Development and implementation of a novel web-based trauma and operating theater registry in Tanzania: The Amber Database initiatives

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ABSTRACT

Surgical conditions arising from trauma burdens pose massive challenges to understanding the real global health burden. This is particularly true in resource-limited settings, where well-structured data infrastructures are lacking, highlighting the essential need for trauma surveillance systems. Trauma registries are comprehensive, prospective data repositories for trauma patients, covering demographic information, injury details, surgical procedures, care, and outcomes. These registries are crucial in trauma care systems, enhancing patient outcomes. The significant surgical burden resulting from trauma-related fatalities in low- and middle-income countries (LMICs) emphasizes the increasing interest in digitizing trauma data infrastructures in these regions. Despite the feasibility of several traditional paper-based pilot trauma registries in LMICs, achieving long-term sustainability remains challenging.

This thesis proposes three interrelated objectives to comprehensively address healthcare structures in resource-limited settings. [Manuscript I] The study was initiated with a comprehensive narrative literature review to assess the progress of Global Surgery 2030 initiatives in resource-limited settings. This assessment aimed to measure progress in surgical services since the inception of the Lancet Commission on Global Surgery (LCoGS 2030) and the National Surgical, Obstetrics, and Anesthesia Plans (NSOAPs). The LCoGS stated six key global surgery metrics, including access to essential trauma/surgical services, surgical workforce, surgical volume, surgical outcomes tracking system, finances, and infrastructure. The review revealed a significant gap between current surgical capacity and the LCoGS 2030 recommendations in resource-limited settings. The key message is that improving surgical care in these settings requires comprehensive approaches, including increasing surgical infrastructures and workforces, implementing insurance plans, and strengthening surgical service tracking systems.

[Manuscript II] To address the need for an increased surgical/trauma workforce in resource-limited settings, the study suggests, among other solutions, targeted training programs. To address these gaps, an eco-friendly and sustainable course called Trauma and Disaster Team Response (TDTR) was developed by McGill's Centre for Global Surgery (CGS) and delivered at the Muhimbili Orthopedic Institute (MOI) in Tanzania. The course, taught mostly by Tanzanian instructors with limited CGS support, was designed to empower medical professionals to provide critical care for trauma/surgical services. The study aimed to evaluate the TDTR’s effectiveness and practicality in advancing professionals' skills and patient outcomes in this setting. Following the implementation of the TDTR course, significant improvements were observed in the skills,

teamwork, and confidence of trauma care providers, as well as in clinical outcomes. Positive feedback from trainees and local communities provided clear evidence of the course's impact, reflecting its success in improving patient outcomes and clinicians' skills and teamwork of trauma care providers. This success has prompted considering expanding the course throughout Tanzania and similar settings and has provided potential solutions to address gaps in the skilled workforce.

[Manuscript III and IV] Finally, WHO recognizes the significant global burden of trauma, particularly in underdeveloped healthcare systems in LMICs. Standardization of trauma registries is critical to saving resources and improving trauma care. Digitization of these registries is particularly important in regions with high injury burdens, such as Tanzania, for mapping injury epidemiology, benchmarking clinical guidelines, and injury prevention. The Amber database, a novel web-based infrastructure for trauma and operating room data, was developed and implemented at the Tanzanian MOI from July 13 to August 23, 2023, to assess its feasibility. Trained staff prospectively collected data from the MOI emergency department and operating rooms, totaling nearly 2400 data: 1097 traumatic patients and 1300 operated patients. Positive feedback from key stakeholders at MOI validated the feasibility of implementing such a digitized platform in a Tanzanian setting. Since its introduction, Amber has quickly become a routine MOI's medical recording system, allowing data to be used for targeted education, quality improvement, and health policy formulation.

In summary, the thesis vividly outlines challenges in global surgical access, underscores the necessity of advancements in trauma education, and proposes the implementation of eco-friendly

trauma and operating room data infrastructures, *Amber database* in Tanzanian resource-limited settings to improve healthcare structures. This platform, launched in July 2023 and reported until August, recorded data for 2400 patients on both trauma and operating room details, growing to nearly 5000 by December 2023, showcasing the feasibility and success at the MOI, Tanzania.

RÉSUMÉ

Les affections chirurgicales résultant de traumatismes posent d'énormes problèmes pour comprendre le véritable fardeau sanitaire mondial. Cela est particulièrement vrai dans les environnements aux ressources limitées, où les infrastructures de données bien structurées font défaut, ce qui souligne le besoin essentiel de systèmes de surveillance des traumatismes. Les registres des traumatismes sont des référentiels de données prospectives et complètes sur les patients victimes de traumatismes, couvrant les informations démographiques, les détails des blessures, les procédures chirurgicales, les soins et les résultats. Ces registres sont essentiels pour les systèmes de soins de traumatologie, car ils améliorent les résultats pour les patients. La charge chirurgicale importante résultant des décès liés aux traumatismes dans les pays à revenu faible et intermédiaire (PRFI) souligne l'intérêt croissant pour la numérisation des infrastructures de données sur les traumatismes dans ces régions. Malgré la faisabilité de plusieurs registres pilotes traditionnels de traumatologie sur papier dans les PRFM, la viabilité à long terme reste un défi.

Cette thèse propose trois objectifs interdépendants pour aborder de manière globale les structures de soins de santé dans les environnements à ressources limitées. [Manuscrit I] L'étude a débuté par une analyse documentaire exhaustive visant à évaluer les progrès des initiatives de Global

Surgery 2030 dans les environnements à ressources limitées. Cette évaluation visait à mesurer les progrès des services chirurgicaux depuis la création de la Commission du Lancet sur la chirurgie mondiale (LCoGS 2030) et des plans nationaux de chirurgie, d'obstétrique et d'anesthésie (NSOAP). La LCoGS a défini six mesures clés de la chirurgie mondiale, notamment l'accès aux services essentiels de traumatologie/chirurgie, la main-d'œuvre chirurgicale, le volume de chirurgie, le système de suivi des résultats chirurgicaux, les finances et l'infrastructure. L'étude a révélé un écart important entre les capacités chirurgicales actuelles et les recommandations de la LCoGS 2030 dans les environnements à ressources limitées. Le message clé est que l'amélioration des soins chirurgicaux dans ces contextes nécessite des approches globales, y compris l'augmentation des infrastructures et des effectifs chirurgicaux, la mise en œuvre de régimes d'assurance et le renforcement des systèmes de suivi des services chirurgicaux.

[Manuscrit II] Pour répondre à la nécessité d'augmenter le nombre de chirurgiens et de traumatologues dans les régions à ressources limitées, l'étude propose, entre autres solutions, des programmes de formation ciblés. Pour combler ces lacunes, un cours écologique et durable appelé Trauma and Disaster Team Response (TDTR) a été mis au point par le Centre for Global Surgery (CGS) de McGill et dispensé à l'Institut orthopédique Muhimbili (MOI) en Tanzanie. Le cours, enseigné principalement par des instructeurs tanzaniens avec un soutien limité du CGS, a été conçu pour permettre aux professionnels de la santé de fournir des soins critiques aux services de traumatologie et de chirurgie. Améliorerisait à évaluer l'efficacité et l'utilité du cours TDTR pour améliorer les compétences des professionnels et les résultats pour les patients dans ce contexte. Après la mise en œuvre du cours TDTR, des améliorations significatives ont été observées au niveau des compétences, du travail d'équipe et de la confiance des prestataires de

soins de traumatologie, ainsi qu'au niveau des résultats cliniques. Les réactions positives des stagiaires et des communautés locales ont clairement démontré l'impact du cours, qui a permis d'améliorer les résultats pour les patients, les compétences des cliniciens et le travail d'équipe des soignants en traumatologie. Ce succès a incité à envisager d'étendre le cours à toute la Tanzanie et à des contextes similaires, et a fourni des solutions potentielles pour combler les lacunes en matière de main-d'œuvre qualifiée.

[Manuscrit III et IV] Enfin, l'OMS reconnaît l'importance du fardeau mondial des traumatismes, en particulier dans les systèmes de santé sous-développés des pays à faible revenu. La normalisation des registres de traumatologie est essentielle pour économiser les ressources et améliorer les soins de traumatologie. La numérisation de ces registres est particulièrement importante dans les régions où le nombre de traumatismes est élevé, comme en Tanzanie, pour cartographier l'épidémiologie des traumatismes, comparer les lignes directrices cliniques et la prévention des traumatismes. La base de données Amber, une nouvelle infrastructure en ligne pour les données relatives aux traumatismes et aux salles d'opération, a été développée et mise en œuvre au MOI tanzanien du 13 juillet au 23 août 2023, afin d'en évaluer la faisabilité. Le personnel formé a collecté prospectivement des données du service des urgences et des salles d'opération du MOI, totalisant près de 2400 données: 1097 patients traumatisés et 1300 patients opérés. Les réactions positives des principales parties prenantes du MOI ont validé la faisabilité de la mise en œuvre d'une telle plateforme numérisée dans un contexte tanzanien. Depuis son introduction, Amber est rapidement devenue un système d'enregistrement médical de routine du MOI, permettant d'utiliser les données pour l'éducation ciblée, l'amélioration de la qualité et la formulation de la politique de santé.

En résumé, la thèse décrit clairement les défis de l'accès aux soins chirurgicaux dans le monde, souligne la nécessité de progresser dans l'enseignement de la traumatologie et propose la mise en œuvre d'infrastructures de données de traumatologie et de salles d'opération respectueuses de l'environnement, la *base de données Amber*, dans des environnements tanzaniens aux ressources limitées afin d'améliorer les structures de soins de santé. Cette plateforme, lancée en juillet 2023 et rapportée jusqu'en août, a enregistré les données de 2400 patients en traumatologie et en salle d'opération, pour atteindre près de 5000 patients en décembre 2023, démontrant ainsi la faisabilité et le succès de cette initiative au sein du ministère de l'Intérieur de Tanzanie.

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Proverbs 3:5-6 (NIV): "Trust in God with all your heart and lean not on your own understanding; in all your ways submit to him, and he will make your paths straight."
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“Cheers to my resilience and commitment!"

CONTRIBUTION TO ORIGINAL KNOWLEDGE (AND AUTHORS)

This manuscript-based thesis comprises three multi-authored articles. Each study has made significant contributions to our understanding of the field, and this thesis provides a cohesive explanation of these contributions. This thesis is an original work by Cherinet Osebo. I [C. Osebo] conducted study design, primary data acquisition, data analysis, and manuscript writing for each study. The valuable contributions of my co-authors in providing materials, designing the studies, and reviewing manuscripts were indispensable. Dr. Tarek Razek (supervisor), Dr. Jeremy Grushka (supervisor/committee), and Dr. Dan Deckelbaum (committee) played pivotal roles in my training in traumatology observership at Montreal General Hospital, Amber database application developments and the design of TDTR course assessment modalities. Dr. Respicious Boniface and Dr. Victoria Munthali served as the regional contact and local principal investigators in MOI, Tanzania played a huge role in guiding and supporting me throughout my project. The specific contributions of each co-author to the three manuscripts are detailed below.

Chapter 2: Manuscript I: Assessing Ethiopia's Surgical Capacity in Light of Global Surgery 2030 Initiatives: Is There Progress in The Past Decade?

Study conception and design: C. Osebo, T. Razek

Data extraction and analysis: C. Osebo

Manuscript writing: C. Osebo

Manuscript editing: C. Osebo, T. Razek, D.L. Deckelbaum, J.R. Grushka

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Chapter 3: Manuscript II: Enhancing Trauma Care through Innovative Trauma and Disaster Team Response Training: A Blended Learning Approach in Tanzania (In revision)

Study conception: C. Osebo, T. Razek

Study design: C. Osebo, T. Razek, D.L. Deckelbaum, J.R. Grushka, K. Khwaja, A.M. Fazlollahi, C. Vlček, E. Farber, J.M. Ortiz, V. Munthali, R.L. Boniface

Data acquisition: C. Osebo, R. Ndeserua, B. Mcharo, A. Lemnge, A. Ulimali, L. Rwanyuma, V. Munthali

Data analysis: C. Osebo, A.M. Fazlollahi

Manuscript writing: C. Osebo

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Study conception and design: C. Osebo, T. Razek

Data acquisition: C. Osebo, V. Munthali, R.L. Boniface

Data analysis: C. Osebo

Manuscript writing: C. Osebo

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Study conception and design: C. Osebo, T. Razek

Data acquisition: C. Osebo, V. Munthali, R.L. Boniface

Data analysis: C. Osebo

Manuscript writing: C. Osebo

Manuscript reviewing and supervision: T. Razek, J.R. Grushka, D.L. Deckelbaum, K. Khwaja, V. Munthali, R.L. Boniface

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Interview participant's consent: Verbal agreements received

Permission: All co-authors are permitted to include the manuscript in this thesis

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LIST OF ABBREVIATIONS

ATLS: Advanced Trauma Life Support

ASCOT: American College of Surgeons Committee on Trauma

BLS Basic: Life Support

DALY: Disability Adjusted Life Year

ED: Emergency Department

GCS: Glasgow Coma Scale

GDP: Gross Domestic Product

HIC: High-Income Countries

ISS: Injury Severity Score

IRB: Institutional Review Board

KTS: Kampala Trauma Score

LMIC: Low- and Middle-Income Countries

MTOS: Major Trauma Outcome Study

MVC: Motor Vehicle Collision

NTDB: National Trauma Data Bank

RTS: Revised Trauma Score

RTI: Road Traffic Injuries

RTA: Road Traffic Accidents

TARN: Trauma Audit Research Network

TRISS: Trauma and Injury Severity Score

TDTR: Trauma and Disaster Team Response

WHO: World Health Organization

CHAPTER ONE: INTRODUCTION

1.1 THE CURRENT GLOBAL HEALTH CHALLENGES FROM TRAUMA

Trauma, often referred to as a "forgotten pandemic," constitutes a significant contributor to global health challenges, resulting in over 5 million deaths annually.[1] Studies have shown that over 90% of injuries affect the population residing in low-and middle-income countries (LMICs) with vulnerable healthcare systems, highlighting disparities.[2] To effectively address this pressing

issue, it is imperative to gain a comprehensive understanding of injury epidemiology. As a solution, the World Health Organization (WHO) has introduced Essential Trauma Care and Injury Surveillance Guidelines to comprehend the geographic burden of injuries and subsequently enhance trauma services.[3, 4] Furthermore, the American College of Surgeons-Committee on Trauma (ACS-COT) has highlighted critical approaches to address the trauma burden, including advancing trauma education, standardizing trauma data documentation, and establishing well-organized trauma care systems.[5] These approaches help understand injury epidemiology, enhance trauma care, and empower healthcare provider knowledge and skills.

Published experiences have demonstrated that in high-resource nations, sophisticated trauma care systems with well-established documentation have contributed to significant reductions in trauma-associated mortality, often ranging from 20% to 50%.[6, 7] In contrast to resource-rich nations, several LMICs face challenges because trauma data is collected retrospectively from the global burden of disease reports, routine hospital and health surveys, and police and criminal records.[8-10] The challenges mentioned hinder our understanding of injury causes, costs, care quality, workforce skills, and clinical outcomes. To address these issues, our project introduces the innovative Amber database, a web-based application designed for collecting trauma and operating theater data. This novel platform aims to bridge knowledge gaps related to trauma burdens by capturing essential information on injury causes, clinical assessments, and patient outcomes. It further underscores the importance of gathering data on operating room activities, including surgical volume, perioperative mortalities, and critical care resource utilization. The Amber database facilitates the digitization of trauma and operating room data acquisition

systems in Tanzanian settings, with the overarching goal of regionalizing trauma care systems and enhancing surgical services.

1.2 COMPREHENSIVE LITERATURE REVIEW AND BACKGROUND

1.2.1 Surgical Disease Burden in Resource-limited Settings

Over the past few decades, significant advancements have occurred in global health, yet progress remains heterogeneous.[11] This concept led to Trauma Surgery being identified "*neglected stepchild of global health.*[12]" According to the Lancet Commission on Global Surgery 2030 (LCoGS 2030) report, an astounding five billion people still lack access to essential surgical, trauma, anesthesia, and obstetrics care.[13] This is particularly concerning because approximately one-third of the global disease burden can be addressed through surgical interventions. Regrettably, a substantial portion of this burden is concentrated in LMICs, defined by the World Bank as countries with a per capita gross national income (GNI) of less than $12,055 United States Dollars (USD).[14] According to the WHO, more than 313 million surgeries are performed globally each year. However, it's alarming that only 6% of these surgeries take place in developing regions, where over a third of the world's population resides. To address this disparity, an estimated 143 million additional surgeries would need to be conducted annually.[13, 15-17] Furthermore, the LCOGS 2030 underscores the importance of establishing a functional perioperative mortality rate registry system. This system is essential for comprehending surgical deaths, complications, and the number of bellwether procedures conducted in surgery-ready hospitals. Therefore, it is imperative to develop well-organized operating theater databases to capture operating room activities accurately and allocate resources accordingly.

After the unanimous adoption of World Health Assembly Resolution (WHA) 68.15,[18] emphasizing the importance of "strengthening of essential and emergency surgical and anesthesia services as part of universal health coverage, substantial progress has been achieved. Since its inception, many LMICs have dedicated substantial efforts to develop comprehensive essential surgical care plans, seamlessly integrating them into their broader National Health Strategic Packages.[19] Furthermore, the WHO has played a pivotal role by creating a 'Modular Process Algorithm' alongside the corresponding process components.[20] These resources have empowered countries to enhance essential surgical services accessible across countries. However, the progress of 'strengthening emergency surgical services initiatives remains stagnant in several resource-limited countries, indicating that these frameworks must be tailored to meet the specific needs of the country.[20, 21]

According to the Global Burden of Disease report, traditional global public health programs have primarily emphasized infectious and communicable diseases such as Malaria, Tuberculosis, and HIV/AIDS as major contributors to global deaths and disabilities.[22,23] As such significant progress has been achieved in reducing the burden of these diseases. However, many LMICs are currently undergoing an 'epidemiological transition' driven by industrialization.[11, 24] Consequently, these nations are experiencing reduced mortality from common infectious diseases and increased life expectancy. [25] In contrast, injuries requiring urgent surgical interventions are emerging as more prevalent public health concerns, underlining urgent attention.[23] The development of sustainable health systems is imperative for advancing the field of global surgery.

1.2.2 Surgical Disease Burden from Trauma

Traumatic injury stands out as a major factor contributing to the global burden of surgical diseases. As such, trauma is a paramount global health concern, contributing to a staggering number of fatalities, long-term disabilities, psychological trauma, and severe economic repercussions.[25, 26] As outlined by Baker et al.,[27] injury is defined as the physical harm incurred due to the sudden application of forces that surpass the body's physiological capacity to withstand. These injuries can emanate from a multitude of causes, encompassing transportation accidents, unintentional incidents like drownings and falls, natural and man-made disasters, exposure to mechanical forces, fire, heat, and acts of violence. It's essential to recognize the multifaceted nature of these injuries and their far-reaching implications on individuals and societies worldwide.

1.2.3 Mortality and Morbidity from Trauma

Mortality data is essential for gauging the scope of a health problem, but it's equally critical to consider nonfatal consequences to gain a thorough grasp of the ramifications of injuries.[26] To achieve this comprehensive perspective, an internationally standardized measurement known as the Disability Adjusted Life Year (DALY) has been devised to assess the global burden of disease.[28] The DALY is a metric used to assess health disparities. DALYs consider not only the years of life lost due to premature death but also the equivalent years of "healthy" life that are lost due to individuals experiencing poor health or disability. To calculate DALYs, two key components are summed up: the years of life lost (YLL) due to premature mortality in the population and the years lost due to disability (YLD) for new cases of health conditions (DALY = YLL + YLD). In simpler terms, one DALY represents the loss of one year of a healthy life,

offering a more all-encompassing evaluation of injuries' influence on both mortality and morbidity.

Between 1990 and 2010, there was a slight increase in the proportion of global deaths attributable to injuries, rising from 8.8% to 9.6%.[28] Despite efforts over the following decade to reduce injury-related mortality, the "Injury and Violence 2021" report from the WHO highlights a persistent challenge. [26] This report reveals that injuries continue to be a significant global concern, causing over 4.4 million deaths each year, accounting for 10% of lifelong disabilities and 8% of global mortalities. Furthermore, a study conducted by Nigel D. Rossiter in 2021 sheds light on the severity of the issue. [1] Rossiter's research uncovered that over 5 million people died of injuries annually, surpassing the combined mortalities of HIV/AIDS, Malaria, Tuberculosis, and COVID-19, as depicted in Figure 1. The annual toll includes 3.2 million deaths resulting from unintentional injuries and 1.3 million from violence-related injuries. Despite efforts to reduce injury-related deaths, the burden remains substantial.

Fig. 1. Trauma-related deaths yearly. Image source, Nigel D. Rossiter.[1]

The 2022 Lancet reports on Global Road Safety showed that road traffic collision (RTC) kills 1.35 million annually worldwide, becoming the eighth leading cause of global deaths.[29] Furthermore, it was responsible for over 50 million people being left with lifelong long-disability, resulting in poor quality of life, lost productivity, and financial insecurity. This burden makes road accidents, homicides, and suicides considered the three top five leading causes of death for people aged 5-29.[26] This evidenced that trauma and injuries massively affect countries' economies by taking the lives of productive age groups. This concerning trend is consistent with the WHO's projection of a 40% increase in road traffic deaths, possibly making it the third leading cause of global mortality by 2030.[30]

Studies have shown significant disparities in trauma-related deaths and morbidity on a global scale. The data indicates that 90% of injury-related fatalities affect populations in LMICs where healthcare systems are less robust. [2] This disproportionately impacts the working-age population in LMICs, with most of them being under the age of 35.[1] Within LMICs in the Americas, Europe, and the Eastern Mediterranean region, injuries in men aged 15-44 years accounted for over 30% of the total burden of disease.[31] Moreover, among the 1.35 million global deaths resulting from RTCs a staggering 93% occurred in LMICs, and nearly 50% of these casualties are road users, including drivers/motorcyclists/cyclists, passengers, and pedestrians. [29] This is a remarkable statistic, considering that LMICs only have 60% of the world's registered vehicles, with Africa accounting for a mere 2%.[29]

Despite the lower number of vehicles, the burden of death and disability resulting from RTCs in these regions is disproportionately high. The burden of trauma continues growing, particularly in

LMICs. Since 2000, Sub-Saharan Africa has witnessed a significant increase in RTCs, with a nearly 50% rise in years of healthy life loss.[26] This alarming pattern aligns with the WHO's forecast that road traffic deaths will become the third leading cause of mortality by 2030. [30] Additionally, other trauma causes like drowning and falls are worrisome, with drowning being the sixth leading cause of death in pediatric age groups and falls ranking as the second leading cause.[26] Inevitably, these figures are only predicted to increase in the future.

1.2.4 Economic Burden of Trauma

The economic consequences of injuries at a national level are frequently underestimated, particularly in the context of road injuries. These injuries not only rank among the top ten global causes of mortality but also have profound economic ramifications, impacting the overall economic well-being and macroeconomic performance.[29] It is essential to move beyond medical data and gain a comprehensive understanding of their economic significance for evidence-based policymaking.

The 2019 research indicates that road injuries are expected to place a substantial financial burden on the global economy, estimated at approximately $1.8 trillion over the period from 2015 to 2030, with figures adjusted to 2010 US dollars.[32] To put this in perspective, it's equivalent to an annual tax of 0.12% on the global gross domestic product. This financial impact results from a combination of factors, including healthcare expenditures that would have otherwise been directed towards savings or investments and losses in employment due to mortality and morbidity. Notably, this economic toll exceeds the entire Gross Domestic Product of Canada, which is the world's tenth-largest economy as of 2017.[33] Notably, the highest overall economic

burdens are borne by the USA ($487 billion), China ($364 billion), and India ($101 billion) due to their large populations, as displayed in Figure 2.[32]

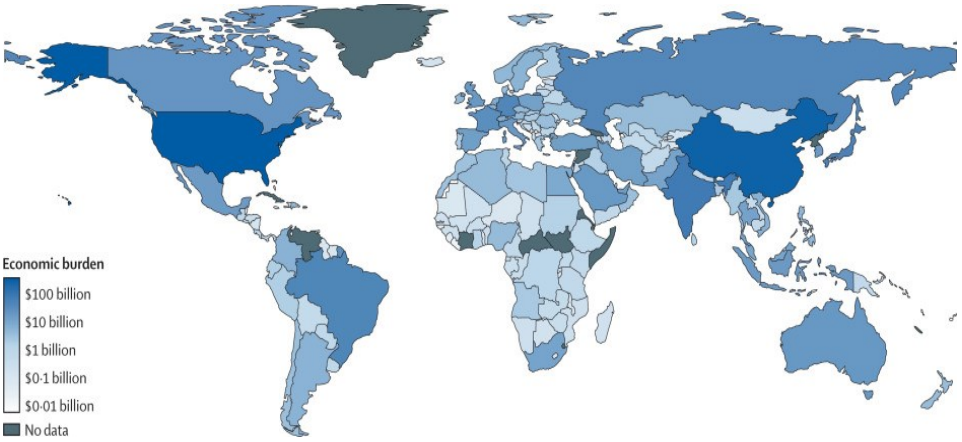


Fig. 2: Macroeconomic burden due to road injuries in 2015–30. Image source, Chen et al.,[32]

In regional terms, East Asia, and the Pacific face the highest total economic loss at $560 billion, while North America ranks second with a $515 billion loss. High-income countries bear the largest economic burden, totaling $963 billion with a per capita loss of $779. In contrast, low-income countries have much lower losses at $11 billion, equating to a per capita loss of $14.[32] In 2015, road injuries resulted in 70 million DALYs worldwide. Interestingly, the economic burden indirectly correlates with population size and DALYs. For example, South Asia accounted for 23.8% of DALYs but only 6.7% of the economic loss. Conversely, North America contributed just 3.9% of DALYs but carried a substantial 28.6% of the economic burden. It's noteworthy that although LMICs bore a relatively lower economic burden from road injuries, comprising 46.4% of the global economic loss, the disease burden, measured in DALYs, remained substantial, making up 89% of global DALYs.[32] Furthermore, As Chen et al.,[32] further narrated, it's important to emphasize the role of treatment costs in the overall economic burden of road injuries. In high-income countries, these costs represent 31.5% of the total economic burden, but

this figure decreases to 13.9% in upper-middle-income countries, 6.2% in lower-middle-income countries, and 3.9% in low-income countries.

