metaverse can be defined using the two axes. 'Augmented reality' lies in the interphase between augmentation and external environment; Virtual worlds can be intimate and simulated; Lifelogging is likely to be augmented and intimate; Simulated external environments are the mirror worlds.

Augmented reality (AR):

Augmented Reality refers to a virtual three-dimensional (3D) version of reality world over which external information is transformed to computer-generated virtual information. Users experience the real-time interactive experience between real world and virtual world. In general, users have employed glasses, lenses, smartphone, and computers, with the typical examples of AR stereoscopic images and 3D construction. This technology is used in assisting surgical and interventional procedures[11, 12].

Virtual reality (VR):

Virtual reality has been recognized as a completely virtual 3D world. In this, individual information is superimposed on 3D computer generated environments that users are enabled to immerse themselves in for interaction and exploration. Users register a virtual personalization avatar in the virtual world for activation and communication. The specific examples cover virtual reality training programs and virtual hospitals[13]. Virtual reality can be used for trauma and surgical training.

Lifelogging:

Lifelogging refers to a record-keeping platform where users can record their real individual information using a virtual format to share with others, with typical examples being Instagram, Facebook, X (formerly Twitter), and health monitors [14].

Mirror worlds

Mirror world (e.g., Zoom meeting, BizConf Video, and 360-degree video) is a virtual world that is replicated in accordance with real external events to create a repeated environmental experience for users [15].

Metaverse and its applications in healthcare

The four types of metaverse as applicable for health care are presented in the table 1 and figure 2

Table 1 Types of metaverse and their application in healthcare

Type of metaverse	Application in healthcare
Augmented reality	Assisting surgical and interventional procedures
Virtual reality	Virtual consultations and surgical training
Mirror worlds	Medical education
Life logging	Monitoring and alerts

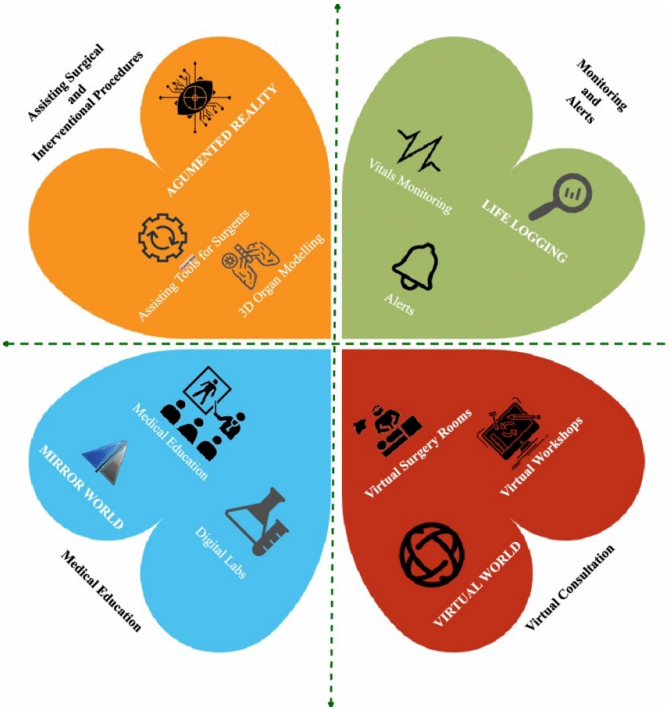

Figure 2 Four types of metaverse and their applications. Reproduced from Metaverse for Healthcare: A Survey on Potential Applications, Challenges and Future Directions." by Chengoden et al. (2022). Reproduced under the terms of the Creative Commons Attribution License.

Metaverse-its applications for trauma care in Sri Lanka

Trauma care in the platinum ten minutes and golden hour

There is ample evidence that prompt attention by well-trained trauma care professionals increase the positive patient outcomes following trauma [16, 17]. However, there are many challenges bringing the patients to the attention to trauma care experts within the golden hour (18). The challenges may range from simply geographical, or situation related as in mass disasters where access is limited to unavailability of human resources in ideal levels. In such challenging situations metaverse technologies may enable remote assistance. The first contact persons can be equipped with AR eyewear to connect with trauma surgeons based in a trauma center. The other experts can also join to provide guidance and support at the initial stages. Quick and seamless flow of information in real-time and expertise will improve the outcomes. In addition, there is evidence that trauma surgery outcomes can be improved using AR technology to visualize medical imaging[19].

Currently Sri Lanka's prehospital ambulance service "Suwasariya" started using Internet of Medical Things (IoMT) and Microsoft HoloLens® AR features, to connect emergency medical team personal with experts remotely (Figure 3). The aim was to enhance patient care during the golden hour of medical emergencies by early attention of medical experts.