1.2.5 Trauma Burden in Tanzania

Trauma is a significant contributor to the global burden of fatalities, especially in developing countries. When adjusted for underreporting, Africa has the highest rate of road traffic injuries resulting in mortality, with 28.3 per 100,000 population, while Europe reports a lower rate of 11.0 per 100,000.[34] Tanzania, a low-income East African country with a population of 60 million, mainly residing in rural areas, mirrors this trend.[35] Tanzania faces a high incidence of injuries across all age groups, including a notable number of injuries in children. As a developing nation, Tanzania is poised to experience a surge in trauma cases, driven by the epidemic of RTCs, urbanization, inadequate infrastructure, and the growing use of motorcycles for transportation. Without preventive measures, injuries and deaths from RTCs are expected to rise. While many of these injuries are preventable, limited data poses challenges to targeted prevention efforts.

The Tanzanian national police reported a 44% increase in RTC, rising from 10,107 in 1990 to 14,548 in 2000, leading to 64% of deaths.[36] Remarkably, in Africa,[29] including Tanzania, only 2% of registered vehicles are available, but when considering the number of vehicles on the road, the likelihood of dying in a traffic accident in Tanzania is 20-30 times higher than in the United States. Furthermore, facility-based injury surveys confirm that traffic accidents are the primary cause of injuries, accounting for 48% of all observed injuries and 61% of injury-related deaths.[37]

The 2020 study conducted in five Tanzanian regional hospitals by Sawe et al. revealed that RTCs accounted for the majority of mechanisms of injury, with 3,786 cases, making up 60.3% of all injuries.[35] A significant portion of patients (63.3%) presented with injuries to the upper and lower extremities, while a smaller fraction (2.0%) had injuries to the chest. The study reported a total 24-hour mortality rate of 3.3%, with 126 patients (2.1%) dying from their injuries while receiving care at the emergency departments. Among those who passed away, 156 individuals (81.7%) had sustained intracranial injuries. This is further supported by a 2019 World Bank report highlighting that Tanzania had recorded a substantial number of trauma-related deaths compared to other Sub-Saharan African countries.[38, 39] Tanzania faces the dual challenges of trauma-related mortality and morbidity, alongside the economic repercussions of injuries. Unfortunately, finding published experiences detailing the costs of injuries at the country level proves to be a challenging task. Hence, the WHO's Global Road Traffic Safety Report emphasizes the significance of research and interventions in this region.

1.2.6 Trauma Care System

Public health is influenced by the effectiveness of trauma care systems as they need to be prepared for injuries that can occur randomly, and the provision of comprehensive care plays a crucial role in determining the outcomes.[40] A trauma care system is a coordinated effort within a specific geographic area that provides various services for the injured and connects injury data with the public healthcare system for injury epidemiology. [41] The well-organized trauma healthcare system includes a trauma registry, prehospital and in-hospital care, and preventive strategies.[41, 42] Furthermore, regionalizing trauma care systems is crucial for a comprehensive approach to trauma care.[43]

According to a 2022 South Korean study, it is recommended that health policymakers in a country consult with physicians when establishing a regional trauma care system to ensure the delivery of evidence-based care for patients with traumatic injuries.[44] Mock and colleagues further emphasized that the establishment of a regional trauma care system necessitates thorough consideration including local norms, regulations, infrastructure, and finances.[4] Generally speaking, an ideal trauma care system should integrate leadership components, professional associations, ongoing education, data acquisition systems, research programs, technology, and disaster response policies.[45]

In high-resource nations, the establishment of complex regionalized trauma care systems has yielded notable reductions in trauma-related mortality. These outcomes are supported by the findings of Jurkovich and Mock, who demonstrated that organized trauma care systems led to a 20% reduction in trauma mortality.[46] Similarly, Liberman et al. reported a substantial decline in trauma-related deaths, decreasing from 51% to 9% following the full implementation of a functional trauma care system in Quebec, Canada. [6] Conversely, LMICs grapple with substantially higher mortality rates, exemplified by trauma patients in regions like Ghana facing double the mortality rate compared to their counterparts in the United States. [47] Moreover, LMICs report deaths at a rate six times higher than high-income nations, largely due to the absence of structured trauma care systems, which, in turn, results in survival rates six times lower for individuals with life-threatening injuries.[48] Nonetheless, an improved trauma care system has the potential to avert more than one-third of trauma-related deaths and disabilities in resource-limited settings, [48, 49] potentially saving up to 200,000 lives, as reported in The Lancet in 2022.[29]

However, challenges such as poorly coordinated systems, inadequate data on injury epidemiology, and limited resources pose formidable obstacles to advancing the trauma care system in LMICs. To address these disparities, the WHO has introduced Essential Trauma Care and Injury Surveillance guidelines for essential trauma care and quality improvement initiatives designed to mitigate variations in trauma-related fatalities among countries. Unfortunately, numerous resource-limited nations have faced challenges in implementing these recommendations.[3, 4] Consequently, the concept of a trauma care system necessitates a comprehensive approach, covering both in-hospital and pre-hospital care systems.

1.2.7 Prehospital Care Systems

The WHO's focus on injury prevention leads to efforts in creating a prehospital trauma care system that fits the economic context of the country.[26] This system involves communication, activation code, transportation, and treatment. High-income countries employ paramedics and physicians at accident scenes to prevent avoidable deaths.[50] In contrast, the absence of prehospital care in resource-limited nations contributes to over 54% of annual deaths and 89% of DALY losses.[51, 32] Prehospital trauma care is essential for reducing preventable deaths.

The challenge lies in improving prehospital trauma care in LMICs, where established emergency medical services (EMS) are frequently lacking. Current estimates indicate that 50 to 75% of the global population does not have access to formal EMS services. [47] The WHO categorizes injury-related deaths into three stages,[52] (i) immediately, (ii) intermediate or subacute phase (death within several hours of the incident), and (iii) late death due to complications, infection, or multiorgan failure. Well-organized prehospital care offers the most significant advantages during the second stage of death, as preventable deaths often occur within this time frame. According to

the 2022 Lancet publication, over 90% of deaths occur within 24 hours of an injury, with 60% occurring within 1 hour, 30% within 1-24 hours, and 10% within 24 hours following the trauma. [29] Consequently, most deaths in LMICs occurring within these time frames are preventable due to the absence of a formal prehospital care system. A study showed that mortality occurred within hours of injury events due to a lack of pre-hospital care, with rates of 81% in Ghana and 72% in Mexico compared with 59% in the US. [53]

The prehospital system requires attention to local norms, resources, and infrastructure. The WHO has outlined a prehospital care program consisting of three tiers.[54]

Tier One: First Responder Care is implemented in regions without formal prehospital trauma care systems. [54, 55] It involves educating local stakeholders like community leaders, police, or taxi drivers to provide initial emergency care until medical personnel arrives. Initiatives, such as training commercial drivers in Ghana, have improved informal prehospital care. [55] Mock et al., [56] stated strengthening lay responders, like grassroots community leaders, can significantly enhance trauma outcomes, and local guidelines aid in this practical and cost-effective approach to reducing preventable deaths.

Tier Two: Basic Prehospital Trauma Care trains individuals in proper basic life support (BLS) to manage scene situations, rescue, stabilize patients, and transfer them to hospitals. [57] It focuses on addressing airway, respiratory, and hemorrhage issues to reduce early fatalities. Initiatives offering BLS training to lay responders in areas with limited access to advanced care have substantially decreased mortality rates, such as in northern Iraq and Cambodia, where a two-day introductory life support course reduced deaths from 40% to 9%.[58]

Tier Three: Advanced Prehospital Trauma Care, led by qualified paramedics or physicians, involves critical care measures such as airway management, chest decompression, hemorrhage control, and more.[52, 59] In LMICs,[60] cost constraints limit many prehospital systems to the first two tiers. Basic life support-trained lay responders in community clinics often provide essential trauma care until transferring patients to higher-level trauma centers. Enhancing the prehospital care system improves regional trauma care, injury trends, and patient outcomes.

1.2.7 Focused Trauma Education Impacts on Trauma Care System

The implementation of formal trauma care systems has significantly reduced mortality and hospital stay duration. According to Havermans et al., the robust infrastructure for in-hospital trauma care has notably improved survival rates for critically injured patients.[61] Furthermore, establishing an organized trauma care system minimizes preventable medical errors and enhances overall patient care. Trauma centers should be equipped with multidisciplinary education and continuous trauma training. [62] Having experienced medical personnel and treating patients in the *golden hour*– the first hour following an injury leads to a higher patient survival rate.[63] Equipping healthcare providers with trauma education is crucial, as the first hour can determine patients' survival probability.

Introducing interdisciplinary trauma teams has been shown to enhance patient outcomes, as demonstrated by a North American study where patients managed by trained trauma teams exhibited better results.[64] To ensure continuity, formal education, and ongoing trauma training should be expanded in LMICs to elevate trauma care. The 2007 WHA resolution 60.22 *calls for action,* urging all member states to enhance their trauma and emergency care systems.[65] This

paradigm encourages the expansion of trauma education programs, and several initiatives in resource-limited settings have been augmented to improve trauma services. Several trauma training programs in resource-limited settings have been augmented to enhance trauma services.[66,67]

Several trauma education initiatives exist, such as the Advanced Trauma Life Support (ATLS®) created by the American College of Surgeons Committee on Trauma and Trauma Team Training (TTT) sponsored by the Canadian Network for International Surgery (CNIS). [67-69] These initiatives have been adopted in various resource-limited settings. The implementation of such programs has led to significant improvements in local infrastructure and injury epidemiology. However, offering full ATLS programs proves to be expensive in most resource-limited settings, resulting in challenges for expansion in developing countries. Bergman and colleagues noted that in LMICs, non-physicians handle most trauma care.[67] The CNIS's TTT is primarily designed as a team-based paradigm, relying not solely on physicians but incorporating various team members. This approach helps in overcoming financial constraints in low-income regions and contributes to the widespread success of the TTT program.[67] Petroze and colleagues further emphasized that training more frontline professionals, such as trauma nurses, has a significant positive impact on critical traumatic patient outcomes.[70] Matured trauma care necessitates multidisciplinary approaches, including mentorship, training, and scholarly research.

The 2022 scoping review estimated that 95% of pediatric mortality in low-income countries is related to injuries.[71] The authors recommended the development of practical pediatric trauma courses to minimize preventable mortalities. Additionally, Anderson et al.,[72] emphasized that

designing environmentally friendly trauma training for Ugandans enhanced trauma care at low costs. In another initiative, Botswana's Health Ministry collaborated with the Norwegian Government on a trauma improvement initiative called "Better and Systematic Team Training," which proved to be effective with limited finances.[66] The program played a critical role in enhancing workforce skills and reforming facilities' infrastructures.

Building a robust trauma system requires education, but most LMICs face challenges such as data limitations, personnel turnover, and resource constraints. To enhance trauma care, it is crucial to integrate trauma education into the medical system. Many healthcare authorities, scholars, and medical associations have confirmed that training programs are essential for improving the trauma care system. Therefore, following the Train-the-Trainer concept,[73] our department, the Centre for Global Surgery at the McGill University Health Centre (CGS-MUHC), developed an innovative trauma education program to reduce injury burdens in resource-limited regions.

1.2.7.1 Trauma and Disaster Team Response Course

Globally, strategies to enhance trauma care in LMICs include developing a pre-hospital care system, structuring trauma care, improving emergency medical services' accessibility, and trauma education and training programs.[74] While the application of ATLS concepts has shown knowledge and skills improvements, widespread integration in LMICs faces challenges due to costs, resource needs, and sustainability issues for limited-resource settings.[69] This, coupled with infrastructure and workforce limitations, hinders effective trauma care. Healthcare disparities

persist in LMICs, prompting CGS-MUHC to design practical trauma training programs to address these gaps.

The CGS-MUHC, a leading trauma institution, collaborates globally to understand and address trauma's impact. Prioritizing trauma education and training, the organization empowers local healthcare scholars and supports the development of organized trauma care systems. Emphasizing trauma and disaster preparedness, CGS-MUHC enhances emergency responses for effective trauma management and lasting healthcare system resilience.

The CGS-MUHC designed the United Nations-endorsed course called Trauma and Disaster Team Response© (TDTR) to convey appropriate trauma management, including disaster response contexts. The course, currently available on the United Nations Institute for Training and Research platform (UNITAR SURGhub: http://surl.li/moghg) free of charge, spans three days, incorporating online and in-person didactic lectures, skill sessions, and team exercises. It emphasizes a multi-disciplinary approach to managing trauma patients, catering to various healthcare professionals such as surgeons, nurses, emergency physicians, anesthetists, and other allied health professionals in trauma care at the emergency department. The course format is flexible and adaptable to different circumstances and locations.

The TDTR course aims to achieve competency in trauma care and disaster responses, establishing a mature trauma team. It ensures an understanding of team members' roles and responsibilities in resuscitating a traumatic patient, the principles of effective patient transfer to higher-level care facilities, and the importance of injury surveillance and trauma registries. This course, provided for Tanzanian healthcare providers, is expected to enhance knowledge in

managing critical patients and reduce preventable injury-related mortality in limited-resource settings.

1.2.8 Trauma Registry

Public health surveillance systems involve the systematic and continuous collection, analysis, interpretation, and distribution of data concerning health events.[75] The purpose is to inform health policymakers about designing guidelines aimed at reducing fatalities and enhancing healthcare services to improve patient care. For example, in ancient Egypt, wounded soldiers were examined on the battlefield, and the documentation of their wounds was used to improve equipment and medical treatments.[76] This historical approach played a role in the development of modern trauma registries, with one of the earliest instances established at Cook County Hospital in Chicago, United States, in 1970.[77,78] These registries gradually expanded throughout the United States, primarily focusing on documenting injury epidemiology to gain a better understanding of the effects of injuries.

Trauma registries are databases established to document the immediate in-hospital care provided to injured individuals, functioning in conjunction with trauma care systems in Western countries. [79] These registries entail the recording of patient data following specific parameters according to the international classification of diseases (ICD 10).[80] Typically, registries encompass information such as patient demographics, injury mechanisms, pre-hospital care, mode of transportation, and in-hospital treatment strategies. Additionally, it incorporates anatomical details, injury descriptions, physiological measurements, surgical procedures, outcomes, financial aspects, follow-up data, and pre-existing comorbidities to assess their impact.

1.2.8.1 Benefits of Trauma Registries

Quality Improvement Measurement

Trauma registries are essential tools for evaluating the effectiveness of trauma care systems.[81] They were initially designed to help hospitals enhance the quality of trauma patient care and have since become integrated into complex trauma care systems. [79] These registries support credentialing, validation, and designation procedures. Mann et al. found that hospitals with established trauma registries reduced mortality rates and improved care for severely traumatized patients, [43] highlighting the significance of trauma registries in quality improvement.

Assessment of Clinical Interventions

Trauma registries provide valuable clinical data on in-hospital care that is not available in administrative databases. [79] It is particularly useful for evaluating the effectiveness of clinical care. While randomized controlled trials offer the most conclusive evidence of clinical care efficacy, trauma registries are a better choice for assessing observational clinical interventions due to cost and time considerations.[82] Registries help develop research hypotheses, design protocols, identify study subjects, and evaluate new treatments and outcomes. However, challenges such as data entry accuracy, missing documentation, lack of uniformity, and high maintenance costs are associated with trauma databases.

Trauma Scoring Tool

Traumatic patients require immediate attention, including assessment, resuscitation, and definitive care within the first hour, which reduces in-hospital trauma deaths.[83] Trauma scoring is relevant in two scenarios: prehospital assessment for urgent transfer and clinical decision-making

in the emergency department.[84] Trauma scoring tools, such as Injury Severity Scoring (ISS), Revised Trauma Score (RTS), and others, play a significant role in predicting patients' survival probability.[79] However, these tools are not universally utilized in LMICs, and some have limitations. The Kampala Trauma Score (KTS) is an exceptional metric, developed in Uganda, and widely adopted in resource-constrained settings.[85] It predicts the survival probability of injured patients effectively and aligns with other injury-scoring systems.

Advocating Injury Prevention

Trauma registries go beyond quality control and can be instrumental in injury prevention.[79] It provides data for programming injury prevention initiatives and assists in shaping legislation related to road safety and other preventive measures. Geographic data from registries help identify injury hotspots, enabling focused prevention efforts.[86] Registries like the Canadian National Trauma Registry and Wisconsin Trauma Care Registry provide data for injury prevention strategies and inform legislative changes based on safety measures such as seat belt usage and curbing drunk driving incidents.[87, 88]

Follow-Up Care

Trauma registries can be used for assessing the post-discharge situations of trauma survivors, ensuring they receive appropriate care, rehabilitation, psychotherapy, and physiotherapy for improved long-term functionality.[79] A unique case is the Victorian State Trauma Registry, which collects data on trauma survivors' post-discharge functional status and returns to work for up to six months.[77] This information can help enhance the quality of life for survivors.

Planning Resources and Research

Trauma registries offer concrete evidence of patient care quality and help identify solutions for resource wastage.[79] They are crucial for public awareness campaigns to highlight the trauma burden and secure finances to address it. Moreover, trauma registries are valuable for research purposes, allowing researchers to address hypotheses that cannot be answered using administrative data. [79, 89] To improve the quality of registries, it is important to establish standardized criteria, and uniform data variables, regionalize registries, provide continuous training, and advance data collection techniques, ultimately reducing missing data rates and improving patient care quality.

1.2.8.2 Trauma Registry in High-Income Countries

The development of trauma registries lacks a standardized set of principles. Institutions have typically created their trauma registries based on their specific needs or to comply with regional or state regulations. [81] This approach has resulted in a lack of consistency in trauma registries. Despite these, successful trauma registries, must contain critical components such as well-defined variables, clear inclusion and exclusion criteria, documentation tools, trained personnel, mentorship programs, and data-cleaning techniques. [81] When designing trauma databases, it's essential to consider their intended use, whether for clinical, administration, or research purposes.

Today, several countries have established their trauma registries. The American College of Surgeons Committee on Trauma (ASCOT) initiated the Major Trauma Outcome Study (MTOS) in 1982, collecting 80,000 data observations from 139 North American hospitals. [90] MTOS,

active from 1982 to 1989, continues to serve as a global benchmark for trauma centers, utilizing the Trauma and Injury Severity Score (TRISS) approach.[91] In 1993, ASCOT established the National Trauma Data Bank (NTDB), the largest compilation of trauma registry data worldwide, comprising over one million records from 405 U.S. trauma centers. It relies on voluntary hospital participation and has counterparts in other countries like the Trauma Audit Research Network (TARN) in the UK (1989),[92] the German National Trauma Registry (1993),[93] the Israel national trauma registry (1995),[94] and the Canadian national trauma registry (1996).[95] These efforts have expanded to regional trauma databases in places like Quebec, Pennsylvania, Victoria, and New York, and they are integrated with trauma care systems. [77, 96] Studies in HICs showed reduced mortalities after the integration of trauma care systems with well-organized trauma registries.[47]

1.2.8.3 Trauma Registry in Low- and Middle-Income Countries

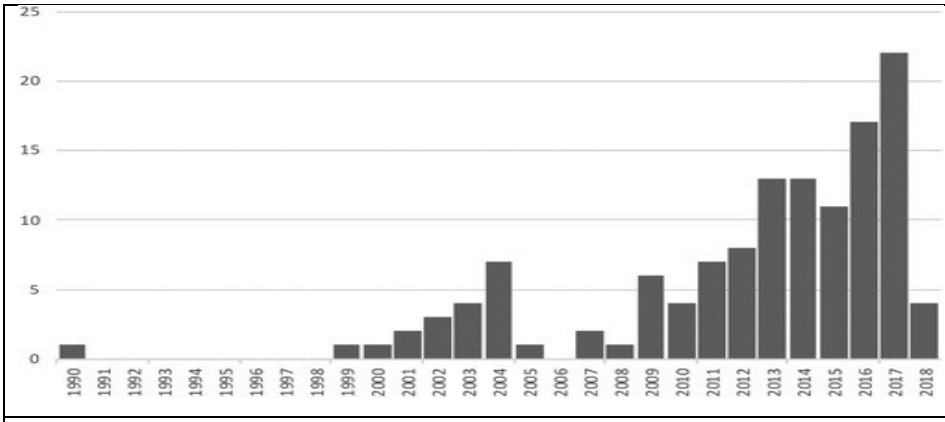
Challenges

Trauma registries play a vital role in healthcare, providing a systematic compilation of patient data for various purposes, including epidemiology, clinical research, quality improvement, policy development, and education programs. While these registries have thrived in HICs, their presence in LMICs remains limited. In LMICs, the presence of trauma registries is notably limited, accounting for only 1% of documented registries in scientific literature, compared to 81% in Western countries.[97] Establishing and sustaining these registries in LMICs involves substantial financial hurdles, with expenses ranging from $1,400 to $45,000, influenced by factors such as regional disparities and registry scale. [98] For example, the South African Pietermaritzburg electronic trauma registry incurred a cost of $96,000, highlighting the considerable financial challenges.[99] Moreover, systemic challenges such as the absence of pre-

hospital care systems, deficient inter-facility communication, limited national trauma databases, and underdeveloped health policies hinder the expansion of trauma registries in LMICs.

Progress and Strategies

Significant progress has been made in developing trauma registries in LMICs since 2000, with purpose-tailored registries launched in various regions (Figure 3).[100] To enhance these registries in LMICs, strategies include strengthening local stakeholder engagement, maximizing the use of available workforces, and expanding trauma education for continuous growth.[101, 102] Partnerships with research institutions and international collaborations offer promising solutions to overcome resource limitations and share expertise.[103] Practical approaches involve implementing minimal critical datasets and conducting random data audits to save time and resources, ensure data quality, and raise awareness about the burden of injuries. [104]



No trauma registries are available in

- 29 middle-income countries
- 33 low-income countries

Fig.3 presents trauma registries in LMICs. Image source, Rosenkrantz et al., 2019.[100]

Successes

Several resource-limited regions have successfully established trauma databases. Notable

examples include the Uganda trauma registry, initiated in 1998, which identified critical care gaps and led to improved patient care and injury prevention legislation.[105] The mortality rate dropped from 7% to 3% in six years, demonstrating its impact. The Tehran registry in Iran, [106] the Karachi trauma registry in Pakistan, [102] and the CGS-MUHC-sponsored electronic trauma registry in Pakistan,[107] and Mozambique have positively influenced health policy, patient outcomes, and injury prevention. The Mozambique trauma database captured over 15,000 patient records in a year, highlighting the need for pre-hospital care systems.[108] The Colombian trauma registries detected gunshot violence and influenced legislation to address the issue.[109] Furthermore, the Malawi trauma registry showed that trauma registries are essential for expense prediction and local resource evaluation, demonstrating their multifunctional benefits.

1.2.8.4 Trauma Registry in Tanzania

A robust trauma care system necessitates the presence of an efficient trauma registry, enabling optimal resource allocation, performance enhancement, injury prevention initiatives, research, and policy formulation.[79] In HICs, the establishment of trauma registries alongside formal trauma care systems has been pivotal in reducing injury-related fatalities. However, in Tanzania, trauma registries are limited, and those existing are often inconsistent and inadequately designed.[110]

The utilization of trauma data from single-site, hospital-based logbooks or mortuary-based sources has proven inaccurate and subject to interpretation, lacking the necessary national networking for comprehensive trauma care system evaluation.[97, 111, 112] To collect patient data, the Tanzanian Ministry of Health (MoH) relies on the Health Management Information System

(HMIS).[113] While the attending practitioners complete patient medical records within the HMIS system, this approach is plagued by data quality and completeness issues, resulting in financial and time burdens for clinicians and facilities. These challenges have prompted the need for an eco-friendly trauma data acquisition tool.

Tanzania currently lacks a national trauma registry system, with published trauma data primarily stemming from individual hospital-based initiatives.[114] The development of a practical trauma registry in Tanzania has been hindered by the absence of structured and consistent hospital records, trained personnel, electronic documentation tools, funding, and necessary infrastructure.[115] The dearth of trauma registries has significantly impeded the country's ability to enhance injury-related outcomes and formulate effective injury prevention programs. Efforts to establish a trauma database in Tanzania began at the Muhimbili Orthopedic Institute (MOI) in Dar es Salaam, proving effective in collecting injury information.[111] However, this endeavor was not without its challenges. As a response, the WHO introduced the "Data Set for Injury (DSI) Standard," aimed at guiding the establishment of trauma databases in resource-limited settings.[3] Nevertheless, the routine documentation of WHO's DSI variables revealed deficiencies in capturing essential elements.[114] A 2020 study conducted in five Tanzanian facilities highlighted significant challenges in documenting the WHO's DSI in trauma patients, emphasizing the need for improvement in existing documentation approaches.[114]

Tanzania currently lacks a context-specific electronic trauma and operating theater data acquisition tool for gathering pertinent injury data, operating room activities, and critical care resources. To address this gap, a novel electronic Amber trauma and operating theater database

was introduced. Sponsored by MUHC-CGS, Amber is a web-based application designed for collecting traumatic patient data as well as operating theater procedures. It comprises a 25-point anonymized trauma dataset covering patient demographics, injury mechanisms, clinical assessments, trauma scoring, anatomic and physiologic descriptors, and clinical outcomes. The Amber operating theater database consists of 15 anonymized variables, designed to register operating room activities.

1.3 STUDY SIGNIFICANCE AND RATIONALES

The study emphasizes the importance of global surgery programs and calls for a comprehensive evaluation of progress in emergency and essential surgical access in resource-limited countries, with a specific focus on addressing the significant health burden posed by trauma.[116] Trauma care systems, supported by robust trauma registry infrastructures, played a crucial role in improving patient outcomes. Despite challenges in LMICs, the implementation of trauma registries demonstrated a substantial reduction in preventable trauma-related deaths, leading to financial savings and advancements in various aspects of trauma care, including benchmarking, resource allocation, advocacy, research, and education programs.[2, 89, 117]

Tanzania faced challenges in trauma care due to underdeveloped systems, a lack of electronic registries, and inconsistent injury prevention efforts.[118] The absence of a centralized national trauma registry hindered a comprehensive understanding of the trauma burden. Local initiatives were limited and lacked uniformity, relying on retrospective and incomplete data collection methods prone to biases.[119, 120] To address these challenges, the project aimed to introduce a simplified web-based Amber database to Tanzania and assess its feasibility in enhancing medical

recording systems. Additionally, trauma education initiatives like the TDTR course, sponsored by CGS-MUHC, were implemented in Tanzanian settings, and their impact on enhancing practitioners' trauma care knowledge and skills was evaluated. Through these efforts, the project sought to gain insights into trauma trends, enhance patient care, and modernize recording systems in Tanzanian settings.

1.4 OBJECTIVES

[1] Examine the current state of surgical care capacity in resource-limited settings based on the Global Surgery 2030 initiatives

[2] Assess the impact of the Trauma and Disaster Team Response course on trauma care providers and clinical outcomes at MOI, Tanzania

[3] Pilot the feasibility of the Amber database by implementing it at MOI, Tanzania to better define injury epidemiology, understand trauma services, and operating theatre activities

Specific Aims

- Establish a functional Amber database at MOI as an integral part of an organizational framework for injury surveillance and operating room activities
- Establish a functional trauma team at MOI to respond to trauma and disasters

1.5 HYPOTHESIS

Implementing the Amber database and conducting the Trauma and Disaster Team Response (TDTR) course, alongside other surgical initiatives, is feasible in Tanzania and contributes to a comprehensive understanding of trauma and surgical disease burden. This initiative identifies

obstacles to accessing essential surgical and trauma services, contributes to trauma training, and informs health policy.

In this thesis, we set out to achieve the three aforementioned objectives. The first objective was accomplished by conducting a narrative review to assess the current surgical capacity in resource-limited settings, as detailed in Chapter 2. Moving on to the second objective, we evaluated the impact of the TDTR course on medical professionals and patient outcomes at MOI, Tanzania covered in Chapter 3. The third objective involved the implementation of a digital Amber trauma and operating theater databases at MOI to evaluate its feasibility, a topic explored in Chapters 4 and 5. Overall, we have confirmed the achievement of all specific objectives, as substantiated by the discussions presented in Chapters 3,4 and 5.

CHAPTER TWO: GLOBAL SURGERY 2030 INITIATIVES: CURRENT STATUS IN RESOURCE-LIMITED SETTINGS

Preface

In 2014, a pivotal moment marked a significant shift in the global recognition of the importance of global surgery.[121] During this period, surgery emerged as an integral component of universal healthcare on a global scale. Of particular concern in the realm of surgical conditions resulting from traumatic injuries that require urgent surgical interventions, especially in developing countries.[22] The heightened awareness resulted in initiatives like the Lancet Commission on Global Surgery 2030 (LCoGS 2030),[121] which aimed to address healthcare disparities in LMICs. These initiatives set six specific metrics for LMICs to achieve by 2030 to enhance surgical care.

Metric 1: Access to Timely Essential Surgery.[13]

By 2030, the goal is to achieve a minimum of 80% coverage of essential surgical and anesthesia services per country. This includes ensuring that at least 80% of the population has access to hospitals capable of performing bellwether procedures like cesarean delivery, laparotomy, and open fracture management within a 2-hour travel distance. Access to these services exhibits regional disparities, particularly in LMICs, which grapple with challenges such as vast geographical areas, shortages of healthcare workers, and limited resources.

Metric 2: Specialist Surgical Workforce Density. [13]

By 2030, all countries should work towards having a minimum of 20 specialist surgical, obstetrics, and anesthesia care providers per 100,000 population. Currently, there is a substantial imbalance in the distribution of surgical specialists, with Africa having significantly fewer specialists, only 11 compared to Europe and North America, having 54. Efforts are underway to expand training programs in LMICs to address this disparity.

Metric 3: Surgical Volume.[13]

LMICs should achieve a surgical volume of 5000 operations per 100,000 people by 2030. However, many LMICs fall significantly short of this target due to resource constraints, distances to healthcare facilities, conflicts, and the impact of events like the COVID-19 pandemic.

Metric 4: Perioperative Mortality Rate (POMR).[13]

By 2030, all countries should have a system in place to monitor the POMR. Tracking the POMR is crucial for improving surgical care, reducing complications, and preventing deaths. However,

many LMICs lack the necessary resources to establish such tracking systems, leading to challenges in estimating mortality rates.

Metrics 5 and 6: 100% Protection Against Impoverishing and Catastrophic Expenditure.[13] The Lancet recommends that LMICs shield their citizens from financial hardship caused by health expenditures related to surgical and anesthesia care. The costs of surgical care can pose a significant financial burden for many individuals, potentially leading to financial crises. Efforts are being made to provide financial protection for the population through various mechanisms and policies.

In response to these initiatives, the World Health Assembly called on LMICs to strengthen essential and emergency surgical services.[18] Since the launch of the Global Surgery 2030 program, Ethiopia,[116] among other sub-Saharan African countries, has taken the lead in implementing strategies to enhance surgical care at the national level and has demonstrated a strong commitment to these goals. However, despite Ethiopia's early adoption of the Global Surgical initiative compared to other resource-limited settings, the status of its surgical capacity has not been adequately assessed to measure progress. These research gaps have spurred our investigation into the current state of surgical services in Ethiopia, with the intent of comparing findings with similar regions using the LCoGS 2030 indicators mentioned above.

Manuscript I: Assessing Ethiopia's Surgical Capacity in Light of Global Surgery 2030 Initiatives: Is There Progress in The Past Decade

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Abstract

Background: Surgical, anesthetic, and obstetric (SAO) care plays a crucial role in global health, recognized by the World Health Organization (WHO) and The Lancet Commission on Global Surgery (LCoGS). LCoGS outlines six indicators for integrating SAO services into a country's healthcare system through National Surgical Obstetrics and Anesthesia Plans (NSOAPs). In Ethiopia, surgical services progress lacks evaluation. This study assesses current Ethiopian surgical capacity using the LCoGS NSOAPs framework.

Methods: We conducted a narrative review of published literature on critical LCoGS NSAOPs metrics to extract information on key domains; service delivery, workforce, infrastructure, finance, and information management.

Results: Ethiopia's surgical services face challenges, including a low surgical volume (43) and a scarcity of specialist SOA physicians (0.5) per 100,000 population. Over half of Ethiopians reside outside the 2-hour radius of surgery-ready hospitals, and 98% face surgery-related impoverished expenditures. Lacking the LCoGS-recommended SOA reporting systems, approximately 44% of facilities exist for handling bellwether procedures. Despite the prevalence

of essential surgeries, primary district hospitals have limited operative infrastructures, resulting in disparities in the surgical landscape. Most surgery-ready facilities are concentrated in cities, leaving Ethiopia's 80% rural population with inadequate access to surgical care.

Conclusion: Ethiopia's surgical capacity falls below LCoGS NSOAPs recommendations, with challenges in infrastructure, personnel, and data retrieval. Critical measures include scaling up access, workforce, public insurance, and information management to enhance SAO services. Ethiopia pioneered in Sub-Saharan Africa by establishing Saving Lives Through Safe Surgery (SaLTS) in response to NSOAPs, but progress lags behind LCoGS recommendations.

Keywords: Ethiopia; Surgical Access; Bellwether Procedures; Saving Lives Through Safe Surgery; Lancet Commission on Global Surgery

Key Messages: Despite Ethiopia's leading SaLTS initiatives in Sub-Saharan Africa, urgent comprehensive strategies are needed to address slow progress in expanding surgical access and align with global surgery standards.

Highlight

- Ethiopia faces significant challenges in SAO care, with a surgical volume of only 43 and 0.5 specialist SOA physicians per 100,000 population.
- The lack of essential tracking systems outlined by LCoGS hinders the evaluation and improvement of SAO services.
- Despite pioneering SaLTS in SSA as a call-to-action for LCoGS NSOAP, Ethiopia faces challenges aligning with global surgery recommendations of SOA services.
- Ethiopia’s surgical services impose severe financial burdens, driving surgical patients into extreme poverty.

- Investing in district hospitals' infrastructures is critical to empower Ethiopia's 80% of the population dwelling with limited SOA access.

INTRODUCTION

Surgery is an integral and irreplaceable component of healthcare.[1] Access to quality SAO care is a fundamental right to health, integral to achieving universal health coverage (UHC) on a global scale.[2] Nevertheless, a significant discrepancy exists between the demand and access to surgical services in low- and middle-income countries (LMICs).[3] The 2015 LCoGS report catalyzed global surgery advocacy, emphasizing challenges for five billion people accessing SAO care. It underscores the need for 143 million additional surgical procedures annually.[4] In LMICs, comprising 40% of the global population but contributing less than 5% to global surgeries, disparities in access are notably pronounced, especially in Sub-Saharan Africa (SSA). [3, 5]

In SSA, the prevalence of surgical conditions is marked by urgent and essential procedures that demand immediate attention, contrasting with developed countries where 80% of surgeries are elective.[6, 7] The study underscores that limited access to medical care contributes to 10% of premature deaths in the Western world, while in resource-limited settings, inadequate access to surgical interventions leads to heightened poor outcomes, emphasizing the crucial role of surgery in treating life-threatening conditions, preventing premature deaths, and improving longevity.[4, 8] Enhancing surgical access in low-income countries, such as Ethiopia, is crucial for increasing life expectancy and improving overall well-being.[9, 10] An SSA country reported common major procedures, including cesarean sections, laparotomies, and appendectomies. [11] Despite a rising burden of conditions requiring urgent interventions, evaluations consistently uncover shortages

in surgery-ready infrastructure, workforce, services, and supplies. [12] Addressing these significant disparities and improving access to emergency and essential surgical care is crucial for reducing the global burden of disease and could prevent an estimated 1.5 million deaths annually in LMICs.[13]

Recognizing the imperative for improved surgical care, the LCoGS proposed the establishment of NSOAPs across five critical domains: service delivery, infrastructure, workforce, financing, and information management. [4] As a proactive response, Ethiopia, a low-income East African country, is at the forefront among other SSA nations, pioneering efforts by adapting NSOAPs through the SaLTS initiative. Ethiopia designates SaLTS as a national priority to enhance SOA services. [10, 14] The country's healthcare system is structured with primary healthcare units, general and specialized hospitals, and private facilities.[15] Ethiopia employs the WHO's Service Availability and Readiness Assessment (SARA) tool for national surgical planning, enabling interfacility comparisons. [16, 17] Initiated in 2008, healthcare reforms in Ethiopia underscore decentralization and collaboration between federal and regional health officials; nevertheless, disparities in access to essential and emergency surgery persist across Ethiopian regions. [15, 18] Surgery plays a crucial role in achieving Ethiopia's 2030 health policy, aligning with the objective of reducing poverty and minimizing preventable premature deaths with equitable resource allocation.[14]

While Ethiopia has led in adopting the LCoGS NSOAP through SaLTS initiatives in SSA, there is currently a dearth of published papers assessing surgical service progress post-SaLTS implementation. This study bridges this gap by presenting the first comprehensive assessment of

Ethiopia's surgical capacities across the mentioned five domains. The evaluation of progress utilizes the LCoGS NSOAP framework and involves a thorough narrative review of both scientific and grey literature.

METHODS

This review was conducted following the PRISMA–ScR guidelines: PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation.[19] We opted to conduct a narrative review considering the broadness of the research questions with broader general topic overviews.

Search Strategy

We conducted a narrative review of published articles on surgical capacity in Ethiopia related to LCoGS indicators. We enlisted the assistance of a research librarian at the McGill University Health Centre to aid our search of the MEDLINE (Ovid interface), Embase (Ovid interface), and Global Health (Ovid interface) databases (Appendix 1). The search strategy included the following words "Ethiopia*" "Surg*" OR "Anesthe*" OR "Obstetr*" OR "Catastrophic expenditure* OR "Impoverished expenditure*" OR "Lancet Commission on Global Surgery*" AND "Bellwether Surgery." The search was limited to articles published between January 1st, 2000, to October 14th, 2022, in the English language. We selected articles from peer-reviewed publications in global surgery. Additionally, the reference lists of these publications were searched for additional relevant articles related to surgical, obstetric, and anesthesia care.

Eligibility Criteria

Articles were included based on their direct correlation to LCoGS metrics and Ethiopia's surgical capacity, delivery, and challenges. Articles that failed to satisfy Ethiopian surgical systems were

excluded. Studies in relevant domains—service delivery, workforce, infrastructure, information management, finance, and outcomes—had data and significant findings compiled. We further reorganized each Lancet Commission indicator as preoperative, perioperative, and postoperative for study simplicity. The preoperative (Infrastructures and Surgical Volume) metrics include 80% of the population within 2-hour travels to hospitals capable of conducting the three bellwether procedures—a laparotomy, cesarean delivery, and open long-bone fracture management, and the availability of 20 SAO providers for a 100,000 population. Perioperative (Surgical Services and Information Management) metrics include performing 5,000 surgeries per 100,000 population annually and establishing a nationwide surgical tracking system. Postoperative (Finances) metrics cover 100% protection against impoverishing and catastrophic healthcare expenditures caused by surgery.[4]

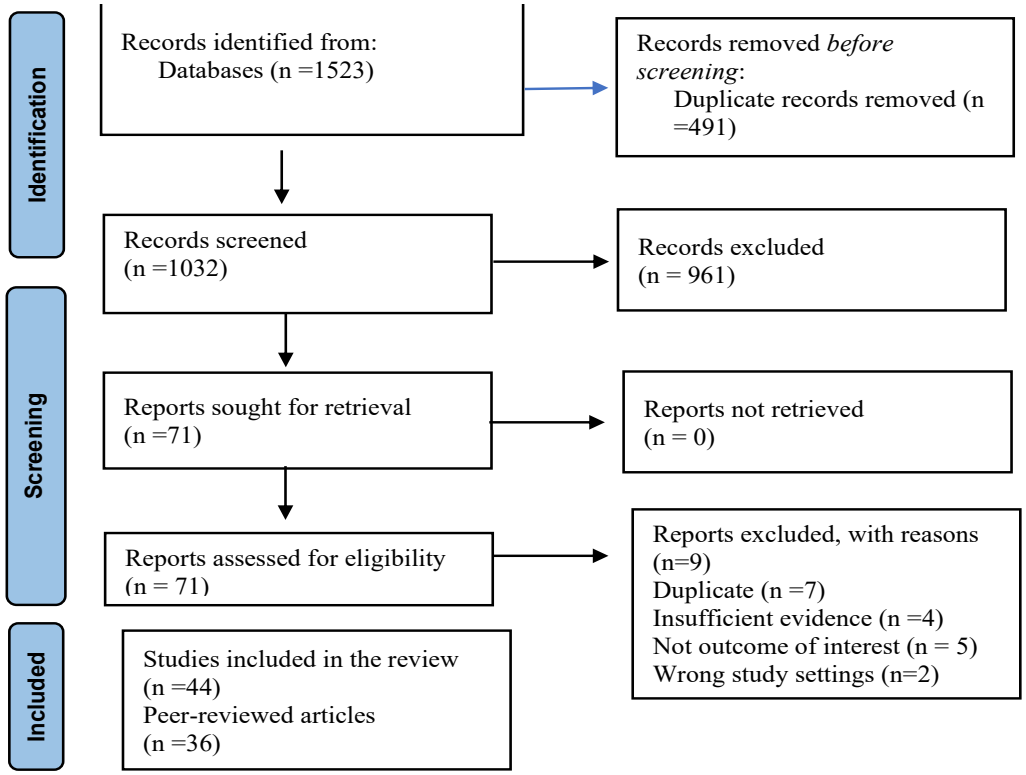
Study Selection and Data Extraction

CO and TR independently screened the titles and abstracts of the identified publications for relevance. The reviewers discussed the included articles for incongruencies and reached a consensus. The same authors then read the full-text articles to identify those that met the eligibility criteria. Articles that passed the two screening stages were then charted for relevant data.

RESULTS

Figure 1 highlights the process of identifying and selecting the articles included in this review. Through MEDLINE (Ovid interface), Embase (Ovid interface), and Global Health (Ovid interface), we identified 1523 citations.

Figure 1 PRISMA flow chart of the search and screening process.



After completing all search strategies, 1032 records underwent title and abstract screening, of which 71 articles were kept undergoing full-text screening. After both stages of screening, 44 articles were included in this review. Of the included articles, 11 were relevant to surgical infrastructure, 12 to workforce, 14 to service delivery, 5 to finance, and 2 to information management. Some of these articles were relevant to multiple domains. Table 1 presents a summary of the narrative review's findings.

Table 1. Ethiopia's Estimates for Lancet Commission on Global Surgery Indicator

Parameter	Indicator	*LCoGS 2030 Goal	Ethiopia's Estimates
Preoperative Infrastructures	Access to essential surgical care	80% of people within 2 hours of a facility capable of performing bellwether procedures *	≤ 50% [19]
	Surgical workforce density	20/100,000 population *	0.54 [20] 5.19 [21]
Perioperative Surgical Services	Surgical volume	5,000/100,000 population *	43 [22] 192 [7]
	Cesarean section	10–15%**	0.6% [23] 3.5% [24]
	Surgical Safety Checklist	100%**	61% [25]
	POMR system	100% national POMR tracking system*	No
Postoperative Finances	Risk of catastrophic expenditure	100% protection*	15%[26] 37 [27]
	Risk of impoverishing expenditure	100% protection*	2% [20]

The table structure is adapted from Shirley and colleagues.[29]

*Lancet and Word Development Indicators on surgical metrics.[4, 21]

**World Health Organization health indicators.[25]

***POMR, perioperative mortality rate. No POMR tracking system in Ethiopia.

? Indicates a range of values found in the review process, illustrating the variability in Ethiopia's current surgical capacity.

Preoperative Indicators

Infrastructures

Eleven studies in Ethiopia assessed surgical infrastructure, emphasizing the need for equitable access to facilities capable of performing essential bellwether procedures, such as cesarean sections, laparotomies, and open fracture management, in line with LCoGS metrics. These

hospitals should be accessible within a 2-hour travel radius for surgical patients.[4] According to Ouma et al., the majority of Africans, averaging around 80%, reside within two hours of surgery-ready facilities, however, for over 50% of Ethiopians, accessing critical care requires traveling beyond this two-hour threshold.[20] In Ethiopia, surgical patients travel 5, 11, 28.4, and 21.3 hours to access services in primary, general, specialized, and private hospitals, respectively.[22]

Ethiopian SaLTS reported that 44% of hospitals offer surgical services, likely reflecting the overall prevalence of surgery-ready hospitals. [14] In a study by Meshesha et al., among 172 health facilities examined, 5.2% were health center operating room (OR) blocks, 44.8% were primary hospitals, 22.1% were general hospitals, 9.3% were specialized hospitals, and 18.6% were private hospitals. [22] Regarding supplies, the Ethiopian Hospital Assessment Tool showed that 33% of facilities lack continuous oxygen, 76% face interrupted electricity, and 59% have unreliable running water. Baseline audits across 28 Ethiopian facilities revealed only 29% had a reliable X-ray machine, and 25% had a functional ultrasound. [10, 14]

The 2020 Surgical Readiness report indicated scores of 66%, 47%, and 53% for primary, general, and specialized hospitals, respectively, on SARA tracer items for essential surgical services. [30] Among the surveyed hospitals, a significant challenge emerged concerning pulse oximeters, with only 63% of hospitals having one for each operating room, while the remaining 37% of hospitals reported some pulse oximetry availability, though not for every operating room. [31] This highlights a disparity in the accessibility of infrastructures across Ethiopian healthcare facilities.

Workforce

Twelve studies in Ethiopia have assessed surgical workforce density; however, none of them reached an exact number of workforces in the country (Table 1). The LCoGS recommends a minimum of 20 SAO specialists per 100,000 populations. The World Bank estimated in 2016 that there were 0.54 personnel per 100,000 population.[32] A 2022 study,[22] surveyed 172 facilities and revealed that 2312 healthcare professionals were found, including 336 surgeons, 364 anesthesiologists and anesthesia care providers, and 165 obstetricians in specialized hospitals. General hospitals had 123 surgeons, 157 anesthesiologists/anesthesia care providers, 76 obstetricians, and 100 integrated emergency surgical officers (IESOs) — nonphysician surgeons. Primary hospitals had 47 surgeons, 126 anesthesiologists/anesthesia care providers, 16 obstetricians, and 194 IESOs. Overall surgical workforce ratios were 7.5/100,000 in primary hospitals, 1.15/100,000 in general hospitals, and 1.31/100,000 in specialized hospitals, averaging an Ethiopian workforce of 5.19/100,000 population. Obtaining accurate data on the surgical workforce in Ethiopia is challenging.

Another study revealed a wide range in the physician-to-population ratio across Ethiopian regions (1:4,715 to 1:107,602). On average, hospitals have 1-2 operating rooms, 4.2 surgeons, 1 gynecologist, and 4.5 anesthesia providers. [31] Notably, more than 56% of general surgeons are concentrated in cities, leaving other regions, despite comprising over 95% of the population, with fewer surgeons. [33] Between 1985 and 2013, 324 general surgeons graduated from Ethiopia, and 327 graduated from Cuba. However, a significant brain drain issue is evident, as many Ethiopian graduates from Cuba reside outside Ethiopia, posing challenges in retaining a skilled workforce.[34]

Perioperative Indicators

Surgical services

Fourteen studies explored surgical service delivery in Ethiopia, but a systematic evaluation of the national capability for safe SOA care is lacking. The LCoGS 2030 targets 5000 surgeries per 100,000 population annually.[4] However, accurate data on surgical volume in Ethiopia remains fragmented (Table 1). In 2016, the World Bank reported 43 surgeries per 100,000, but by 2019, Kifle et al. indicated a significant tenfold increase to 465 surgeries per 100,000.32,35 The 2020 SaLTS recorded 221,260 surgeries, equivalent to 192 per 100,000. [14] These diverse data reveal fluctuations in surgical volumes.

Markedly, the Ethiopian Ministry of Health encourages cesarean delivery as a preventive measure, showcasing excellence in surgical capacity. Cesarean rates in Ethiopia rose from 0.6% in 2008 to 3.5% in 2016. [24, 25] In 2022, 22 a large study identified 69,717 surgical procedures, revealing bellwether procedures in primary hospitals: 3,770 cesarean sections, 444 laparotomies, and 14 open fracture management procedures. General hospitals performed 7706 cesarean sections, 1036 laparotomies, and 392 open fracture management procedures, while specialized hospitals conducted 12,673 cesarean sections, 1128 open fracture management procedures, and 1162 laparotomies. Private hospitals contributed 2198 cesarean sections, 706 laparotomies, and 785 open fracture management procedures. Among procedures, emergency procedures related to trauma or obstetrics accounted for 54.3% of cases, varying from 34.9% to 82.6%, with higher rates completed in city centers. [31] Limited surgical supplies in certain hospitals constrain them to address emergencies. For instance, general surgeons in district hospitals may lack expertise for

specific cases, such as thoracic surgery, primarily handling tasks like occasionally placing chest tubes. [22]

Hospitals encounter challenges in achieving maximum surgical volumes, marked by extended waiting times and referral burdens to higher centers. Average pre-admission waiting times for essential surgical care vary from 9.68 days in primary hospitals, 37.6 days in general hospitals, 35.9 days in specialized hospitals, and 1.42 days in private hospitals. The study analyzed 8584 surgical referrals, mainly from primary healthcare units (3956) and public primary hospitals (3540). Referral reasons include a shortage of skilled professionals (30%) and insufficient equipment (22%), with 50% attributed to factors like supply, beds, blood, investigations, finances, and the absence of an ICU.[22, 31]

Information management

Efficient surgical information management is crucial for quality improvement, but Ethiopia lacks sufficient studies on SOA information management, with only two identified. The national tracking system, LCoGS-recommendation, is currently absent in Ethiopia, relying on incomplete and illegible sources like admission records and operative logbooks. [4, 30] The Ethiopian District Health Information Systems (DHIS-2) reported a POMR of 1.4% in 2020. [36]

Regarding safety and quality, several attempts were made to monitor surgical-site infections (SSI) and surgical safety checklists (SSC) in Ethiopia. In 2012 Chao et al. reported an SSI rate of 1%.[31] After almost a decade, the 2020 DHIS-2 reported a rate of 1.2%,[36] while the meta-analysis for the same year revealed a 9.8% SSI rate, [37] showcasing discrepancies likely attributable to a

shortage of tracking systems. Compliance with SSC in Ethiopian hospitals, integrated into the surgical care strategy for patient safety, was estimated at 61% in recent studies, while DHIS-2 reported 81%.[26, 36]

Postoperative Indicators

Finance

Five studies explored the finances of surgical care in Ethiopia, focusing on protection against impoverished expenditure (IE) and catastrophic health expenditure (CHE), crucial LCoGS indicators for surgical patients. By 2030, SOA care could cost the global economy $12.3 million, causing 81 million people to face CHE, with an additional 48.5 million incurring non-medical costs. [4, 38] A study from Papua New Guinea found a simple appendectomy costs between $11,300 and $13,300, unaffordable for patients.[39]

Ethiopian surgical patients incurred US$204 in medical expenses and US$611 in non-medical costs, including transport, food, and lodging. [40] According to World Bank estimates,[27] 98% of Ethiopians are at risk of IE due to surgery, leaving only 2% protected, defined as out-of-pocket (OOP) payments driving people into extreme poverty. Furthermore, 85% face the risk of CHE, with only 15% protected, exemplified by direct OOP payments exceeding 10% of the household's annual income. Similar studies estimated the risk of CHE in surgical patients was 62.7%, indicating that 37.3% were protected (Table 1).[28]

DISCUSSIONS

The review highlights priority policy areas for improving Ethiopia's surgical system. Despite limited specific SOA care data, a comprehensive literature review provides significant evidence. Local capacity assessments like SARA and SaLTS have informed robust LCoGS NSOAP pathways to enhance healthcare structures.[14] SaLTS, a national flagship, aims to enhance access to safe, essential, and emergency SOA care. Success aspects include strong government leadership, utilization of existing learning systems, recognition of partnerships, engagement of stakeholders, the definition of locally relevant care packages, and enhancing and scaling up nationally based on early learning experiences.[10] The WHO recommends evidence-based priority setting, exemplified by Ethiopia's SaLTS initiatives. This review's data, including SaLTS establishments, were summarized into policy briefs for evidence-informed priority setting during the SaLTS development. Despite Ethiopia's pioneering efforts in SSA, assessing SaLTS progress using LCoGS NSOAP metrics is scarce. The following sections detail how the review results informed priority setting in Ethiopian SOA care.

Preoperative

Equitable access to surgery-ready facilities in Ethiopia, a vital metric targeting 80% accessibility within 2 hours by 2030, faces challenges. Surgical patients, on average, travel 28 hours to reach specialized hospitals for critical care, underscoring substantial disparities in location, transport, and infrastructure availability. Transport challenges in surgical emergencies frequently result in delayed presentations and increased complications, significantly impacting hemorrhagic mortalities from delayed obstetric and trauma emergencies. [22, 31] Currently, 44% of bellwether hospitals serve the 117 million Ethiopian population, prompting efforts to double this number to

80% by 2025. [14] However, achieving this target is challenging given the current COVID-19 pandemic and Ethiopian political situation.[41] To date, in Ethiopia, the exact number of surgery-ready hospitals capable of providing essential and emergent surgeries is unclear.