Figure 3 Suwasariya Emergency Medical Technician (EMT) using VR technologies. Image courtesy Mr Sohan De Silva, Chief Executive Officer of Suwasariya Foundation, Sri Lanka.

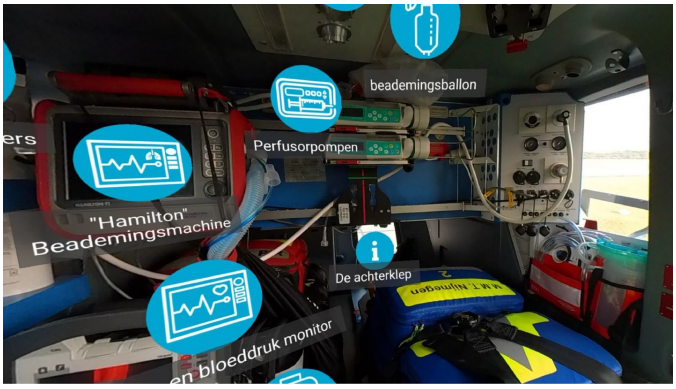

Figure 4 VR technologies used for simulation of extrication of trauma patient by helicopter team by using 360° camera and special 3D software. From Virtual Reality Techniques for Trauma education by Holla, M. & Van Den Berg, M. (2022). Injury. Reproduced under the terms of the Creative Commons Attribution License.

Trauma Training

One of the key applications of Metaverse technologies in trauma care is for training of healthcare personnel. In Trauma care, opportunities to learn from attending to real patients are limited. The trauma situations need the care from the most experienced professionals available. Real trauma situations can hardly be used for hands on training. In addition, there is minimal time for formal teaching while managing victims of trauma, but practical experience for healthcare professional is of utmost importance.

Metaverse and other immersive technologies like (VR) and (AR) technologies could be used to simulate various trauma scenarios, diagnose conditions, and practice critical interventions and surgical techniques in a risk-free environment. Among the 4 types of the metaverse, the most diverse and actively used technology in education is virtual reality[1]. It allows leaners to improve their skills and knowledge to a level which cannot be offers by traditional teaching and training methods, help to understand complex concepts, and can be used as a way of assessing trauma management and decision-making abilities [1,3].

Holla M et al. states that in a systematic review in 2021, the majority suggested that VR based head mounted devices have beneficial effects for medical education. Another systematic review in 2022 reported that participants highly appreciated using VR than most other training methods. VR outperformed traditional methods of learning surgical procedure[20]. These technologies offer immersive learning for trauma care.

Authors Hella et.al describes how VR technologies used for simulation of extrication of trauma patient by helicopter team by using 360° camera and special 3D software which creates clickable labels inside the VR space (Figure 4). Using VR, participants were able to experience prehospital trauma care, at a level that was impossible without VR.

Telemedicine and remote medicine

Telemedicine, the provision of remote medical services, has experienced a significant acceptance since the COVID -19 pandemic. It popularizes and increase the use of telephone or video consultations. Metaverse platforms and applications can add an immersive experience for this, particularly through VR headsets, creating a sense of presence unmatched by traditional online channels. This allows patients to virtually meet clinicians. This will be useful in provision of care to remote and rural settings, for people with mobility issues and in disaster situations.

Facilitating digital health economy

Metaverse technologies enables patients to meet global experts and experts will be able to provide their services to a global client. Robotic surgical systems are allowing surgical operations to be performed even the surgeon and the patient are at two distant locations. Facilitating scans and tests at local facilities, with results easily shared with specialists globally and vice versa will improve accessibility. Financial transactions associated with these will facilitate development of digital health economy. Development of AI based algorithms for image recognition etc. and the associated intellectual property rights will open up a new avenue in income generation and they may be future commercial determinants of health.

While metaverse technology has many advantages, it is not without challenges such as ethical and medico legal concerns [21, 22].The initial cost for devices is one such concern. But with the advancement of technology and manufacturing techniques the costs have come down. While these applications can have an initial cost, they are still useful in developing countries such as Sri Lanka, where trained human resources for trauma care are lacking. It may also be cost effective to provide remote services from established trauma centers to a certain extent to the rural areas, rather than transferring patients. However, these need careful technology assessment and this an area where expertise needs to be developed in Sri Lanka. In addition, training personnel to use new technology, establishing alternatives in system failures also need to be addressed. These present significant challenges to health management. Maintaining privacy, confidentiality of data and data security, ethical concerns, and safety during incorporation of technology for trauma care is of utmost importance. Metaverse is here to stay, and it will change the way we care for trauma.

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