Despite efforts to increase medical service accessibility in impoverished rural nations, maternal care barriers persist. In 2010, out of the 3% of pregnant women who underwent emergency cesarean sections, 20% were performed for urban women, while only 0.5% were performed for the poorest rural females, where over 80% of the country's population dwells.[24] Existing challenges were further evidenced by studies indicating that merely 61% of 18 hospitals in two large Ethiopian regions had only one functional operating room, with some district hospitals lacking any. [10, 42] To address gaps, the government has allocated funds to renovate 370 operating rooms, with 80 completed. An additional 420 operating rooms are under construction in health centers, benefiting underserved rural communities, supported by a $50 million fund for procuring equipment.[10] SafeSurgery2020, through SaLTS, invests in improving oxygen access, planning to construct two oxygen plants in referral hospitals, aligned with the national roadmap, and leveraging successful models from other African countries.[10, 43]

The review reveals a concerning shortage of SOA workforce in Ethiopia, with figures ranging from 0.53 to 5.2 per 100,000 population, indicating data discrepancies. [22, 32] Uneven distribution is evident, with 38% of surgical subspecialists concentrated in urban areas, while 87% of district primary hospitals lack any SOA personnel. [35, 42] This shortage and imbalance impact patient care, satisfaction, and the overall economy. Expanding SOA residency programs can address workforce challenges, with proposed solutions including the design of rural practice pipelines for

medical students and addressing infrastructure deficiencies.[31, 44] Strategies to discourage emigration and retain Ethiopian surgeons are also crucial.[34] Hospital-based training, following the WHO Global Code of Practice, has shown success in retaining graduates in rural areas, exemplified by the Pan-African Academy of Christian Surgeons at Sodo Christian Hospital in Ethiopia.[33] University-based training programs remain pivotal in nurturing academic SOA specialists, driving surgical education, research, and innovation in the country.[33, 34] The health systems strengthening approach seeks to enhance rural workforce conditions by supporting a functional regional SOA hub, focusing on improving the supply chain, staffing, and infrastructure for sustainable and effective healthcare.

Perioperative

The review underscores a substantial shortage of surgical procedures in Ethiopia, ranging from 43 to 192 procedures per 100,000, with the accurate figure likely falling in the middle. [14, 23] Ethiopia is projected to fall short of its goal of 5,000 surgeries per 100,000 population by 2060–2070. [45] A study revealed that 46% of bellwether procedures occurred in higher hospitals in cities, with only 17% taking place in district primary hospitals; however, LCoGS mandates all primary hospitals to perform essential life-saving surgeries, showcasing significant disparities in access to care.[22] Consequently, SaLTS aims to enhance surgical service delivery across all healthcare levels, focusing on upgrading health centers for major and emergency surgical and obstetric procedures in rural areas and empowering district hospitals for more complex surgeries. [4, 10, 14]

Despite WHO's recommendation of evenly distributed cesarean section rates between 5% and 15%, Ethiopian urban hospitals perform the majority, leaving limited access for rural

communities.[25, 46] Maternal mortalities decreased from 597 in 2010 to 401 per 100,000 live births in 2017, encouraging more equitable cesarean distribution.[36] The Ethiopian Ministry of Health aims to increase the current 3.6% cesarean section rate to 10% to meet life-saving procedure needs, aligning with WHO guidelines.[14] Furthermore, Ethiopia lacks sufficient studies on SOA information management, and while DHIS-2 reports a POMR of 1.4%, other estimates range from 2% to 3.3%. [36, 47] The absence of surgical tracking systems hampers obtaining reliable nationwide statistics. In response, Ethiopia's SaLTS initiative seeks to prospective collection and reporting of the six LCoGS indicators, [4, 10] along with achieving a national mortality rate below 2% and implementing 100% SSC at all facilities. [14] SaLTS enhances capacity, addresses referral system inefficiencies, and ensures high-quality service.

Postoperative

In Ethiopia, surgical patients face substantial financial burdens, incurring an average of US$204 in medical expenses and US$611 in non-medical costs.[40] The World Bank reported only 2% are protected from IE and 15% from CHE, but the norm is that 100% should be protected from surgery-related costs.[4, 27] The majority of Ethiopians experience forced out-of-pocket payments, leading to 18% skipping medical care due to financial constraints, resulting in delayed surgical interventions, leading to poor outcomes. [48] Access to surgery appears limited to those who can afford it, highlighting the need for financial support and policy interventions.[28]

To address financial challenges, Ethiopia has implemented policies, including fee waivers for those unable to afford medical care and the introduction of community-based health insurance.[49] Strengthening such programs is crucial to ensuring equitable access to surgical services.

Furthermore, the SaLTS governance section prioritizes tracking national budgetary allocations to surgical services, aiming to reduce CHE and IE for patients.[10, 14] The initiative advocates for the inclusion of surgical procedures in national health insurance schemes, offering protection to patients and ensuring appropriate reimbursement for health facilities providing surgical services. Investing in surgery has proven economically beneficial, with positive outcomes.[50] Recognizing surgery as an essential part of healthcare, 28 SAO care should be integral to Ethiopia's national health system, irrespective of income level.

LIMITATIONS

While this narrative review comprehensively addressed Ethiopia's surgical system, additional research is needed to cover policy areas not included, ensuring SaLTS's comprehensiveness and overall enhancement of the surgical ecosystem. Reliance on scientific and grey literature poses a potential risk of publication bias, and considering the two-decade span, some data may be outdated. The review is grounded in the LCoGS NSOAPs five framework, which may not be a perfect fit for all contexts, as exemplified by Ethiopia's expansion of SaLTS to eight pillars.10 Ongoing adaptation of the framework is crucial, incorporating lessons learned during SaLTS development. The scarcity of primary research on surgical capacity in Ethiopia limits generalizability, potentially leading to over- or underestimation. The narrative review's broad scope and the limited scientific literature on the topic introduce a possibility of selection and narrative bias. Despite limitations, the review provides insights into the current surgical landscape since adopting the SaLTS program, mirroring other countries' NSOAPs.

CONCLUSIONS

This assessment identifies areas for strengthening Ethiopia's surgical structure, incorporating insights from the SARA measurement and SaLTS assessment tools.[10, 14, 17] While a comprehensive examination of Ethiopian surgical capacity is lacking, this paper guides countries developing NSOAPs, drawing on Ethiopia's experience with SaLTS integration into its national health system. While Ethiopia has been a pioneer among African nations in this regard, our findings underscore shortages in meeting LCoGS metrics, signaling areas for improvement. Policymakers can use this review to shape surgery-related guidelines, and NGOs working on surgical services may gain valuable insights for future development. Challenges facing SaLTS include ensuring consistent implementation of its pillars across all regions, attracting new partners and investors, robustly evaluating early results, and sustaining momentum. [10, 14] Moving forward, SaLTS interventions will shape the national scale-up, strengthening SOA care across Ethiopian regions evenly. Strengthening the monitoring and evaluation of SaLTS strategies is crucial for informing evidence-based interventions and implementation policies, benefiting not only Ethiopia but also other LMICs.

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Author Contributions

CO and TR contributed to the study's conception and screening. CO, TR, JG, and DD were involved in the study design, data curation, and analysis. CO wrote the entire manuscript draft.

CO, TR, JG, and DD were involved in manuscript editing. All authors actively participated in editing and critically reviewing the manuscript and granted their approval for publication.

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CHAPTER THREE: ENHANCING TRAUMA CARE THROUGH EDUCATION

Preface

The WHO's Trauma System Maturity Index (WHOTSMI) highlighted deficiencies in trauma care systems in LMICs compared to high-income nations.[122] The key points include:

[1] Prehospital trauma care is well-established in HICs but limited in LMICs.

[2] In-hospital trauma care in HICs is led by professionals with Advanced Trauma Life Support (ATLS) knowledge, while LMICs often lack skilled staff.

[3] Trauma education, like ATLS, is crucial, but its implementation in LMICs is hindered by factors including cost.

[4] Establishing digitized trauma data infrastructures for effective trauma care systems remains a challenge in LMICs.

The preceding manuscript identifies challenges in accessing essential surgical care, including limited skilled workers for life-saving procedures, absence of data documentation systems, poor infrastructure, and a shortage of educational programs to enhance the surgical care provider pool and skills. The proposed solution to address these gaps involves expanding trauma and surgical education and training in resource-limited settings, following the WHOTSMI metrics. In this preface, we explore the pivotal role of trauma education in advancing trauma care systems, particularly in LMICs. We emphasize the positive impact of formal trauma care systems and interdisciplinary trauma teams. Additionally, we delve into the adoption of trauma training programs and their significance in educating healthcare frontliners for critical and trauma care. Stressing the necessity for practical trauma courses, we underscore the value of cost-effective,

eco-friendly training initiatives. These challenges are common in resource-limited settings, including data limitations, personnel turnover, and resource constraints. This reinforces the importance of integrating trauma education through team-based approaches and the Train-the-Trainer paradigm.

The preface introduces the Trauma and Disaster Team Response (TDTR) Course in Tanzania, utilizing a cost-effective and eco-friendly blended learning approach. This course aims to cultivate a proficient trauma response team, reducing preventable injury-related mortality in resource-limited settings. We designed assessment tools to evaluate the feasibility and impact of this training on enhancing practitioners' trauma care knowledge and skills. The study aims to gain valuable insights into trauma approaches, paving the way for improved traumatic patient care, modernized triaging systems, and established functional trauma teams and disaster responses in Tanzanian settings, crucial for reducing trauma and emergency disaster burdens in the country

Manuscript II: Enhancing Trauma Care through Innovative Trauma and Disaster Team Response Training: A Blended Learning Approach in Tanzania.

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Abstract

Background

In Tanzania, inadequate infrastructures and shortages of trauma-response training exacerbate trauma-related fatalities. McGill University's Centre for Global Surgery (CGS) introduced the Trauma and Disaster Team Response course (TDTR) to address these challenges. This study assesses the impact of simulation-based TDTR training on care providers' knowledge/skills, and clinical outcomes.

Methods

The study used a pre-post-interventional design. TDTR, led by Tanzanian instructors at Muhimbili Orthopedic Institute (MOI) from August 16-18, 2023, involved 22 participants in blended online and in-person approaches with simulated skills sessions. Validated tools assessed participants' knowledge/skills and teamwork pre/post-interventions, alongside feedback surveys. Clinical outcome including 24-hour emergency department patient arrival-to-care time and

mortalities was evaluated four months pre/post-TDTR interventions. Data analysis included paired t-tests, Mann-Whitney U test, Chi-square tests, and multivariate regressions ($p \leq 0.05$).

Results

Participants' self-assessment skills significantly improved (median increase from 34 to 58, $p<0.001$), along with teamwork (median increase from 44.5 to 87.5, $p<0.003$). Over 99% of participants expressed satisfaction with TDTR meeting their expectations, with 97% interested in teaching future sessions. The six-month post-intervention arrival-to-care time significantly decreased from 29 to 13 minutes, indicating a 55.17% improvement ($p<0.004$). Pre-intervention, 1.59% (40/2510) of patients died, compared to 0.92% (27) post-intervention ($p= 0.073$).

Conclusion

The study confirmed the effectiveness of surgical skills training in Tanzanian settings and highlighted TDTR's role in improving teamwork, patient outcomes, and healthcare structures. To sustain progress and empower independent trauma educators, ongoing refresher sessions and expanding TDTR across Tanzania and other LMICs are recommended to align with global surgery goals.

INTRODUCTION

The burden of trauma-related fatalities disproportionately affects low- and middle-income countries (LMICs), where healthcare systems are underdeveloped [1]. Limited trauma education, inadequate infrastructures, and immature trauma systems exacerbate disparities, leading to significant disability and economic insecurity in these regions [2,3]. Advancing trauma training tailored to the context of LMICs is essential to address such challenges [4]. Gold-standard courses like the Advanced Trauma Life Support (ATLS) are effective but face practical

limitations in LMICs due to cost and infrastructure constraints [5]. Improved trauma systems consist of effective trauma care, wherein multidisciplinary teams, including skilled medical professionals, residents, and allied clinicians, ensure rapid resuscitation, stabilization, and prioritization of patient care, ultimately improving clinical outcomes [6].

Despite advancements in trauma services, preventable trauma deaths persist, with errors during initial emergency department (EMD) evaluation and resuscitation contributing significantly [7]. Patient safety threats stem from both clinicians' knowledge gaps and deficiencies in trauma teams' non-technical skills, such as communication and leadership; crucial for timely decision-making and effective interventions [8]. Traditionally, medical education programs have overlooked multidisciplinary team-based training, assuming individuals acquire teamwork competencies without formal training; however, trauma curriculums have recently integrated team-oriented training [9,10].

Acknowledging the importance of team-based training and addressing affordable and sustainable training gaps in LMICs, McGill University's Centre for Global Surgery (CGS) developed the Trauma and Disaster Team Response (TDTR©) course. This tailored 3-day blended learning program includes a freely accessible online component through the United Nations SURGhub: http://surl.li/moghg. Livergant et al. revealed that trauma training in LMICs lacks evidence of sustainability, cost-effectiveness, interdisciplinarity, and patient outcomes, often lacking local support [11,12]. Conversely, the TDTR empowers LMIC authorities and instructors, adopting multidisciplinary approaches. Its affordability, UN endorsement, and success in local capacity-building signify a shift towards locally empowered initiatives, diverging from reliance on Western-based instructors. Moreover, TDTR centers on enhancing patient care by improving

triaging systems and establishing functional trauma teams in Tanzanian settings, critical approaches in trauma protocol [8,13]. It also facilitates translating teams' simulation-based learning into real-patient practices for enhanced outcomes.

Although the impact of team-based training on clinical outcomes is under-researched,[10] we hypothesize that TDTR improves clinicians' and teams' skills and clinical outcomes. This study assessed TDTR's impact on trainees' short-term outcomes and four-month post-intervention effects on 24-hour EMD patients' arrival-to-care time and mortalities at Muhimbili Orthopedic Institute (MOI). Achieving these objectives demonstrates the feasibility of teaching surgical skills in LMICs.

METHODS

Design

A single-group pre-post-intervention study with TDTR as the intervention, adhering to EPOC guidelines [14].

Settings and Collaboration

Dar es Salaam-based MOI is Tanzania's national trauma/orthopedic, and neurosurgery center. Partnering since 2006, MOI authorities extended an invitation to CGS in 2023 to enhance trauma services, focusing on reducing preventable injury-related deaths through team-based trauma education.

Participants

The MOI faculty preselected 22 participants encompassing one pediatric orthopedist, two anesthesiologists, one anesthetist, five residents, seven physicians, and six nurses (Table 1). The

course was primarily run by Tanzanian faculty with limited CGS support and was conducted in English.

Intervention

The TDTR employs blended-learning models suitable for LMICs, starting with online lectures and quizzes. Certification requires passing quizzes (not evaluated in the study) and completing simulation-based hands-on training. The in-person sessions occurred from August 16 to 18, 2023 (Resource 1).

Instructors' day: In a one-day pretraining phase, MOI's TDTR-certified instructors, familiarized themselves with course evaluation, topic selections, and honed their skills on mannequins through collaboration with visiting faculties from CGS.

Day 1: On-site lectures covered primary and secondary surveys, immediate life-threatening injuries, disaster response, and triage. Hands-on training exercises emphasized essential trauma assessment techniques and team approaches on primary surveys, including single, polytrauma, and mass casualty scenarios.

Day 2: Lectures covered pediatric and pregnancy injuries, burn patient and pain management, patient transfer principles, and trauma system/registry implementation. MOI instructors used local mannequins for trainees in four hands-on skill stations, including:

- Basic airway management.
- Surgical airway techniques, including cricothyroidotomy.
- Chest decompression procedures.
- Intraosseous venous access, spine immobilization, splinting, and tourniquet application.

Day two concluded with evaluating simulation-based teams' technical/non-technical skills dynamics with debriefing.

Outcomes

Clinical outcomes included four-month 24-hour EMD mortalities and patient arrival-to-care time—critical metrics for trauma service efficiency [10]. Note: Arrival-to-care time at the EMD refers to the duration from a patient's arrival (timestamped) to receiving initial medical attention or care (timestamped) from healthcare providers. Short-term outcomes evaluate trainees' immediate knowledge, skills, and teamwork.

Data Collection

Self-skill evaluation (Pre/Post): Participants assessed their skill competencies using 0 (beginner) to 2 (expert) scaling questionnaires, totaling 66 points (Resource 2).

Teamwork evaluation (Pre/Post): Teams were assessed during simulated trauma scenarios. Four diverse teams were established, each managing simulated polytrauma patients using an actor. Instructors used a 0-2 scoring rubric, totaling 100 points, to evaluate primary/secondary surveys, interventions, and teamwork during critical situations (Resource 3). Teams underwent blinded evaluations (unaware of the rubric lists) with instructors rotating for post-evaluations to minimize potential biases, followed by debriefing sessions.

Survey: Participants used a Likert scale ranging from "strongly disagree" to the highest rating, indicating strong agreement. Trainees also completed open-ended questionnaires to provide feedback. The survey, administered in English, was conducted after course completion (Resource 4).

Clinical data (before/after): Clinical outcomes were assessed four months before (February-May 2023) and after (September 2023 – December 2024) TDTR implementation. Data extractions utilized MOI's eMEDICO platform, EMD logbooks, and electronic trauma databases. August, the course month, served as an interim period for incorporating program outcomes into clinical practice.

Validations

Validations involved McGill University medical students participating in Surgical Exploration and Discovery programs for evaluating course assessments. All issues were reviewed during faculty meetings, and final versions were approved by MOI before implementation. Four nurses from MOI, previously trained, collected clinical data four months pre/post-intervention using the aforementioned data sources. These data's quality and completeness were then confirmed by local senior principal investigators (VM and RB).

Analysis

Outcomes measures were analyzed using both parametric and non-parametric tests, depending on the data distribution. Categorical data underwent chi-square tests, while the Mann-Whitney U test was utilized for continuous variables such as EMD patient arrival-to-care time due to skewness. Confounders for dependent variables, like mortality, were assessed using multivariate regression in SPSS v23.0 ($p \leq 0.05$). Results were presented as a mean, median, and interquartile ratio (IQR). Trainees consented to score analysis following established standards [15], and McGill University and MOI granted ethics approval.

RESULTS

Demographics

Twenty-two participants completed the TDTR course, including specialists (one pediatric orthopedist, two anesthesiologists, one anesthetist), five residents, seven physicians, and six nurses. The average age was 33 years (range 25-41), with 11 males and 11 females. The mean work experience was 4.9 years (range 1-10) (Table 1).

Table 1: Participants' demography presented as absolute median and interquartile ratio

Demographics	Specialists (n=4)	Residents (n=5)	Physicians (n=7)	Nurses (n=6)	All (n=22)
Sex (M: F)	3:1	4:1	4:3	0:6	11:11
Age (Yrs.)	36 (34-37)	33 (28-36)	30 (27-36)	30 (25-41)	33 (25-41)
Experience (Yrs.)	6 (5-6)	4 (3-7)	3 (1-7)	6 (4-10)	5 (1-10)

The table presents demographic information for different groups of participants. The first row indicates the number of participants in each group (n). It also includes information about the sex ratio (M: F), and further, the trainees' age and work experience in years (Yrs.) are presented with the median and interquartile range (in parentheses).

Self-skill evaluation

Participants demonstrated statistically significant improvements in their self-skill assessments. Before taking the TDTR course, the median score was 34 (range 23-49), which significantly increased to 58 (range 48-66) ($p< 0.001$) following attending skill sessions (Fig.1). The mean difference score, signifying improvements in trainees' skill levels, was 24.10 [95% CI, 21.31 to 26.87; $p< 0.001$] points. All 22 subjects exhibited an increase in post-course skill evaluation scores, almost 1.7 times higher than their pre-course scores ($p<0.002$).

Fig. 1 Mean changes in pre- and post-self-skill evaluations for participants in the course Data are presented as the mean with 95% CI (error bars) n = 22 of participants.

Experience level

Skill improvement was influenced by participants' years of experience. Clinicians with five years of experience or less improved their scores with a mean difference of 24.27 [95% CI, 19.07 to 28.83; p<0.001] points. Participants with over six years of experience also showed significant improvement, with a mean difference of 23.71 [95% CI, 17.33 to 30.10; p<0.00] points (Fig.2).

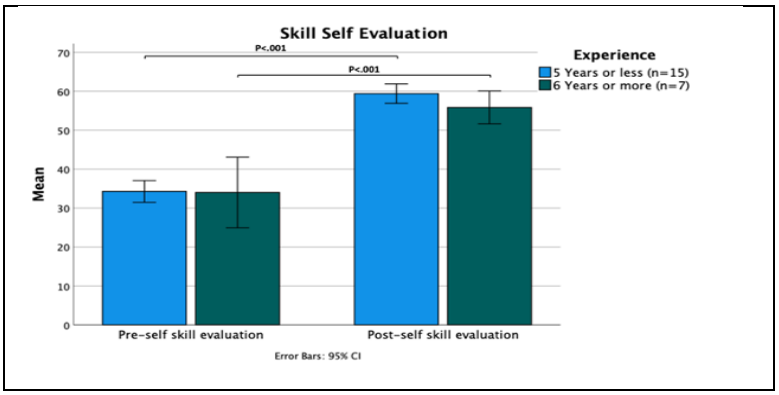

Fig. 2 Skill improvement based on years of trauma care experience. Pre and post-self-skill evaluations for participants with 5 years or less of experience (Blue bars; n = 15) and those with 6 years of experience or more (Green bars; n = 7) Data are presented as the mean with 95% CI (error bars)

Sub-analysis

All professionals demonstrated significant skill improvement in pre- and post-evaluations. Physicians showed progress with a mean difference of 26.27 [95% CI, 18.34 to 33.73; p<.001] points, while residents improved by a mean difference of 23.40 [95% CI, 18.57 to 28.23; p<.001] points. Nurses also improved by a mean difference of 23.17 [95% CI, 15.30 to 31.00; p<.001] points. Additionally, anesthesiologists, anesthetists, and orthopedists demonstrated improvement, with a mean difference of 22.50 [95% CI, 10.12 to 34.88; p<.015] points (Figure 3).

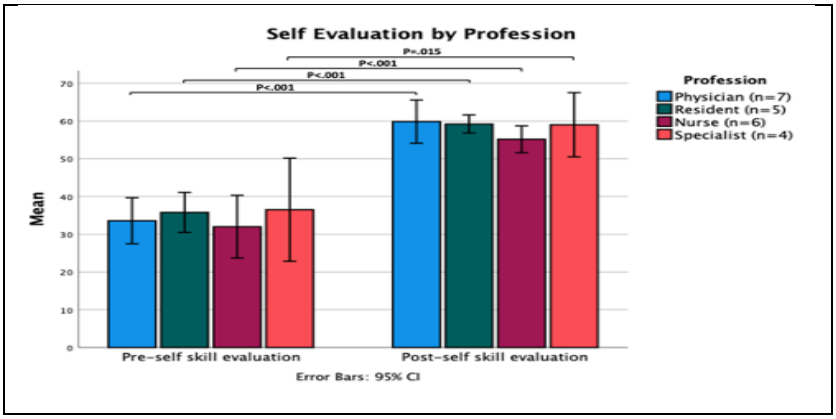

Fig 3 Skill improvement among different professionals. All professionals demonstrated significant skill improvement in pre- and post-self-evaluations. Pre- and post-skill evaluations for physicians (Blue bars; n = 7), Residents (Green bars; n = 5), Nurses (Burgundy bars; n = 6), and Specialists (Orange bars; n = 4). Data are presented as mean with 95% CI (error bars)

Team approach

When analyzing teamwork using validated rubrics during injury moulage scenarios, the four groups achieved scores of 39%, 50%, 37%, and 62% before attending any team exercises. However, the post-teamwork evaluation significantly improved to 88%, 92%, 87%, and 87%, respectively. The mean score increased from 47 to 88.5 in the post-team evaluation [95% CI, 27.67 to 55.33; p< 0.003] points (Table 2).

Table 2: Pre/Post Team Approach Evaluation Scores and Means Among Trainees

Group	Pre-team Evaluation	Post-team Evaluation	Mean pre-Eval	Mean post-Eval	P value
A	39	88			
B	50	92			
C	37	87			
D	62	87			
Total/100			47	88.5	$p<0.003$

The table presents teamwork evaluation across four groups as mean scores. There was a significant difference in the pre-and post-teamwork evaluation scores for the total group ($p<0.003$). The higher mean post-eval score suggests an improvement in team approach skills after the training.

Survey analysis

Participants (98%) agreed that course objectives were clearly defined and achieved. Lectures were found valuable (99%), and 100% expressed the usefulness of skill stations and teamwork. Despite some suggestions for improvement, 99% of trainees found the TDTR course met their expectations, with high confidence (95%) in handling traumatic patients and strong willingness (97%) to recommend and teach the course. Some feedback included recommendations for improvements in course duration, practical sessions, faculty numbers, and opportunities for skill exchange at the partner institution. Concerns were expressed about logistics and payment for participation. Selected responses include:

Participant 7: "*…I found it highly beneficial as it strengthened my understanding of ABCDE principles and efficient triaging systems which I was familiar with but hadn't effectively implemented previously. Now, I feel confident in my ability to handle trauma patients systematically…*"

Participant 12: "…*Interactive lessons and the utilization of practical simulation sessions were effective and facilitated easier learning*…"

Participant 19: "*...The team approach simulations, followed by real-patient practices, greatly boosted my self-esteem and underscored the significance of emergency readiness, rapid response in mass casualty situations, and the practice of effective teamwork, which was a new experience for us..."*

Clinical Improvements

Over 5440 major trauma patients met inclusion criteria, pre-intervention 46.14% (2510) and post-intervention 53.86% (2930), revealing no gender, injury severity, or body region differences (Table 3). Median ages were 30 years (IQR 21–43) and 31 years (IQR 21–44) in the pre- and post-intervention groups, respectively ($p < 0.002$). Motor vehicle collisions (MVCs) were evenly higher in both groups ($p < 0.001$). Both groups primarily received transferred patients via ambulances, with similar patterns of motorbike-and car-related transport accidents mainly on drivers.

Table 3: Trauma patient characteristics pre/post-intervention

	Pre (N = 2510)	**Post (N = 2930)**	**p-Value**
Age (Years)	**Median (IQR)**	**Median (IQR)**	P < 0.002[a]
	30 (21–43)	31 (21–44)	
Sex	**No. (%)**	**No. (%)**	p = 0.931[b]
Male	1546 (61.59%)	2261 (77.17%)	
Female	964(38.41%)	669 (22.83%)	
Transferred from Other Hospitals	**No. (%)**	**No. (%)**	P<0.023[b]
Yes	1968 (78.41%)	2001 (68.29%)	
No	542 (21.59%)	929 (31.7%)	
Mode of Arrival	**No. (%)**	**No. (%)**	P<0.019[b]
Ambulance	1409 (56.14%)	1662 (56.72%)	
Other Transport Means	1101 (43.86%)	1268 (43.28%)	
Mechanism of Injury	**No. (%)**	**No. (%)**	p < 0.001[b]
MVC	1397 (55.66%)	1724 (58.84%)	
Fall	821 (32.71%)	935 (31.91%)	
Blunt Assault	93 (3.71%)	127(4.33%)	

Crush	199(7.93%)	89 (3.04%)	
Vehicles Involved in RTCs*	**No. (%)**	**No. (%)**	P<0.031[b]
Motorbike	773 (55.33%)	1126 (64.94%)	
Car	461(32.99%)	405 (23.36%)	
Tricycle/Bajaji	143(10.24%)	92(5.31%)	
Road Users	**No. (%)**	**No. (%)**	P<0.028[b]
Driver	539 (38.58%)	646 (37.25%)	
Passenger	427(30.57%)	578 (33.33%)	
Pedestrian	431(30.85%)	510 (29.41%)	
Overall KTS**	**Mean (SD)** 6.25 (2.92)	**Mean (SD)** 5.85 (2.91)	P = 0.461[a]
KTS Severity Ranges	**No. (%)**	**No. (%)**	p = 0.402[b]
9-10 (Mild)	1367 (54.46%)	1836 (62.66%)	
7-8 (Moderate)	864 (34.42%)	987(33.68%)	
≤ 6 (Severe)	279 (11.12%)	107 (3.65%)	
Body Region	**No. (%)**	**No. (%)**	p = 0.260[b]
Single	1499 (59.72%)	1625 (55.46%)	
Polytrauma	1011(40.28%)	1305 (44.53%)	

The table compares patient demographics, injury patterns, road traffic collisions (RTCs*), and body regions injured pre- and post-intervention. **Injury severity score is assessed using the Kampala Trauma Score (KTS), a validated tool in LMICs for predicting survival probability. Significance tested with t-Test (a) and Chi-Square (b)

Post-intervention, improvements in 24-hour EMD mortalities and patients' arrival-to-care time were evidenced (Table 4). The pre-intervention attended time decreased from 49 minutes (IQR 315–1092) to 32 minutes (IQR 406-1136). Arrival-to-care time significantly reduced from 29 minutes to 13 minutes post-intervention, representing 55.17% post-intervention improvements ($p<0.004$). Pre-intervention, 40/2510 (1.59%) patients died, compared to 27/2930 (0.92%) post-intervention ($p = 0.073$). After adjusting for confounders including survival status, age, and injury severity, multivariate regression analysis revealed significant reductions in mortality odds and arrival-to-care time delays ($p < 0.023$) with the intervention, suggesting TDTR potential to lower mortality rates and improve care efficiency in trauma patients.

Table 4: Comparison of patient outcomes and healthcare processes pre-post-intervention

24-Hour EMD Patient Status	**Pre (N=2510)**	**Post (N= 2930)**	***p*-Value**
Care Time (minutes)	**Median (IQR)**	**Median (IQR)**	**p< 0.004[a]**
Arrival Time	20 (300-1080)	25 (364-1120)	
Attended Time	49 (315-1092)	32 (406-1136)	
Arrival-to-Care-Time	29 minutes	13 minutes	
Disposition	**No. (%)**	**No. (%)**	**P=0.018[b]**
Discharged	645 (25.69%)	902 (30.78%)	
Admitted To Ward	1297 (51.67%)	1033 (35.26%)	
Admitted To ICU	102 (4.06%)	93 (3.17%)	
Taken To Operating Theaters	423 (16.85%)	874 (29.83%)	
Referred To Other Hospitals	3 (0.12%)	5 (0.17%)	
Overall Outcomes	**No. (%)**	**No. (%)**	**P=0.073[b]**
Died	40 (1.59%)	27 (0.92%)	
Survived	2470 (98.41%)	2903 (99.08%)	
Mortality Odds			**p<0.023[c]**
Arrival-to-Care Time Delays			

The table compares EMD's 24-hour trauma patient care time, disposition, and outcomes, focusing on death and survival. Significance was assessed using the Mann-Whitney U test (a) and Chi-square (b). The multivariate regression (c) was conducted with death and arrival-to-care time as dependent variables. Independent variables included age, survival rate, injury severity, and TDTR intervention.

DISCUSSION

Tanzania's absence of prehospital care systems coupled with MOI's underdeveloped triaging, malfunctioning equipment, and skilled personnel shortages hampers effective trauma management [16]. In LMICs, where 95% of disaster-related deaths occur, merely 1% of trauma-related publications originate [17]. This data scarcity fueled by prohibitive course costs poses challenges for policymakers to assess the impact of existing trauma education programs [4,5].

McGill's CGS developed the TDTR program to address training gaps, focusing on local affordability and sustainability. Implemented in Palestine, Senegal, and Nepal, it's freely accessible through the SURGhub platform, benefiting LMIC clinicians. The program utilizes

blended learning to enhance trauma care skills and teamwork, aiming for improved healthcare delivery and patient outcomes. Participants complete online lectures with quizzes, a prerequisite for in-person training and certification, demonstrating the effectiveness of blended learning in Tanzanian contexts.

Self-evaluation approaches in existing literature [18,19] identify strengths and improvement areas, fostering self-awareness and self-directed learning [20]. Post-intervention, participants' self-skill evaluation scores nearly doubled ($p<0.002$), highlighting enhanced trauma management approaches, behaviors, and skills. Participants, regardless of trauma service experiences, significantly improved self-skills post-intervention, consistent with other studies [19], affirming TDTR program benefited both novices and experienced healthcare providers. Physicians appeared to benefit more from TDTR compared to residents, which aligns with similar findings [18]. This could be attributed to physicians' extensive trauma exposure or potential overrating in self-assessments [18,21]. It's worth noting that physicians' self-skill reports can vary, with studies suggesting discrepancies compared to objective measurements [22] or improved accuracy with experience [23]. Overall, participants benefited from the program, and their self-assessments generally aligned with their abilities. However, novice nurses and anesthetists tended to overrate their skills compared to experts [18,24].

Unlike studies evaluating individual performance [21,22], TDTR focused on teamwork in trauma resuscitations, mirroring real-life clinical situations. Studies emphasize the importance of trauma team training, highlighting simulation as a valuable tool for teaching and assessing multidisciplinary team performance [10]. Simulation exercises provide realistic training

opportunities linked to observable team processes and performance metrics, followed by debriefing sessions to discuss team dynamics and interactions. This approach allows teams to identify effective processes and strategies for improvement. There has been a growing emphasis on teamwork training to enhance patient safety [25]. While teamwork training is common in emergency medicine,[26] its transferability to clinical settings is scarce [10].

Teams' post-intervention scores signify improvements, highlighting the course's efficacy in team building for complex trauma cases. The TDTR program advanced teams' technical and non-technical skills in high-pressure trauma scenarios, consistent with similar findings [8,10], emphasizing the training's role in enhancing team dynamics to improve patient outcomes. Integrating simulation training with real-world practice enhances teamwork skills and healthcare processes [27]. Our study adds to this body of literature by showcasing how our trainees effectively translate simulation-based training into real patient care at MOI EMD. Notably, debriefing sessions play a crucial role in significantly enhancing teams' skills when dealing with traumatic patients at EMD, thereby fostering improved teamwork and healthcare processes. These interdisciplinary teams then transitioned into MOI's functional trauma teams, consistent with documented experiences [25,28]. Despite teams demonstrating effectiveness and cohesive membership, resource-limited settings often face fluctuating team compositions over time, suggesting continued structural development.

In healthcare, a triaging system is a methodical process that categorizes patients based on medical urgencies upon hospital arrival to allocate resources efficiently and deliver timely care [13]. Effective implementation of trauma teams and triage systems, critical in trauma protocol,

enhances care efficiency and enhances outcomes [8,13,29]. Before TDTR's introduction, MOI encountered challenges in implementing cohesive team and triaging systems, leading to delays in providing timely care. During training, we extensively practiced with trainees on efficient assessment techniques and integrated triaging flowchart protocols, underscoring organizational transitions in enhancing care efficiency. Post-intervention, there was over a 17% increase in traumatic cases at EMD, contributing to a 140% rise in bed occupancy rate [30]. TDTR's emphasis on triaging measures addressed overcrowding at the EMD by swiftly managing and relocating patients to trauma bays, reflecting advancements in healthcare processes.

Motorized injuries are prevalent in Tanzania, [30] with higher rates observed in both pre-post-TDTR-interventions. Ambulances remain the primary mode of transport, and in transport-related accidents involving road users, drivers were primarily injured (Table 3). Post-intervention, the 24-hour EMD exhibited improved healthcare efficiency and patient outcomes. The waiting time from critical patients' arrival-to-care time decreased by 16 minutes, signifying a 55% improvement ($p<0.004$). This reduction reflecting implemented training positively influenced care delivery efficiency and patient outcomes along with optimizing hospital resource utilization [25].

The trauma protocol stresses the importance of immediate life- and limb-saving care within the golden hour, crucial for preventing over 60% of preventable deaths within the first hour of injury in LMICs [1,29]. MOI’s mortality rates reduced post-intervention, aligning with Townsend et al.'s statements of a 9% reduction in time correlating with decreased injury-related mortality [31]. Efficient trauma services exhibited significant post-intervention improvements in 24-hour

EMD disposition status ($p<0.018$), signifying enhanced care efficiency. Tanzanian authorities acknowledged the substantial benefits of TDTR programs in shaping organizational frameworks. Improved teamwork behaviors and clinical outcomes underscore teaching surgical skills facilities and TDTR's impact on LMIC trauma systems.

LIMITATIONS

The study's limitations include potential biases in self-assessments across professionals, especially in the absence of relevant prior training. The single-center study limits generalizability, necessitating longitudinal multicenter studies. The lack of control groups and non-randomized study designs inherently acknowledges confounding factors that can hinder direct attributions of improved healthcare outcomes to training initiatives; however, statistical methods were used to control confounders. Additionally, various external factors, including data extraction approaches, workforces, and service delivery, were considered; however, significant changes were minimal overall, except for observed administrative modifications post-intervention. Suitable methodologies are encouraged to assess TDTR's impact on healthcare outcomes. Despite constraints, TDTR's initiatives, including a larger patient population to assess MOI's clinical improvements, demonstrate its potential for enhancing trauma services in resource-limited settings.

CONCLUSION

The TDTR program prioritizes collaboration with local champions to foster sustainable education initiatives. Despite the surgery being labeled as a *neglected stepchild of global health in LMICs*, [32] TDTR has demonstrated the feasibility and positive reception of teaching surgical

skills among Tanzanians. Through hands-on training with real patients and enhanced triaging systems, trauma teams have improved their clinical practices, leading to organizational shaping in trauma services. Moving forward, ongoing refresher sessions are essential to maintaining advancements in trauma resuscitation. Incorporating participants' feedback on course length and format and assessing TDTR's impact on healthcare processes longitudinally is recommended. Expanding TDTR across Tanzania and LMICs and bolstering local instructor capacity for sustainable and independent trauma education is imperative for achieving global surgery objectives.

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Author Contributions:

CO, TR, DD, JG, KW, VM, and RB contributed to the study conception. CO, DD, TR, AF, CV, EF, JO, and AP were involved in the study design. Data acquisition was conducted by CO, VM, RN, BM, AL, AU, and LR. CO and AF were involved in data analysis. CO wrote the manuscript. All authors actively engaged in manuscript editing, critically reviewing it, and granted their approval for publication. VM and RB, senior authors, and local principal investigators at the Tanzanian Injury Control Centre (ICC-T) based at MOI ensured the accuracy and validity of the data presented in this manuscript.

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CHAPTER FOUR: IMPROVING TRAUMA DATA INFRASTRUCTURE IN RESOURCE-LIMITED SETTINGS: THE AMBER DATABASE INITIATIVES

Preface

In the preface, the first two manuscripts shed light on global surgical initiatives and the challenges of trauma education, along with proposed solutions in LMICs. These manuscripts particularly highlight the shortages in critical surgical interventions and the limited availability of affordable trauma training programs, which hinder the delivery of essential emergency care. It's crucial to acknowledge the geographical disease burden, as emphasized by both the WHO and Global Disease Burden reports.

[Manuscript III] is the cornerstone of this project, providing a thorough exploration of the surgical disease burden from injury and trauma services within Tanzanian populations. In this manuscript, we introduce a proposed approach to tackle challenges associated with trauma data documentation systems by implementing digital data infrastructure platforms. Such digitized registries play a crucial role in offering precise geographical data on trauma burdens and trauma services, assisting healthcare facilities in benchmarking clinical guidelines, implementing quality improvements, and devising strategies for injury prevention.

Nonetheless, Tanzania faces unaddressed trauma burdens due to the absence of trauma data acquisition systems. To address these challenges, we introduce the Amber database, an innovative web-based application tailored for acquiring traumatic data in Tanzania. Our primary objective is to implement the Amber database at a Tanzanian hospital and assess its feasibility while prospectively collecting comprehensive patient data. This initiative aims to

comprehensively understand injury trends, clinical care practices, and patient outcomes at the emergency department. The findings from this study are crucial for gaining insights into Tanzania's trauma epidemiology, approaches to managing traumatic patients, and existing gaps in care. These insights inform the development of injury prevention initiatives, the establishment of clinical guidelines, the implementation of quality improvement programs, and the expansion of educational initiatives to address gaps in clinical care.

Manuscript III: Impacting Trauma Care in Tanzania: Lessons from the Web-Based Amber Database Implementation

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Abstract

Background: Trauma poses a significant global health challenge, with resource-limited nations experiencing higher fatalities due to inadequate trauma care infrastructure and data deficiencies. Tanzania, exemplifying such challenges, lacks comprehensive trauma data systems. To address such gaps, we introduced the *Amber database*, a real-time, web-based trauma, and operating theaters registry application, to enhance injury surveillance and operating room activity documentation approaches in Tanzania.

Methods: The Amber database was implemented at Muhimbili Orthopedic Institute (MOI), collecting data on traumatic and operated patients from July 13 to August 23, 2023. The analysis involved descriptive statistics to assess injury trends and surgical landscape which was presented in mean, standard deviation, median, and interquartile ratio. Additionally, semi-structured interviews with stakeholders were conducted to identify the platform's challenges and areas for improvement. Ethical approval was obtained from McGill University and MOI's Ethics Board.

Findings: Collected data comprised almost 2400 data, encompassing 1300 operated patients and 1097 traumatic patients. The analysis of traumatic patient data (1097) highlighted road traffic collisions (RTCs) as the primary cause, constituting 61%, leading to fractures in 57.33% of cases and head injuries in 29.32%. Most injuries occurred in Dar es Salaam, predominantly among adult males (76.75%). Ambulances transported 61% of patients, and the median time from injury to hospital arrival was one day [IQR, 24 hours-196 days]. While 59.16% received timely care within 30 minutes of hospital arrival, over 22.24% were forced to wait for over one hour. The report also showed that 2.73% of mortalities occurred among those admitted, primarily from severe head injury resulting from RTCs (73.33%) leading to drivers (40%), pedestrians (23.3%), and passengers (10%).

Regression analysis, considering mortality as the dependent variable and factors including injury location, injury to hospital arrival, and arrival to care time, reveals a statistically significant [95% CI: 7.37-18.01, p< 0.0001], suggesting that these factors are associated with a higher likelihood of mortalities on studied patients. Among the operated patients, 75.7% underwent emergency surgeries, primarily for hemorrhage control (81.2%). The perioperative mortality rate was 2.2%. Interviewed stakeholders praised the Amber database for its simplicity and ability to identify care gaps, showcasing strong support from local communities.

Conclusion: The feasibility of the Amber database was successfully demonstrated, becoming MOI's standard medical recording system and gaining endorsement for nationwide expansion. This innovation supports targeted injury prevention, education, quality improvement, and healthcare policy development.

Keywords: Trauma registry, Amber database, Operating theater database, Tanzania, Web-based platform

INTRODUCTION

Trauma is a leading global cause of death, resulting in life-long disabilities, psychological trauma, and economic repercussions. A 2021 study revealed that over 5 million people die from injuries annually, a mortality rate more significant than that of HIV/AIDS, Malaria, Tuberculosis, and COVID-19 *combined*.[1] The WHO reports that trauma accounts for 8% of global fatalities and 10% of life-long disabilities.[2,3] Unintentional incidents result in 3.2 million annual fatalities, while violence-related injuries cause 1.3 million deaths each year.

Furthermore, the 2022 Lancet report on road safety revealed that road traffic crashes (RTCs) cause 1.35 million annual fatalities worldwide, ranking as the eighth leading global cause of death, with 93% occurring in LMICs. RTCs also result in over 50 million individuals living with life-long disabilities, leading to reduced quality of life, lost productivity, and financial insecurity.[4] Trauma ranks among the top five leading causes of death for those aged 5-29, significantly impacting the economies of countries by affecting the lives of productive age groups.[2] This evidenced that trauma and injuries massively affect countries' economies by taking the lives of productive age groups.

Moreover, since 2000, RTC in Sub-Saharan Africa has seen a substantial increase, with the loss of healthy life years rising by nearly 50%.[2] This trend aligns with the WHO projection of a 40% increase in road traffic deaths, potentially making it the third leading global cause of death by 2030.[5] What makes these statistics even more alarming is the expected continuation of this trend. Studies have also highlighted disparities in the global trauma burden. Ninety percent of injuries affect populations residing in resource-limited settings, where healthcare systems are vulnerably designed.[6] Underdeveloped trauma care systems have exacerbated trauma burdens, leading to a 3-30% gross domestic product (GDP) deficit in LMICs.[7,8] These burdens can also have financial repercussions on patients and their families following a traumatic injury, potentially resulting in reduced income for individuals living with life-long disabilities.[9]

Trauma care systems provide comprehensive healthcare for injured patients in defined geographical areas. [10] A trauma registry is a central component of an organized trauma care system, collecting prospective data on patient demographics, injury patterns, clinical

interventions, and injury epidemiology.[11] It further helps design quality improvement programs, education initiatives, and injury prevention strategies where injuries are considered a *hotspot*. In high-resource nations, advanced trauma care systems and sophisticated trauma registries have contributed to a 20-50% reduction in trauma-associated mortality and improved patient outcomes.[12,13]

Published studies have demonstrated that patients with life-threatening but potentially treatable injuries are six times more likely to die in countries without organized trauma care systems compared to those in countries with well-resourced trauma care systems equipped with functional trauma registries.[14] This evidence underscores the necessity of implementing well-structured trauma registries, which are essential tools in reducing traumatic mortalities and enhancing patient care.[14,9] Nevertheless, undeveloped coordinated trauma care systems and inadequate injury data infrastructures such as trauma registries are formidable barriers to improving trauma services in LMICs, leading to increased preventable trauma fatalities.[15]

Trauma registries in Tanzania are frequently incomplete, collected retrospectively on paper, and susceptible to recall biases.[10] This project addresses gaps in trauma data infrastructures by introducing a novel electronic registry called *Amber database*. It is a web-based application designed for collecting data on traumatic patients, operating room activities, and critical care resource requirements. The database records real-time data, providing accurate injury epidemiology and surgical landscape for Tanzania. Amber database includes 15 anonymized operating theaters data and 25-point anonymized traumatic patient data, covering demographics, injury mechanisms, clinical assessments, trauma scoring, anatomical and physiological

descriptors, and clinical outcomes. The project's primary objective is to pilot the feasibility of implementing the Amber database in a Tanzanian hospital, with the overarching goal of national expansion to impact the country's trauma/surgical services structures.

METHODOLOGY

Study Settings

Tanzania, a low-income East African country with a population of approximately 60 million, has a demographic composition of 35% urban and 65% rural residents.[16,17] The healthcare system operates on a three-tiered structure comprising primary, secondary, and tertiary levels of care. The Muhimbili Orthopedic Institute (MOI) in Dar es Salaam plays a vital role, with 362 beds dedicated to specialized care in orthopedics, traumatology, and serving as Tanzania's sole neurosurgery center. Affiliated with Muhimbili University of Health and Allied Sciences,[18] MOI provides a range of services, including trauma care, neurosurgery, orthopedics, operating and intensive care units, radiology, and pharmacy—all operational around the clock. Despite historical reliance on manual documentation, MOI's trauma bay and operating theaters are well-equipped with essential infrastructures.

Collaboration and Planning Phase

Building partnerships is essential in establishing data infrastructures in LMICs.[11] MUHC-CGS closely collaborated with MOI authorities to establish the Injury Control Centre-Tanzania (ICC-T) at MOI in 2006. Before initiating data collection, we conducted a needs assessment in collaboration with MOI's trauma unit, addressing specific requirements and discussing web-based medical recording system standards. The selected local project coordinators serve as

liaisons for MOI and CGS, and both parties are committed to outlined obligations in the memorandum of understanding. The partnership aims to reduce preventable deaths, enhance training/education, and standardize trauma and operating theater data systems.

Study Instruments

We introduced the Amber database to MOI as a user-friendly, web-based application having three interrelated components: Global Surgery Collect (for authorized personnel for data collection), Global Surgery Studio (an administrative web interface for site administrators for data management), and Amber Server (a highly secure cloud-based data storage: Amber Collect (cglobalsurgery.ca). Amber is versatile, and accessible on cellphones, desktops, and tablets, requiring only a browser. It functions offline, seamlessly uploading data when a network connection is available, making it suitable for diverse environments. Unlike previous trauma registry apps, which were often considered too technical for non-physicians,[19] Amber is purposefully designed for use by allied healthcare professionals, nurses, and data ethnographers. This user-centric approach enhances accessibility and usability, making it more inclusive for a broader range of healthcare practitioners.

Completing the 25-point injury data in Amber takes less than 90 seconds without distracting from patient care. Its speed and ease of use stem from the integrated design, enabling the collection of validated data that directly informs health policy, advocacy, and education efforts. Additionally, the Amber database features an integrated data analysis tool, automatically incorporating collected data for valuable insights upon record completion. The trauma database covers patient demographics, injury mechanisms, characteristics, and clinical outcomes, aligning

with WHO injury surveillance guidelines tailored to local needs. Patient demographics include age, gender, education, occupation, origin, injury location, time, date, and transfer history. Injury mechanisms encompass causes, intent, settings, and substance use, with additional details for motor vehicle collisions.

Injury characteristics involve physiological descriptions, anatomically affected areas, and outcome sections capturing patients' status at the emergency department (ED), admission details, and two-week follow-up once admitted and injury severity. Amber's Trauma Scoring system relies on the Kampala Trauma Score (KTS), a validated tool for injury severity scoring introduced in Uganda in 1998, to assess patient survival.[20] The modified KTS II scaled from 0 to 10, incorporating patient age, systolic blood pressure, respiratory rate, serious injuries, and neurologic status (Table 1).[21] A score below Alert or KTS below 7 indicates the need for urgent medical intervention.[22] This scoring system has demonstrated effectiveness in predicting early trauma-related deaths and improving outcomes in resource-limited settings. Finalizing records involves updating the two-week traumatic patient savings and uploading them to the Amber server (Appendices; supplementary). The neurologic status is graded on the AVPU scale presented below.

- 3 – Alert: A (GCS 13-15)
- 2 - Verbal response: V (GCS 9-12)
- 1 - Painful response: P (GCS 4-8)
- 0 – Unresponsive: U (GCS $\leq$ 3)

Table 1 presents injury severity scoring using the Kampala Trauma Scoring scale

Component	Description	Score
A	Age, y	
	5–55	1
	<5 or >55	0
B	Systolic blood pressure on admission, mm Hg	
	>120	2
	50–120	1
	0–49	0
C	Respiratory rate on admission, /min	
	10–29	2
	30+	1
	≤9	0
D	Neurological status	
	Alert	3
	Responds to verbal stimuli	2
	Responds to painful stimuli	1
	Unresponsive	0
E	Serious injuries	
	None	2
	One	1
	More than one	0

KTS is calculated by summing a+b+c+d+e.
KTS ≤6 is severe, KTS 7-8 is moderate, and KTS 9-10 is mild.

Inclusion/Exclusion Criteria

All patients who were presented to MOI's ED were included. No exclusion criteria were applied.

Study Design

The research utilized a mixed-method approach, combining a prospective observational study design following the implementation of the Amber database with a qualitative study involving semi-structured interviews with key MOI stakeholders (Appendices; questionnaire). This approach aimed to identify challenges, areas for improvement, and successes related to the

components and functionality of the Amber platform and generate innovative solutions in response.

Implementation phase

The project coordinator conducted meetings with MOI stakeholders, including Co-Directors of the ICC-T, the head of the emergency department, selected data collectors (two nurses for trauma data), the chief executive director, and other officials. Due to the longstanding partnership between the Tanzanian hospital and CGS, research permission was granted. CGS sponsored two Samsung Galaxy A tablets with the Amber software loaded for data collection at MOI. These tablets were provided to MOI officials. Before launching the Amber database in Tanzania, two crucial phases were completed: stakeholder training and behavior shaping.

Stakeholders Training: A brief training program was conducted for healthcare professionals involved in trauma data registry usage, including senior trauma care providers, allied healthcare practitioners, data collectors, and administrators. I provided introductory training and one-on-one tutoring. To ensure sustainability, a subcommittee was established for ongoing training.

Human Behavior Shaping: In the previous Tanzanian system, paper-based forms were utilized for the trauma registry, and data were manually transcribed into the IOS-exclusive iTRAUMA™ electronic registry. Amber streamlined this process by enabling real-time data collection within the application. Trauma staff underwent training on Amber's taxonomy and workflow. During the two-week follow-up, additional information, including updates on the two weeks' data for admitted traumatic patients, and outcomes were sourced from the MOI's eMEDICO– the

centralized patient medical information storage systems. The project coordinator meticulously reviewed and validated each data point for the research project. The same approach has also been adopted by the local principal investigators to ensure the registry's completeness and contribute to quality improvements within hospitals.

Data Collections

Trained data collectors diligently entered patients' information into the Amber platform 24/7 from July 13 to August 23, 2023. The mentioned dates are solely for this project reporting, as the Amber database has been integrated into the official MOI medical recording system since its inception and is currently functioning. Following Porgo et al.'s recommendations, [23] on-site data collectors were deployed to register trauma cases around the clock to ensure accuracy. Data collection took place shortly after traumatic patients' resuscitation to ensure completeness and timeliness. The collected data was de-identified and securely stored in the Amber studio with restricted access.

Outcome and Data Analysis

The primary trauma outcome measure assessed disposition status in the ED, including mortality, ward/ICU admissions, taken to operating theaters, transfer to other hospitals, and mortality and discharge within 24 hours. This analysis aimed to understand patient flow in Tanzania's trauma care system and surgical landscape aimed to inform efforts related to injury prevention policy, educational initiatives, and benchmarking clinical guidelines. Data were extracted into Microsoft Excel (Microsoft Corp., Redmond, WA, USA) from the Amber studio, which was auto-generated for analysis. Descriptive statistics were presented using mean, standard deviation (SD),

median, and interquartile range (IQR). Regression analysis was applied to assess the primary outcome. Qualitative data from semi-structured interviews were analyzed according to the protocol.

Data Completeness and Accuracy

The effectiveness of the Amber database was evaluated after six weeks of implementation. We assessed data completeness, leveraging Amber's built-in system's automatic detection and prevention of incomplete entries savings. This feature successfully minimized instances of missing or inadequate data. For data accuracy, we computed collected data into Microsoft Excel, considering compliance rates for each dataset to calculate the overall accuracy rate.

Ethical Consideration

Registry implementation typically doesn't require patient consent as it's a routine hospital data collection. Ethical approval from Tanzanian's MOI and McGill University was obtained, and CGS granted permission to use the Amber database in Tanzanian hospitals. Collaborative forums ensured a clear understanding of scholarly work dissemination, with a binding agreement ensuring local stakeholders acknowledged their crucial contributions to the Amber database's program.

RESULTS

Demographics

This section analyzes trends from the Amber trauma database, covering 1097 cases at MOI during the study period. Of the trauma patients, 842 out of 1097 (77%) were male, with a mean

age of 32 [SD, 20.15]. Figure 4 highlights a more pronounced age disparity, especially in the 21-30 age range. In serious injury cases requiring hospitalization (AVPU<4 score), 30% were females, and 60% were males (p< 0.001).

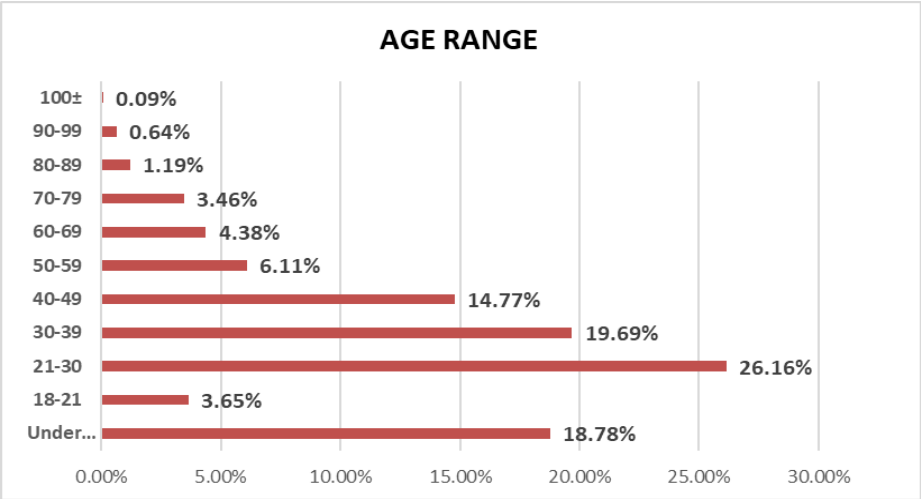

Fig.4: The graph shows the Age groups on the vertical axis

Trauma Location

Most injury cases and traumatic patients were concentrated in the Dar es Salaam region, comprising 892 out of 1,097 cases (81.31%), followed by the Pwani and Morogoro regions, accounting for 92 (8.39%) and 31 (2.83%) patients, respectively. Among those originating from the Dar es Salaam region, the most common injury district was Kinondoni Municipal Council, representing 446 out of 1,097 cases (40.66%), followed by Ilala Municipal Council, with 225 out of 1,097 cases (20.51%), as illustrated in Figure 5.

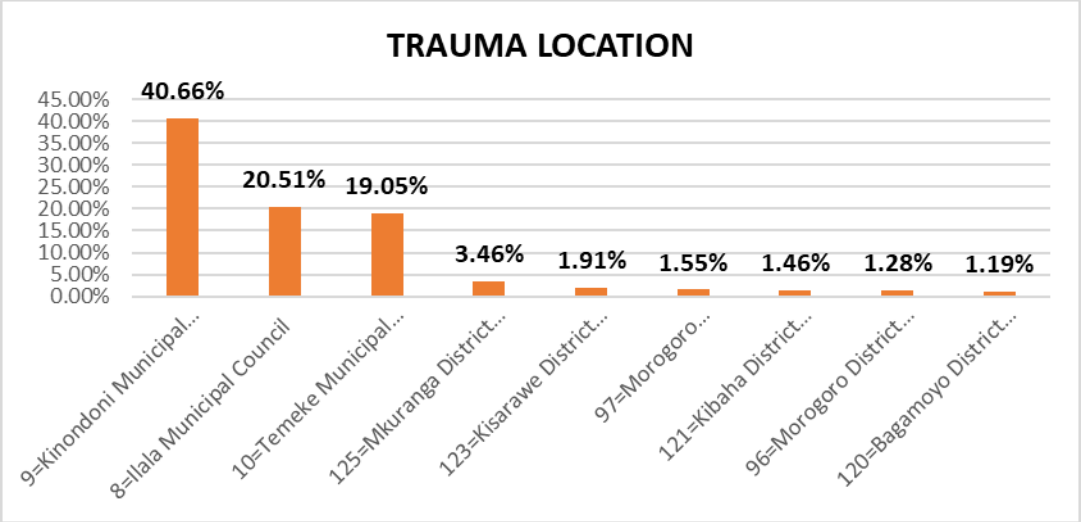

Fig. 5: The graph shows the districts where trauma patients originated on the horizontal axis

Patients' educational backgrounds and occupations

Concerning education, most patients, 538 out of 1,097 (48.77%), had completed primary school education, as depicted in Figure 6.

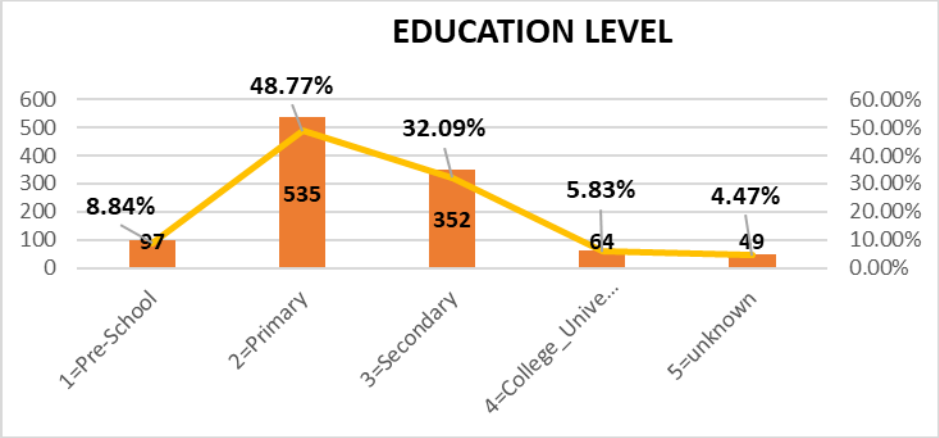

Fig.6: The graph shows the injured patients' level of education

Among all trauma cases, 26.25% (288 out of 1,097) were self-employed, followed by students/children at 22.33% (245 out of 1,097), and drivers at 165 (15.01%, Figure 7).

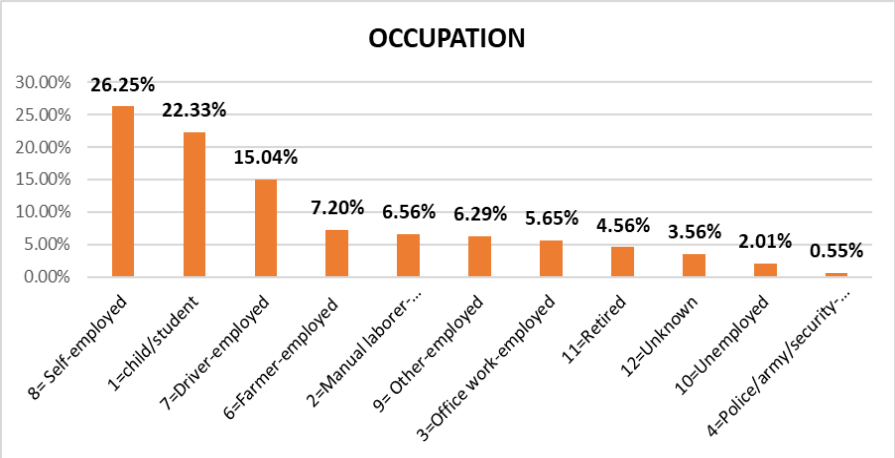

Fig.7: The graph presents injured patients' source of income

Patient transfer and mode of arrival

Regarding patient transfers to the MOI, out of the total cases, 72.84% (789 out of 1,097) were transferred from other hospitals. On average, most patients (34.64%, 273 out of 1,097) were transferred from the Kairuki Medical Center (Figure 8).

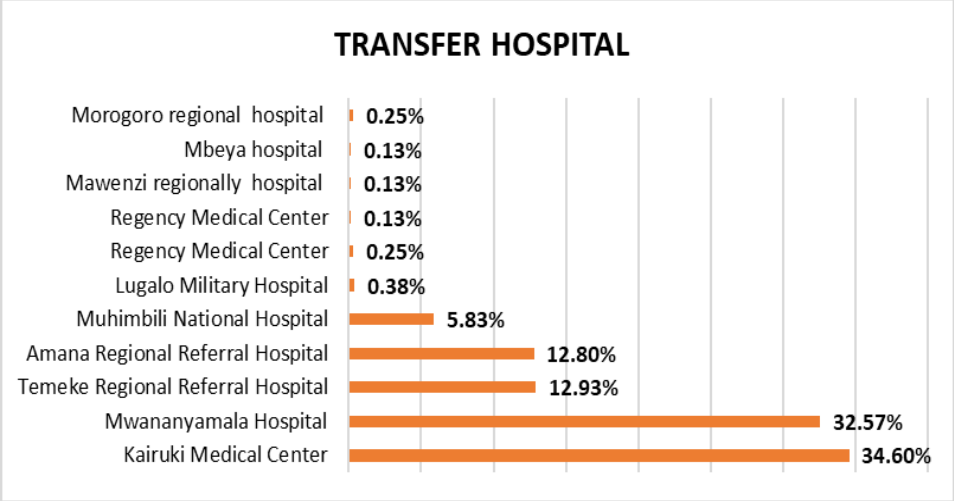

Fig.8: The graph shows major injured patients transferring hospital

Among all traumatic patients, the most common mode of arrival was by ambulance, accounting for 61.17% (671 out of 1,097). However, 28.53% (313 out of 1,097) of injured patients arrived at MOI via private vehicles, while 4.38% (48 out of 1,097) used bicycles, motorcycles, or Bajaji to reach the hospital (Figure 9).

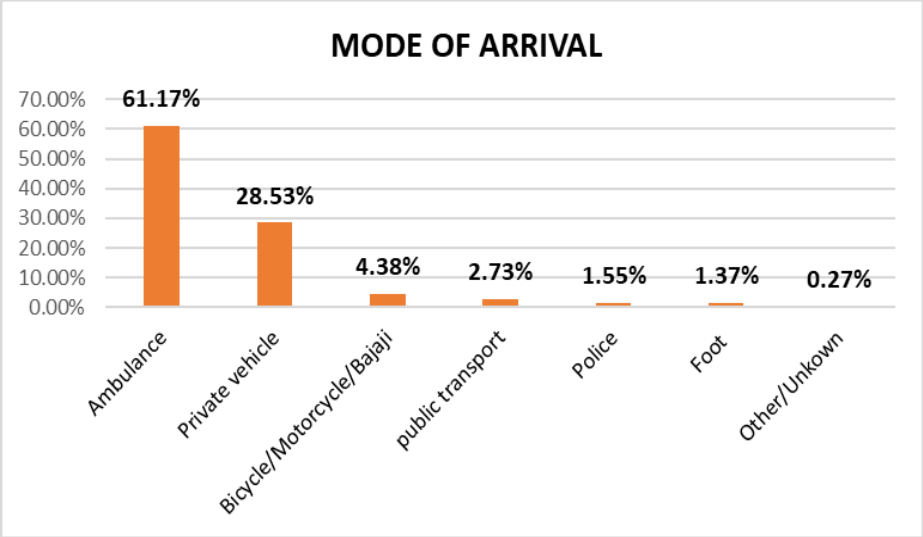

Fig.9: Mode of hospital arrival for trauma patients

Injury characteristics

Various aspects of the injuries were analyzed, including the mechanism of injury, injury types, disposition, injury severity, and timeliness of care across trauma cases. The primary injury mechanisms were motor vehicle collisions (MVCs), accounting for 60.98% (669 out of 1,097) of cases, followed by falls at 31.45% (345 out of 1,097), and blunt trauma at 4.83% (53 out of 1,097). Gunshots were the least common injury cause, accounting for 0.09% (1 out of 1,097), as shown in Figure 10.

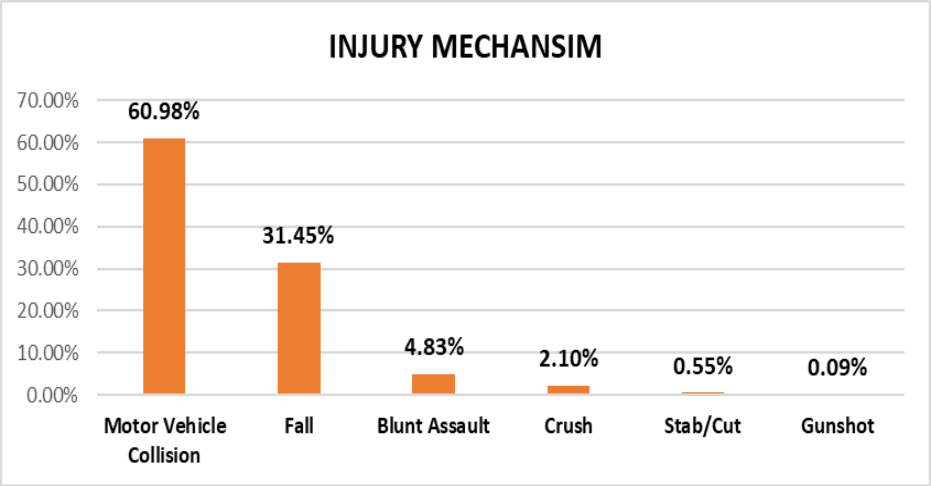

Fig.10: The graph presents the injury mechanisms seen at MOI

In terms of injury types, over 1,378 distinct injuries were diagnosed at MOI's emergency departments. The most frequent finding across all trauma cases was lower extremity fractures, accounting for 34.25% (472 out of 1,378), followed by head injuries at 29.32% (404 out of 1,378). Burn and neck injury patients were not seen at MOI, as such cases are primarily managed at the Muhimbili National Hospital, which is within walking distance from MOI. All types of fractures made up approximately 59.43% (819 out of 1,378), and among the fractures, 75.85% (622 out of 819) were open fractures requiring urgent surgical interventions. Spine fractures accounted for 2.90% (40 out of 1,378), with a single patient (2.70%) found to have paralysis (Table 2). Regarding the anatomic location of injuries, it's noteworthy that in most trauma cases, a substantial 60.96% (810 out of 1,378), were observed in the extremities. The head and neck region followed closely behind, with 32.00% (441 out of 1,378) of injuries localized in this area.

Table 2 Presents injury patterns seen at MOI

Value	Frequency	Percentage	All Fracture	Open Fracture	Paralysis
Facial fracture	**10**	**0.73%**		**0.10%**	
Fracture spine	**40**	**2.90%**		**0.00%**	**2.70%**
Upper extremity fracture	**231**	**16.76%**		**19.91%**	
Pelvic fracture	**29**	**2.10%**		**3.45%**	
Lower extremity fracture	**472**	**34.25%**		**33.47%**	
Skull fracture	**37**	**2.69%**		**18.92%**	
Head injury	**404**	**29.32%**			
Neck injury	**0**	**0.00%**			
Thoracic injury	**10**	**0.73%**			
Abdominal injury	**8**	**0.58%**			
Cut/Open wound	**19**	**1.38%**			
Sprain/strain	**14**	**1.02%**			
Upper extremity dislocation	**15**	**1.09%**			
Lower extremity dislocation	**17**	**1.23%**			
Burn	**0**	**0.00%**			
Soft tissue (extremities)	**72**	**5.22%**			
Total	**1378**	**100.00%**	**59.43%**	**75.85%**	**2.7%**

The table presents injury patterns observed at MOI are categorized based on the type of trauma, such as blunt extremity trauma, head injury, and other types of injuries. The table provides a breakdown of the frequency of each injury pattern observed at MOI during the study period.

Road traffic collision patterns

In this study, the term Road Traffic Collisions (RTC) is used to encompass a wide range of incidents related to transportation activities, including various modes of transport such as motor vehicles, bicycles, pedestrians, and other road-related events. It's essential to clarify that RTCs are a subset of Transport Accidents, specifically focusing on accidents and incidents involving motor vehicles and traffic-related events on roadways. When examining injury settings, we found that transport accidents were the most common, accounting for 680 out of 1097 (61.99%)

cases, followed by home-related injuries at 206 out of 1097 (18.78%). The injury settings were unknown in 22 out of 1097 (2.01%) cases, as indicated in Figure 11. Furthermore, it's worth noting that within the category of RTCs, MVCs account for 669 out of 1097 (60.98%), representing injuries related exclusively to motor vehicles. Therefore, RTCs encompass a broader scope, including all road-related trauma cases involving both motorized and non-motorized road users, constituting approximately 680 out of 1097 (61.99%) of the total cases in our study.

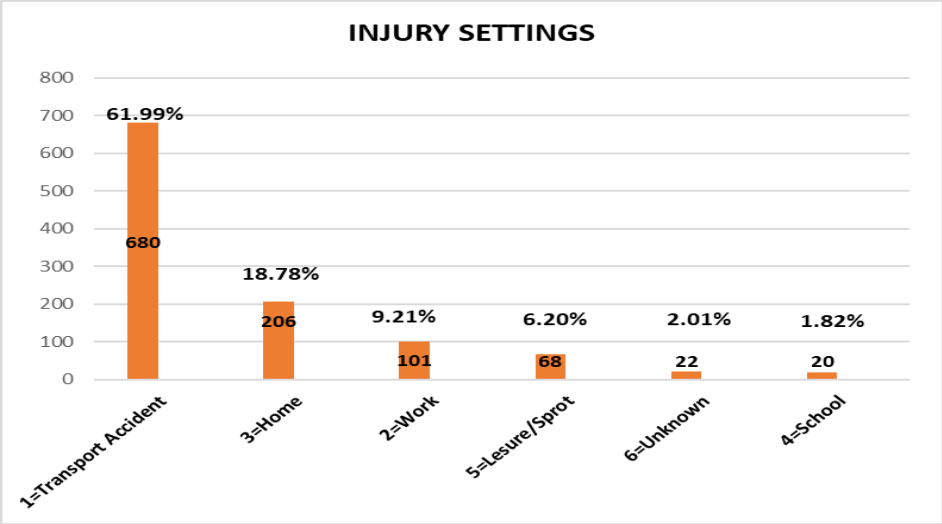

Fig.11*:* The graphs present trauma settings across the cases

The analysis now delves into providing insights into the injury patterns related to road users, various vehicle types and sectors, helmet/seatbelt usage, and specific crash details. Among all the categories of road-related vehicles, motorbikes were the most prevalent, accounting for 461 out of 672 cases (68.60%), followed by cars at 142 out of 672 cases (21.13%), and three-wheel tricycles/Bajaji at 33 out of 672 cases (4.90%). Trains, on the other hand, represented the least common category, making up only 1 out of 672 cases (0.15%), as depicted in Figure 12.

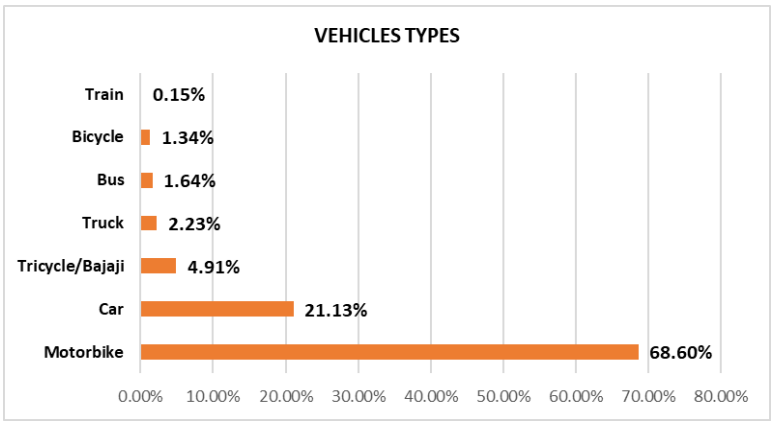

Fig. 12: This graph illustrates the types of vehicles involved in road-related collisions

Among these collisions, commercial vehicles were the most prevalent vehicle sectors, constituting 532 out of 672 cases (79.17%), followed by private vehicles comprising 126 out of 672 cases (18.75%), as depicted in Figure 13.

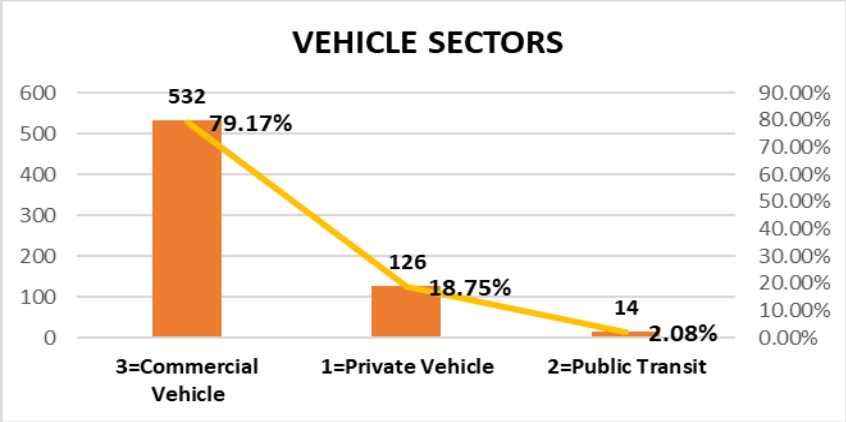

Fig.13: The graph presents vehicle sectors causing road traffic accident

Road user roles and safety measures

In this analysis, we used transport accidents as the denominator for calculating the distribution of various road user roles. This approach allows us to understand the involvement of different road users in accidents, regardless of the number of vehicles involved. Among all types of road users

involved in RTCs, over 249 out of 680 (36.62%), traumatic patients were drivers/riders of all types, as shown in Figure 14, where they were primarily struck by commercial vehicles, accounting for 532 out of 672 (79.17%). Nearly, 216 out of 680 (31.72%) were passengers, followed by pedestrians, accounting for 207 out of 672 (30.44%).

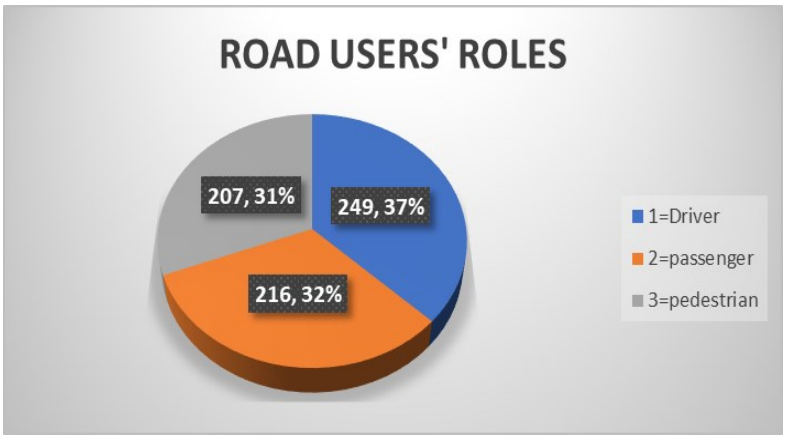

Fig.14: The pie chart shows injured patients' role on the road at the time of accidents

Among all road-related vehicles, including motorbikes and bicycles, accounted for a total of 470 out of 672 (69.94%) cases. In terms of safety measures, approximately 181 out of 470 (38.51%) motorbike riders and passengers, as well as cyclists, were not wearing helmets at the time of the accidents. The helmet usage status of 98 out of 470 (20.95%) remained unknown. Furthermore, when it comes to car-related accidents, including cars, buses, and trucks, which accounted for 168 out of 672 of all road-related accidents, only 23 out of 168 (13.69%) were wearing seatbelts during the incidents, and over 113 (67.26%) patients seatbelt usage was unknown (Figure 15).

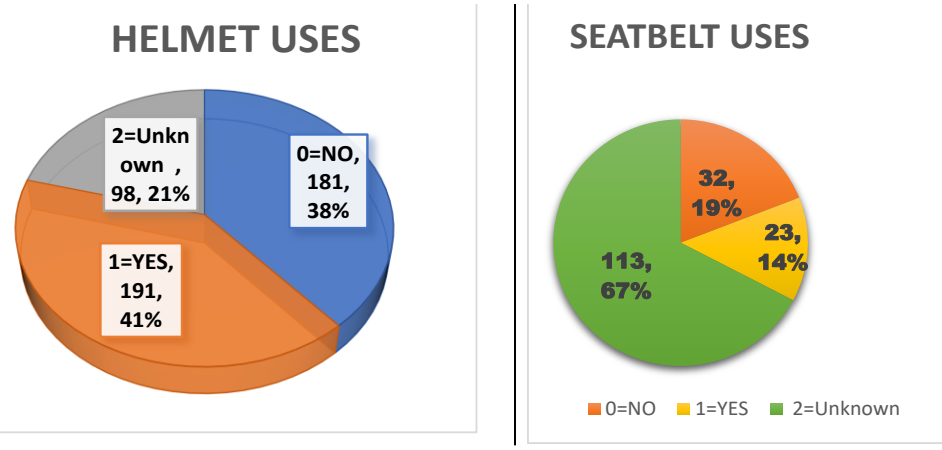

Fig.15: The pie chart illustrates safety measures used by road users

Injury intents

Regarding injury intents, most injuries were unintentional, constituting 1040 out of 1097 (94.84%), while self-inflicted injuries were the least common, totaling 2 out of 1097 (0.18%), as indicated in Figure 16.

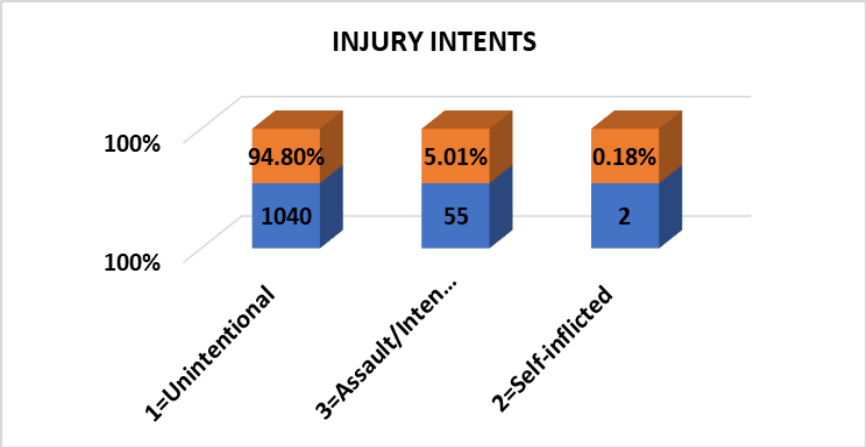

Fig.16: The graph shows the injury intents across all trauma cases

Peak time for road traffic accidents and substance uses

Two noticeable surges in RTCs remain consistent for all road users, aligning with the morning and evening rush hours. The morning rush hours occur between 5:00 a.m. and 9:00 a.m., and the evening rush time occurs between 4:00 p.m. and 8:00 p.m., as shown in Table 3. Notably, non-motorized road users, specifically pedestrians and cyclists, experience a higher proportion of RTCs during these peak hours and very few during nighttime hours. In contrast, cars, trucks, and buses have a higher number of accidents occurring at midnight between 12:00 a.m. and 2:00 a.m., likely attributed to factors such as reduced visibility, driver fatigue, or speeding, coupled with a decreased presence of pedestrians on the roads during those hours and reduced enforcement of safety measures by law enforcement.

Table 3 Shows Road users' accident peak time

Peak time	Start Time	End Time
Midnight	12:00 AM	2:00AM
Morning	5:00 AM	9:00 AM
Evening	4:00 PM	8:00 PM

Alcohol use was confirmed in 11 out of 1097 (10.12%) traumatic patients based on self-report and suspected by healthcare providers. For approximately 78 out of 1097 (7.11%) patients, the status of alcohol use was unknown, as shown in Figure 17.

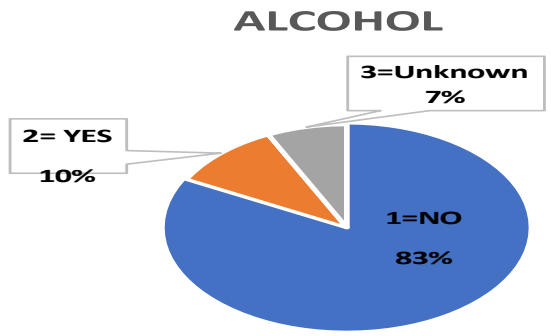

Fig.17: The pie chart shows alcohol consumption across all traumatic patients

Injury to hospital arrival time

The median time it takes for patients to reach the hospital after experiencing trauma was approximately 1 day [IQR, 0 days (within 24 hours) to 191 days], (Figure 18). However, the majority, 476 out of 1097 (43.39%), arrived at hospitals one day after the injury scene, followed by 333 (30.36%) who arrived within the first 24 hours. It's worth noting that this overall figure includes minor cases where immediate care might not be urgently required.

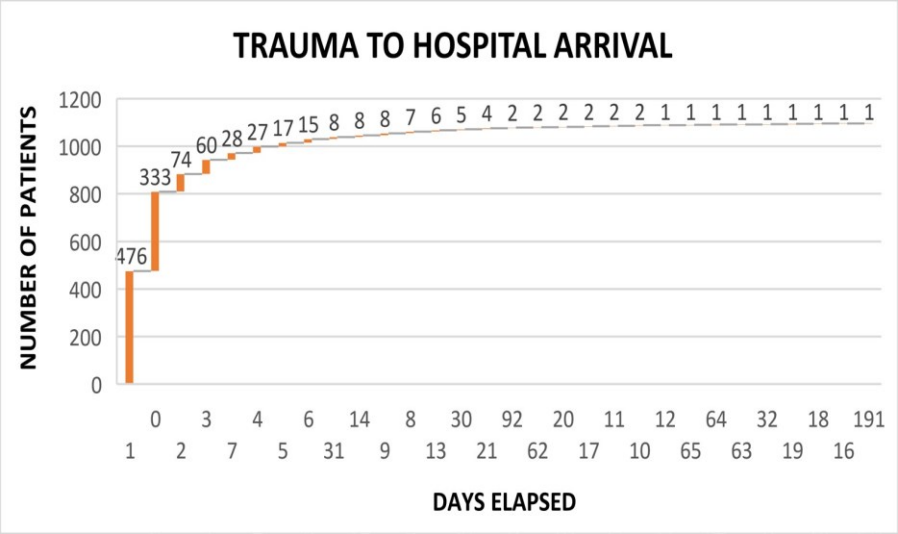

Fig.18: The graph shows the time elapsed from the injury scene to hospital arrival in days

Hospital arrival to intervention time

To better understand the timeliness of traumatic patient care upon their arrival at the MOI. Among patients who arrived at the hospital and tended to receive the first medical intervention (intervention defined in these cases as the first time the patients were clerked by healthcare providers), they received care with a mean time of 29.89 minutes [SD, 20.22], with a range from 1 minute to 80 minutes. Overall, most traumatic patients, 649 out of 1097 (59.16%), received the necessary medical care within 30 minutes of hospital arrival. This was followed by 191(17.41%) receiving intervention within the 30–45-minute range. It's worth noting that there is considerable variability in these timeframes (Figure 19).

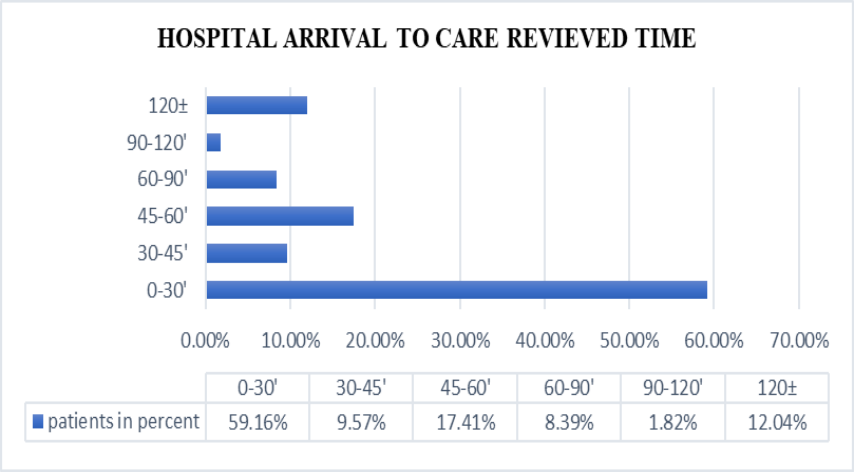

Fig. 19: Illustrates the intervention time interval in minutes (y-axis) for injured patients upon arrival at MOI

Injury severity

Injury severity is evaluated through several key factors: age range, arterial pressure, respiratory rate, neurological status, and serious injuries. The average arterial systolic blood pressure (SBP) for all injured patients was 122 mmHg [SD, 17.49], while the mean arterial diastolic blood pressure was 75 mmHg [SD of 11.16]. On average, 667 out of 1097 (60.80%) patients had SBP ≥ 120 mmHg (Figure 20).

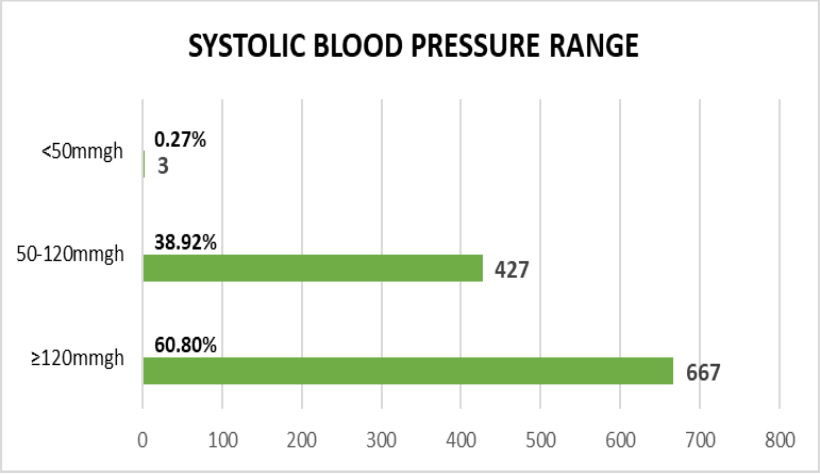

Fig.20: The graph shows systolic blood pressure ranges for traumatic patients

Furthermore, 1043 out of 1097 (95.08%) patients had a respiratory rate between 10-29 breaths per minute (bpm), as shown in Figure 21.

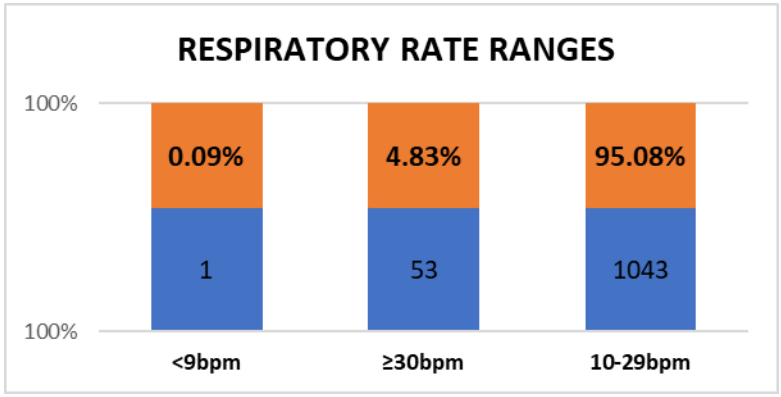

Fig.21: The graph displays patients' respiratory rat range

Neurological status, assessed through the AVPU score, revealed that 917 out of 1097 (83.59%) patients were alert upon hospital arrival, as shown in Figure 22.

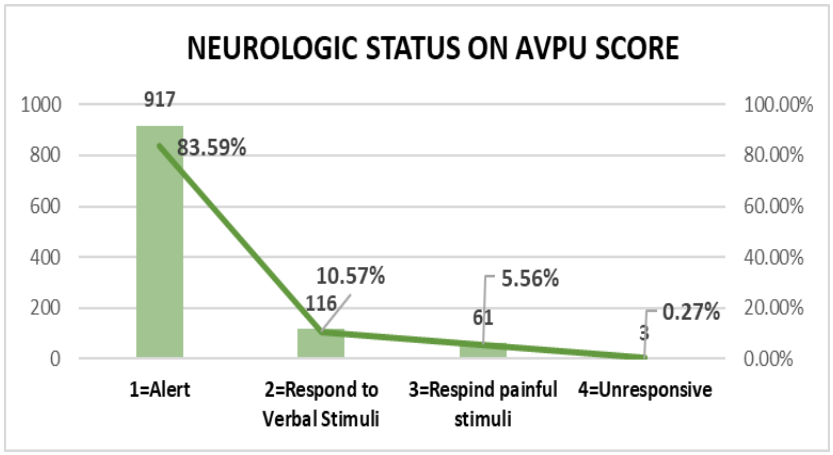

Fig.22: The graph shows traumatic patients' neurologic status on the AVPU score

In this analysis, we define a serious injury as one that involves body parts. Accordingly, 944 out of 1097 (86.05%) patients sustained one serious injury, while 30 (3%) did not have one (Figure 23). This information provides valuable insights into the prevalence and characteristics of serious injuries within the patient population.

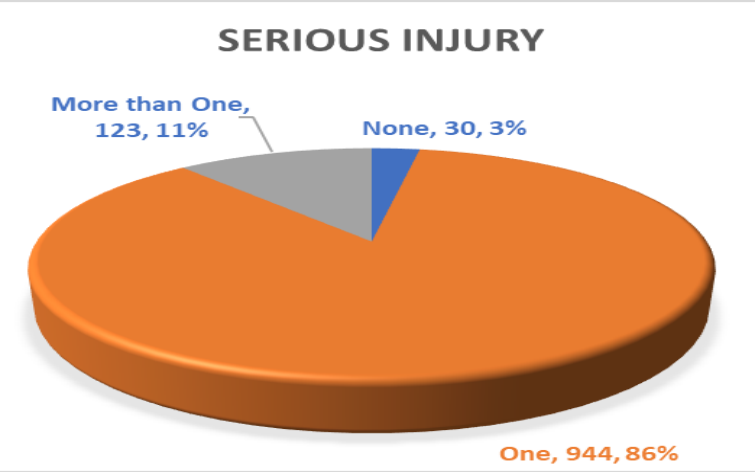

Fig.23: The graph displays the number of serious injuries across all cases

Based on crucial injury severity parameters, vital for estimating patient survival likelihood, we applied the Kampala Trauma Score (KTS 2). Among patients with complete records, the mean KTS was 8.46 (SD, 0.89). Most patients had a KTS score of 9, comprising 652 out of 1097 (59.43%). Assessing severity ranges, approximately 38.38% had moderate to severe injuries (KTS below 9), necessitating urgent medical attention. However, the majority still had a KTS of 9-10, making up 61.62% of patients, indicating mild injuries.

Table 4: The table displays the severity of traumatic patients in KTS

KTS	frequency	percentage	KTS Range	Severity	Total
9	**652**	**59.43%**	**≤6**	**Sever**	**4.10%**
8	**287**	**26.16%**	**7- 8**	**Moderate**	**34.27%**
7	**89**	**8.11%**	**9-10**	**Mild**	**61.62%**
6	**36**	**3.28%**			
10	**24**	**2.19%**			
5	**7**	**0.64%**			
1	**1**	**0.09%**			
4	**1**	**0.09%**			

Disposition and two-week follow-up

Disposition data in the Amber trauma registry provides insights into the outcomes of trauma cases in the casualty department on the day they visit the hospital (the 24-hour outcomes) and the 14-day outcome (two weeks follow-up) following hospital admissions. Among all trauma cases evaluated within the same day (within 24 hours), the majority, comprising 380 out of 1097 (34.64%) individuals, were admitted to wards as assigned, and 353 out of 1097 (32.18%) were immediately taken to the operating theaters for urgent surgical interventions. However, approximately 327 out of 1097 (29.81%) injured patients received treatments and were discharged on the same day of hospital arrival. Nearly 2 out of 1097 (0.18%) patients were transferred to another health facility for better management. Unfortunately, one patient was declared dead on arrival with a possible severe head injury after a sustained road transport accident as a passenger, as displayed in Figure 24.

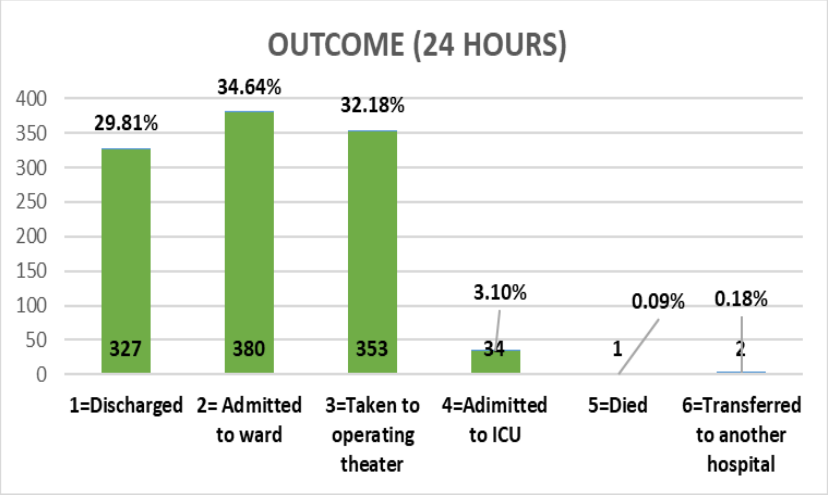

Fig.24: The graph shows patients outcomes within 24 hours of hospital arrival

At the 2-week follow-up, a total of 795 out of 1097 (72.47%) patients were found in the Amber database. Among these patients, the 2-week outcomes for those who were initially admitted revealed that 169 out of 795 (15.41%) of them had continued to stay in the hospital, while the majority, 595 out

of 795 (54.24%), were discharged. Unfortunately, 30 out of 795 (3.73%) of the admitted patients died, as presented in Figure 25.

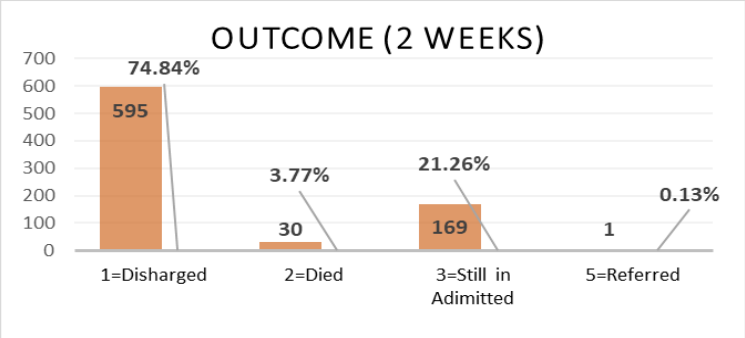

Fig.25: The graph shows a 2-week follow-up for patients admitted to the MO's wards

Mortality patterns

Table 5 displays the mortality rates among patients admitted for the 2-week follow-up. Notably, 2.73% of these patients died, and most of them were male (87%). It's interesting to note that approximately 7% of the deceased were children under the age of 5, with the majority falling within the 5-55 years age range. Surprisingly, over 46% of the patients who passed away arrived at the hospital more than one day after the injury occurred.

Table 5 Shows mortality details across patients seen at MOI

Sex		Age		KTS		AVPU		Injury To Hospital (Dys)	
M	87%	<5	7%	≤6	50%	Alert	3%	1	47%
F	13%	>55	10 %	7-8	37%	Verbal stimuli	63%	0	23%
		5-55	50 %	9-10	13%	Painful stimuli	7%	3	13%
						Unresponsive	27%	2	10%
								7	3%
								4	3%

Kinondoni Municipal Council, an urban district in the Dar es Salaam region, had the highest number of deaths, accounting for about 30% of the total (Figure 26). Additionally, more than 50% of the patients who had a KTS ≤6 fell within the severe range and did not survive. Approximately 27% of these patients were unresponsive based on neurological assessments.

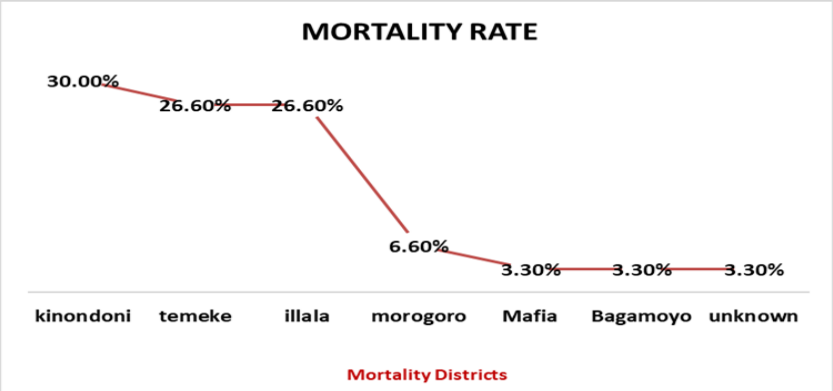

Fig.26: This graph displays major injury mortality districts in Tanzania

Among the deceased patients, the majority (80%) died due to head injuries, while lower extremity fractures accounted for 16.67% of deaths. Additionally, one patient died due to spine injuries resulting in paralysis. Notably, the waiting time for care varied among deceased patients, with the fastest care received immediately (0 minutes) and the longest wait being 1 hour and 41 minutes, as demonstrated in Figure 27.

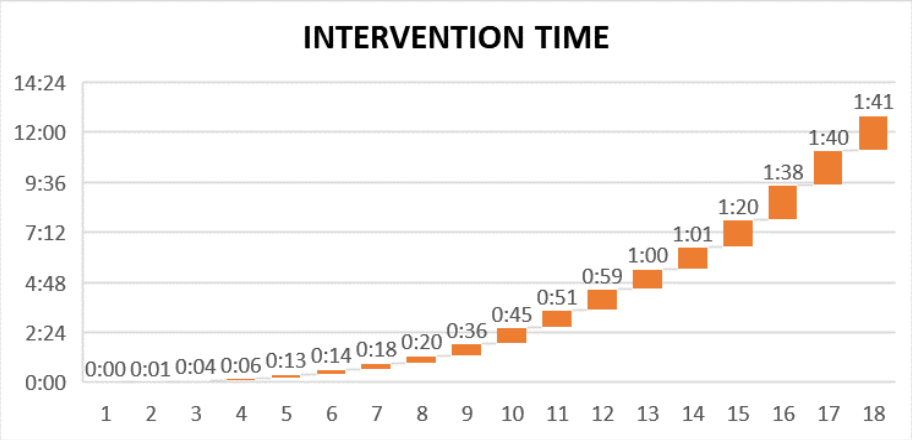

Fig.27 illustrates an intervention time (hours) for the deceased patients at MOI

Most deaths, totaling 22 out of 30 (73.33%), resulted from RTCs. Among these road users, 40% were drivers, 23.3% were pedestrians, and 10% were passengers. Fall-related fatalities accounted for 7 out of 30 (23.33%), while one patient died due to a blunt assault. Additionally, 6 out of 30 fatalities (20%) occurred due to injuries sustained at home from falls, and 2 out of 30 cases (6.67%) were linked to work-related injuries. The specific circumstances of injury for two patients remained unknown. This data provides insights into the diverse contexts of fatal injuries, offering valuable information for injury prevention strategies. Statistical analysis, considering mortality as the dependent variable and factors including injury location, injury to hospital arrival, and arrival to care time, reveals a statistically significant [95% CI: 7.37-18.01, $p< 0.0001$]. This suggests that these factors are associated with a higher likelihood of mortality in studied patients.

Data Completeness

Data completeness was assessed by calculating the ratio of valid values to the total number of data fields within the Amber database. The Amber database system offers a unique advantage in this regard, as it minimizes the occurrence of missing or incomplete data by automatically rejecting incomplete entries. This feature contributes to achieving higher data completeness rates in this project.

Semi-structured interview analysis

The implementation of the Amber digital health record system at MOI garnered enthusiastic support from local champions, as reflected in the following selected responses:

MOI administrators expressed appreciation: Regarding the previous data collection tool, iTRAUMA^{TM}, it had a meaningful impact on our institution, but it had drawbacks, such as limited data access. However, Amber is amazing; it's easier to collect data, takes less time, and provides complete data access without restrictions. The transformative role of the database in bolstering patient

care, refining data quality and accessibility, and fostering educational initiatives for enhanced trauma services and community well-being is paramount. The expansion of this data infrastructure to the ministry level is eagerly awaited, where it will emerge as an indispensable national medical recording system.

Amber Trauma data collectors expressed: During previous data collections, the risk of missing data during holidays and off-hours was significant; however, Amber enables us to track such patient data from our central medical data storage, eMEDICO, and incorporate it into the Amber data system. Under the guidance provided by the project coordinator on accessing and updating the 2-week outcomes data, patient files were completed and stored on the Amber server for future reference. Amber's user-friendly interface and comprehensive access render it an invaluable tool for our project.

DISCUSSION

The MOI in Tanzania serves as a crucial trauma referral center for the Dar es Salaam region and neighboring countries like Uganda and Kenya, handling a significant volume of trauma cases. The success of implementing the Amber trauma database at MOI underscores its potential to improve trauma data collection and guide resource allocation and preventive strategies. This project represents an innovative endeavor to unveil insights into the burden of injuries by scrutinizing information obtained through prospective data collection within regional trauma registries. Moreover, the Amber trauma registry encompasses the specific variables outlined in the WHO dataset for injury analysis, enhancing its significance.[24]

This project unveiled a notable prevalence of trauma cases at the hospital, predominantly impacting young males (mean age: 32 years). Most affected individuals belong to the economically active age

group of 18 to 45 years, with a heightened mortality risk observed within this demographic (ages 5-55), aligning with previous research.[25, 18] This trend carries adverse consequences, affecting the productivity of individuals, families, communities, and the nation. Hence, the establishment of a long-term trauma registry can play a pivotal role in enhancing care standards and mitigating injury rates in the region.

Males' increased susceptibility to injuries is linked to their propensity for risk-taking behaviors, often observed in activities like boarding moving city buses in urban areas like Dar-es-Salaam. While trauma itself doesn't discriminate based on gender, cultural norms in Tanzanian society contribute to this gender difference, consistent with Pakistan's findings.[26] Males, predominantly in physically demanding jobs, face higher occupational hazards, increasing their vulnerability to traumatic incidents and fatalities (87%), particularly in work-related injuries, which ranked third among causes of fatalities. Disparities in healthcare-seeking behavior, often influenced by limited education, highlight the need for public awareness campaigns to mitigate the injury burden.

Approximately 73% of injured individuals were transferred from various hospitals, with Kairuki Medical Center being a primary contributor. These hospitals serve as regional referral centers, efficiently referring trauma cases to larger facilities like MOI. However, 40% of transferred patients had mild injuries and were managed at MOI, being discharged on the same day, highlighting challenges in interfacility referral systems. The development of a sustainable trauma registry demonstrated the crucial role in analyzing referral trends and enhancing Tanzania's referral and pre-hospital trauma system approaches.

The Amber database highlighted various means of transportation for patients arriving at the ED,

including ambulances, private vehicles, and public transport, evenly distributed. while 61% of patients arrived via ambulance, over 39% used other means, including arriving on foot, aligning with South African studies.[28] Achieving an ideal pre-hospital system with all severe trauma cases transported by ambulance is challenging in LMICs with limited resources. To address this, training laypeople as first responders, as recommended by the WHO, is a crucial initial step. Increasing ambulances staffed with trained paramedics has proved crucial for safe patient transport in high-resourced settings. LMICs like Ghana and Madagascar have successfully trained taxi drivers as first responders, while Uganda trained motorcycle taxi drivers, resulting in improved patient care. [29-31] Expanding layperson first responder training involving local individuals is vital for optimal resource utilization, drawn from experiences in other LMICs. Implementing and monitoring these measures through a long-term trauma registry can establish a more efficient pre-hospital care system.

The 2022 Lancet report on road traffic injuries highlighted around 1.4 million fatalities and 50 million injury disabilities annually.[4] Road traffic injuries are the leading cause of death globally for individuals aged 5 to 29 years.[4] Sustainable Development Goal (SDG) target 3.6 aims to reduce road traffic injuries by 50% by 2030.[4,32] The primary cause of injuries in the Amber findings was related to RTCs (62%), with drivers/riders (37%), passengers (32%), and pedestrians (31%) affected (4). A similar study identified reckless driving (52%), negligent pedestrians (7%), careless motorcyclists (3%), and cyclists (7%).[33] These trends reflect assigning blame to the victims, as encapsulated in the Ghanaian saying, "The Dead are Always Wrong," and challenges in LMICs such as inadequate transportation infrastructure and enforcement of traffic regulations.[33]

Motorbike accidents accounted for 69% of motor vehicle injuries leading to hospitalizations, reflecting the widespread use of motorbike taxis in Tanzania. [34] This trend is consistent with findings

reported in Cameroon (55%), Uganda (50%), and Malawi (43%).[35-37] As motorbike prevalence increases, there's a potential rise in road traffic injuries associated with their use, highlighting the urgency for comprehensive legislative measures, awareness campaigns, and stricter enforcement of traffic regulations.

Despite global efforts, gaps persist in reducing transport-related deaths. Strategies proposed in The Lancet report to alleviate the burden of road traffic injuries include curbing speeding, preventing drunk driving, and enforcing the use of helmets, seatbelts, and child restraints, which could potentially prevent 25–40% of fatal road injuries.[4] Such measures are particularly significant for LMICs, where over 90% of transport-related deaths and disabilities occur. In Tanzania, challenges persist as car-related accidents (25%) serve as secondary causes of RTCs, yet only 14% of drivers and front passengers use seatbelts, aligning with a similar study where over 40% did not possess seat belts. [38] Helmet usage is mandated for motorbike (70%) riders/passengers and cyclists, but only 41% of them reported using helmets in our study. A similar study from Dar es Salaam revealed that 53% of riders were observed wearing helmets, but a significant 92% of them did not provide helmets for their passengers.[33] These findings showcase poor compliance with adhering to safety measures. Drink-driving is a significant concern, with over 10% of individuals in this study found to be under the influence of alcohol upon admission, same in the Zambian study (30%). [39] Addressing these issues requires implementing feasible actions to safeguard public well-being and protect valuable assets.

Our findings reveal two distinct peaks in RTCs during morning and evening rush hours, occurring between 5:00 a.m. and 9:00 a.m. and 4:00 p.m. and 8:00 p.m., respectively. Non-motorized road users, especially pedestrians and cyclists, experience higher proportions of RTCs during these peak hours. Fewer accidents involving pedestrians and cyclists occur at night, potentially due to reduced traffic

volume. Conversely, accidents involving cars, trucks, and buses peak between 12:00 a.m. and 2:00 a.m., potentially related to factors like reduced visibility, driver fatigue, or speeding. Law enforcement efforts during these peak times, are crucial to reducing RTC burdens, aligning with findings from a study in Malawi.[40]

Falls are the second most common cause of injuries, representing 35% of cases, with 19% occurring at home. Elderly individuals (aged over 60 years) accounted for 20% of these falls, while young children (under 18 years) comprised 40%. Elderly individuals were more prone to head injuries due to reduced agility, while children exhibited a higher likelihood of lower limb fractures. Among mortalities, 23% resulted from fall injuries, highlighting their significance. High-risk environments, such as slippery surfaces and poorly maintained housing stairs, contribute to fall patterns, corroborated by studies in Malawi and Mozambique.[40,41]

The analysis highlights key aspects of medical care for traumatic patients, indicating a timely response with 59% receiving prompt attention within 30 minutes of arrival. Most patients showed healthy arterial systolic blood pressure (61%) and stable respiratory rates (95%). Neurological assessments revealed that 84% of patients were alert upon arrival, suggesting positive neurological status. However, over 86% sustained single injuries, while 11% experienced polytrauma. About 38% had a moderate to severe KTS score, indicating the severity of injuries requiring urgent care. Head injuries were significantly associated with increased mortality risk, emphasizing the need for expanded neurotrauma services.

Within 24 hours, 35% of patients were admitted to wards, and 32% were taken to operating theaters. Unfortunately, one patient was declared dead on arrival due to a head injury sustained in an RTC,

while 30% received care and were discharged. On the 2-week follow-up, among those admitted, 55% were discharged, while 16% remained in the wards. Regrettably, 3.77% died, with 87% being male and 7% children under 5. Most deaths (80%) were due to severe head injuries, followed by extremity fractures (17%), primarily from RTCs (74%). Among the deceased, 40% were drivers, 23.3% were pedestrians, and 10% were passengers. The overall mortality rate at MOI was 2.83% (31/1097) during the study period, providing valuable insights into patient trajectories and outcomes.

The "three delays" paradigm encompasses delays in seeking care, reaching care, and receiving care, revealing concerning trends in this context. [42] Patients encountered all three types of delays, with a median duration from injury to hospital arrival of one day. Among mortalities, only 23% arrived at MOI within 24 hours, emphasizing the critical importance of seeking timely medical care. Delays in receiving care varied significantly (ranging from 0-1:41 minutes), underscoring the challenges critical patients face even after reaching healthcare facilities. Addressing these delays is crucial within hospital quality improvement programs to minimize preventable deaths, aligning with WHO guidelines emphasizing timely and efficient care.[43] Delays in seeking and reaching care result from various factors,[44] highlighting the need to enhance prehospital care systems and involve laypersons in reducing trauma care delays. Further research is needed to assess the impact of prehospital delays on individuals' decisions to seek medical care.

STUDY STRENGTHS

The project's seamless integration of the Amber database into MOI's daily medical recording systems has garnered official recognition from the administration, highlighting several strengths:

Acceptance by Local Administrators: The project's acceptance and integration into MOI's routine medical recording system demonstrate robust support from local key administrators, addressing

tangible needs and providing practical value within healthcare settings.

Routine Use: The database's effortless transition into a routine medical recording system reflects its smooth assimilation into the hospital's daily operations, becoming a crucial tool for efficiently managing patient data and enhancing healthcare workflow.

Endorsement for Expansion: Local administrators' intention to inform the Ministry of Health and expand the platform to other hospitals across the country underscores the project's strength and potential to extend its positive impact beyond a single institution, benefiting healthcare facilities nationwide. Overall, the widespread acceptance, seamless routine use, and endorsement for expansion of the Amber database at MOI demonstrate a successful implementation with practical value and potential contributions to electronic medical recording systems on a broader scale.

STUDY LIMITATIONS

The implementation of the Amber trauma database in Tanzania has demonstrated feasibility despite encountering challenges. A small team of two nurses managed data collection for the trauma registry at MOI. However, the dataset may not fully capture daily presentations of traumatic patients due to swift treatment and discharge of minor trauma cases at the ED, especially during staff shortages and off-hours. Despite systems in place, diverse clinical settings increased the likelihood of missing data. Inaccuracies in recording sensitive patient variables were uncovered, such as ages (789 or -125), blood pressure (-129/679 mmHg), and respiratory rate (189 breaths per minute), attributed to human errors during data entry. Proactive measures were implemented by local principal investigators and the project coordinator to enhance collection procedures. The Amber operating theater database lacks crucial local variables, prompting an ongoing collaboration between MOI and MUHC-CGS to address this gap. The study's focus on patients at MOI limits its generalizability, and the Amber database lacks post-discharge information on trauma patients' health status and interventions provided. Efforts are

needed to incorporate such data for comprehensive trauma outcomes assessments, as demonstrated by the Victoria trauma registry.

CONCLUSION

This project represents a groundbreaking achievement with the successful implementation and feasibility of the web-based Amber database platform in Tanzania. Launched in July 2023 at MOI, it revolutionized trauma data management. The paper offers valuable insights into trauma patterns and services in Tanzania, particularly focusing on the prevalence of road traffic injuries (RTCs) in the Kinondoni district of Dar es Salaam. It emphasizes the need for reinforcing traffic regulations and addressing delayed medical attention for trauma patients. The research highlights the potential of trauma registries to inform preventive policies and enhance clinical care, advocating for advancements in registries to include more comprehensive data on care and patient outcomes. By addressing a leading cause of morbidity and mortality, this work lays the foundation for national leadership to create safer environments. Overall, the Amber database implementation signifies a transformative shift in data management, enhancing patient care and resource allocation, with feasibility and potential for broader adoption underscored by local support and practical benefits. This digital system reflects a commitment to expansion for improved healthcare worldwide.

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data analysis and wrote the entire manuscript. CO, TR, JG, DD, KK, VM, and RB were involved in manuscript editing. All authors reviewed and approved the manuscript.

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CHAPTER FIVE: THE VALUE OF DIGITIZING OPERATING THEATER DATA MANAGEMENT SYSTEMS IN LMICs: THE AMBER DATABASE EXPERIENCES

Preface

The manuscripts included in this collection shed light on the pressing issues surrounding surgical access and trauma care in low- and middle-income countries (LMICs), with a particular focus on Tanzania. [Manuscript III] served as the cornerstone of this project and provided a thorough exploration of the surgical disease burden from trauma and trauma surgery services within Tanzanian populations. It introduced a proposed approach to tackle challenges associated with trauma data documentation systems by implementing digital data infrastructure platforms. Such digitized registries played a crucial role in offering precise geographical data on trauma burdens and trauma services, assisting healthcare facilities in benchmarking clinical guidelines, implementing quality improvements, and devising strategies for injury prevention.

[Manuscript IV] continues the discussion initiated by Manuscript III, focusing on the Amber platform, specifically an operating theater recordings database that presents surgical services in Tanzania. Surgical interventions are essential for treating a significant portion of conditions in LMICs, yet access to these services remains limited, leading to heightened mortality rates. Operating theaters (OTs) play a vital role in delivering quality patient care, but resource constraints often impede their efficiency, highlighting the importance of effective information management systems. Tanzania's healthcare system faces significant challenges in providing surgical services to its population, with a large portion lacking access altogether. Despite efforts

to improve surgical workflows through electronic systems, digitized data infrastructure for OTs remains lacking, posing obstacles to policymakers striving to enhance service delivery.

In response to these challenges, the Muhimbili Orthopedic Institute (MOI) launched an innovative web-based OT recording platform in 2023, aiming to address data management issues and improve perioperative care. Unlike traditional platforms, this system offers eco-friendly, cost-effective, and sustainable solutions, allowing for direct postoperative data entry and timely updates. The implementation of this platform at MOI serves as a crucial step towards improving perioperative data management and providing comprehensive insights into Tanzania's surgical landscape. Through this collection, we aim to explore the impact of innovative solutions like the web-based OT recording platform on perioperative data management and patient outcomes at MOI. By assessing the effectiveness of these interventions, we can inform future initiatives aimed at improving surgical care delivery in LMICs like Tanzania.

Manuscript IV: Digitizing Operating Theater Data in Resource-Limited Settings: Understanding Surgical Care Delivery Post-implementation at Tanzanian Referral Hospital

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Abstract

Background

In resource-limited settings, inadequate data infrastructures exacerbate the understanding and impact of surgical diseases. We aimed to introduce a robust operating theater data registry platform in Tanzania, which lacks structured surgical services repositories. The goal was to promptly report achievements and identify challenges, gaps, and areas for improvement.

Methods

In July 2023, we implemented data repository platforms at Muhimbili Orthopedic Institute's (MOI) operating theaters. We initiated prospective data entry post-procedures, ensuring timely updates of perioperative outcomes. The report examined surgical volume and workflow details. Descriptive and statistical analyses assessed the platform's impact on identifying challenges and successes in surgical care delivery systems.

Results

MOI's nine operating theaters performed 1300 procedures, including 978 (75.7%) electives and 322 (24.77%) emergencies. Orthopedics/trauma (596, 45.85%) was the predominant specialty. Trauma-related hemorrhage led emergency procedures (1,056, 81.2%). For all types of surgical procedures, general anesthesia was the most common sedative, used in 601 out of 1300 operations (46%), while local anesthesia was the least used in 215 (16%). 1146 out of 1300 patients (88.15%) received prophylactic antibiotics before surgical incisions. Among all surgical patients, 93.46% (1215 out of 1300) were discharged directly to their homes, while 0.62% (about 8 patients) were transferred to another hospital. There were 29 deaths (2.23%), with 12 occurring within 30 days of surgery and one intraoperatively.

Conclusion

The platform revealed heightened surgical volume, serving as region-specific data for global surgical care trends in MOI, Sub-Saharan Africa. Addressing non-physical inefficiencies is crucial for reducing cancellations and enhancing outcomes. The platform received positive feedback, emphasizing the importance of enhancing workflow to genuinely improve surgical care access.

INTRODUCTION

Access to surgical care remains limited in low- and middle-income countries (LMICs), although more than 11% of medical conditions in these regions are surgically treatable [1-3]. Emergent surgeries are common, but the scarcity of resources often leads to challenges in providing critical care, resulting in increased mortality rates [4, 5]. Effective management of operating theaters (OTs) is essential for hospitals, both for financial sustainability and for ensuring high-quality

patient care [6]. Given that surgical operations account for over 60% of hospital admissions, optimizing OT management is a priority for hospital administrators [7].

However, the performance of OTs heavily relies on efficient information management systems, which are crucial for identifying areas for improvement [8]. Although efforts have been made to adopt electronic medical records (EMRs), many LMICs still rely on paper-based approaches due to infrastructure limitations. A study across 68 LMICs revealed that 64% reverted to paper-based data entry due to challenges such as limited EMR guidelines and software complexity, highlighting the need for improved approaches [9, 10].

In Tanzania, where the healthcare system spans primary, secondary, and tertiary levels, providing surgical services to the population of 60 million remains a challenge, with over 90% lacking access [11]. The National Surgical, Obstetric, and Anesthesia Plans (NSOAPs) have identified gaps in service delivery and information management [12]. While the introduction of electronic master OT scheduling systems has improved surgical workflows, the absence of digitized OT data infrastructures indicates areas for improvement [13, 14].

Muhimbili Orthopedic Institute (MOI) serves as Tanzania's national center for orthopedics/trauma and neurosurgery, offering services round-the-clock. However, like many other hospitals, inadequate data management poses challenges for policymakers seeking to enhance OT services. In response, an innovative web-based OT recording platform was launched at MOI in 2023. This platform offers eco-friendly, cost-effective, and sustainable solutions, allowing users to access it across various devices. It enables direct postoperative data entry,

conserves resources, and ensures timely data updates. Unlike other platforms, it incorporates built-in systems to prevent data deletions and incomplete savings, thus minimizing missing data and providing comprehensive insights into MOI's surgical landscape [15, 16]. This study presents an implementation report for the innovative web-based OT recording platform introduced at MOI, highlighting outcomes, challenges, lessons learned, and successes during the implementation process. It aims to evaluate the platform's effectiveness in improving perioperative data management at MOI.

METHODS

Settings and Collaboration

MOI, Tanzania's referral neurosurgery and orthopedics/trauma center, collaborated with McGill University Health Centre's Center for Global Surgery (MUHC-CGS) in 2023 to establish digitized operating theater data infrastructures. This initiative seeks to serve as a model for other sub-Saharan nations with limited data repositories.

Study Instrument

MUHC-CGS sponsored an innovative web-based application for MOI, comprising Global Surgery Collect (data collection), Global Surgery Studio (data management), and Amber Server (secure cloud storage). Accessible across devices with only a browser requirement, the platform functions offline and uploads data seamlessly when a network connection is available. It features an integrated data analysis tool for insights and enables prospective data collection for health policy. Moreover, the Amber operating theater database comprises 15 well-defined variables, precisely documenting MOI's operating room activities. These variables cover comprehensive

variables including various surgical and anesthesia details, clinical assessments, and perioperative outcomes. This level of detail facilitates precise analysis and evaluation of surgical procedures, resource utilization, and patient care. In essence, the variables in the Amber operating theater database provide a structured framework for capturing the intricacies of MOI's surgical operations, contributing to the enhancement of trauma care and surgical outcomes. Finalizing records involves updating the perioperative outcomes savings and uploading them to the Amber server.

Data Collection

Two ethnographers and clinicians received training to prospectively record daily data on the platform at nine operating theaters. Data from July to August 2023 were analyzed. Semi-structured interviews with local stakeholders guide the refinement process, ensuring the platform's effectiveness and sustainability.

Analysis

Descriptive and summary statistics were utilized to assess outcome measures. Parametric and non-parametric tests were chosen based on data distributions. Data, automatically generated within the platform's studio through built-in systems, were extracted for analysis using Microsoft Excel (Microsoft Corp., Redmond, WA, USA), with a significance level set at $p \leq 0.05$. Qualitative analysis followed standard protocols [17]. Ethical approval was granted from McGill University and MOI.

RESULTS

During the study, over 1300 operated patients' data from the MOI's nine operating theaters were collected. Among these, 794 (61%) were male patients, while 506 (39%) were female ($p<0.001$). Most patients arrived at MOI from Dar es Salaam region's (857, 65.65%), Ilala district, accounting for 209 (15.9%) cases. Emergency surgeries (injury and non-injury) accounted for 978 (75.7%) cases (Figure 1).

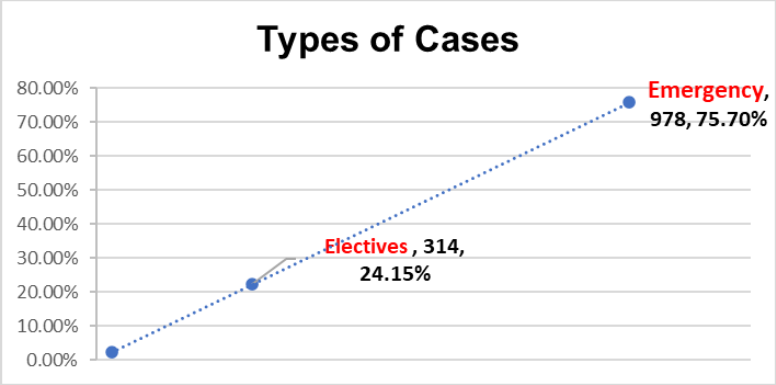

Fig.1 presents the types of cases

The primary indication for surgery was hemorrhage intervention, accounting for 1056 out of 1300 cases (81.2%). In contrast, viscus and hollow organ perforations represented the least common indication for surgery, with only four patients (0.3%), as depicted in Figure 2.

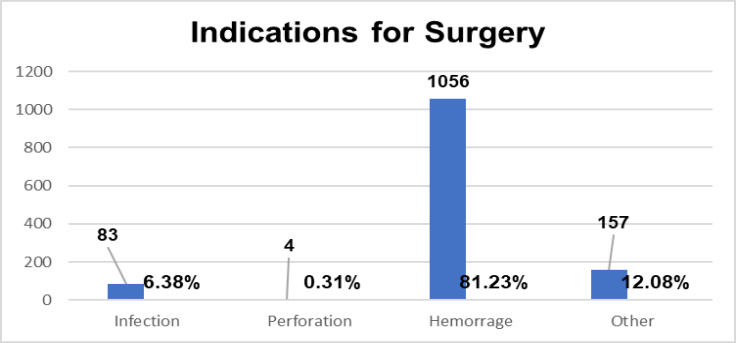

Fig. 2 shows an indication of surgery

A total of 596 cases out of 1300 (45.85%) surgical procedures were performed on extremities for orthopedic indications, while the pelvis accounted for 26 (2.00%), as illustrated in Figure 3.

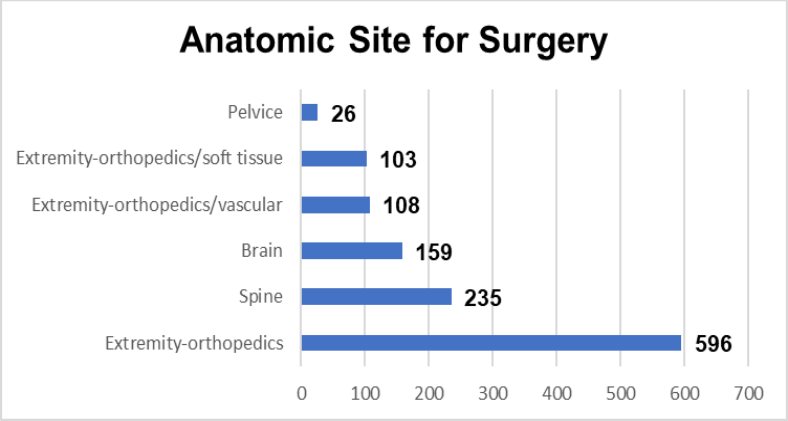

Fig. 3 presents the body site where surgery was performed

Antibiotics and Anesthesia

In the realm of surgical antibiotic prophylaxis, a significant proportion of patients, specifically 1146 out of 1300 (88.15%), received it before incision (Figure 4).

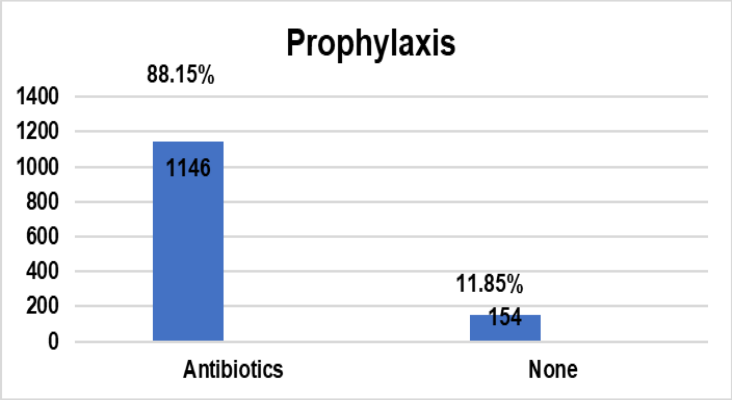

Fig. 4 presenting supplementary prophylaxis for surgical procedures

Among various sedative options, general anesthesia emerged as the predominant choice, administered in 601 out of 1300 operations (46%), whereas local anesthesia was employed least

frequently, accounting for only 215 cases (16%) (Figure 5). When assessing the risk profiles associated with elective surgeries using the American Society for Anesthesiology (ASA) classification system (ranging from 1 to 5), the distribution among grades was as follows: grade 1: 269 cases (85.74%), grade 2: 23 cases (7.3%), grade 3: 20 cases (6.39%), and grade 4: 4 cases (1.15%) ($p<0.004$).

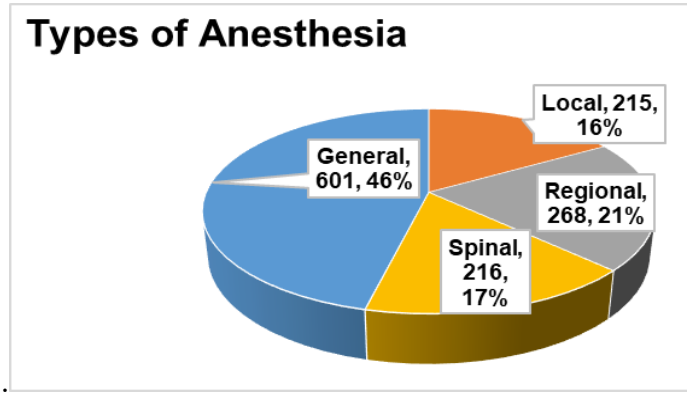

Fig. 5 displays the types of anesthesia used for surgical procedures

Disposition and Outcomes

Following surgery, most patients, totaling 93.46% (1215 out of 1300), were discharged directly to their homes, while a minimal proportion, approximately 0.62% (around 8 patients), required transfer to another hospital (Figure 6).

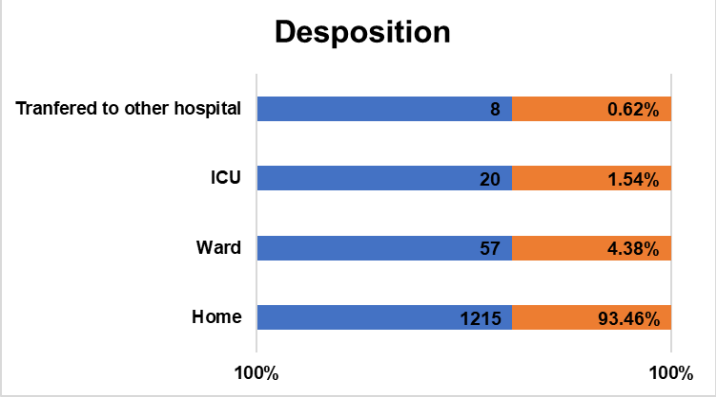

Fig. 6 illustrates the disposition of patients following surgeries

However, 2.23% (29 patients) experienced mortality (Figure 7). Stratifying the ASA risk for death revealed the following distribution: grade 1 (63%), grade 2 (20%), grade 3 (13%), and grade 4 (5%) ($p<0.001$). The overall perioperative mortality rate (POMR) was recorded at 2.23%.

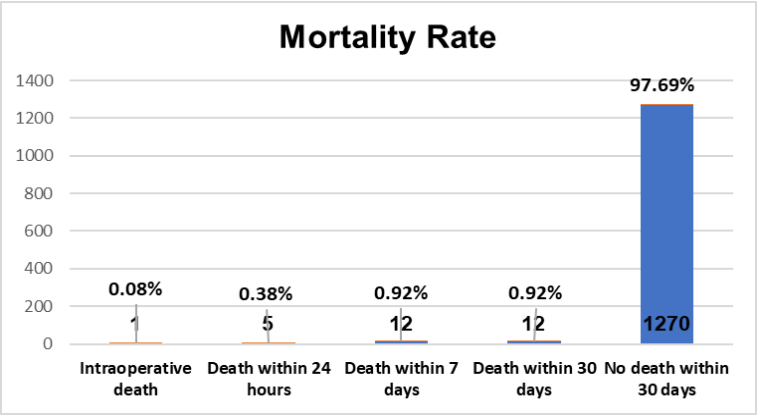

Fig. 7 illustrates surgery-related mortality rates observed at MOI

Data Completeness

To gauge data completeness, we computed the ratio of valid values to the total number of data fields. The platform's inherent design features automatically reject incomplete entry savings, thereby contributing to a higher completeness rate. However, despite these mechanisms, challenges in achieving maximum accuracy were noted, as certain crucial data points were occasionally misdocumented, resulting in a slight decrease in accuracy.

Qualitative Feedback

Semi-structured interviews conducted with stakeholders from MOI provided valuable insights into the web-based OT recording platform. Administrators expressed enthusiasm for its potential expansion to other hospitals, citing its ability to enhance understanding of surgical landscapes,

improve services, and inform policymaking. Identified improvement areas included addressing missing health metrics on platform questionnaires and overcoming technological challenges in integrating the platform with existing data storage systems to ensure comprehensive data coverage. Data managers and clinicians appreciated the platform's effectiveness in resolving past data issues and software glitches. They highlighted its user-friendly interface and compatibility across various devices, including cellphones, which helped conserve resources. Suggestions for improvement included ongoing training, regular monitoring of platform functionality, and the provision of manuals for future reference.

DISCUSSION

The published experiences showcased that surgical procedures constitute a significant portion of hospital admissions, accounting for approximately 60% to 70% of all admissions and over 40% of total hospital expenses.[18] Hospital stays involving surgeries conducted in OTs incur significantly higher costs, approximately 2.5 times more than stays without surgical procedures.[19] The OTs in healthcare facilities are among the costliest to operate, making them a prime target for innovations aimed at improving cost-effectiveness and efficiency, all while maintaining patient safety and care quality.[19] However, the efficient healthcare system faces challenges like rising operational costs, a lack of digital documentation, and inadequate infrastructure, particularly in resource-limited settings.[20]

The Lancet Commission on Global Surgery (LCoGS 2030) emphasizes the importance of effective national surgical programs with specific metrics and targets. One critical metric calls for "100% of countries to have tracking systems in place to monitor perioperative mortality rate

(POMR) to document deaths related to surgical procedures. [21] This underscores the need for comprehensive data collection and analysis to improve the safety and quality of surgical care globally. In LMICs, addressing the challenge of POMR has been hindered by the lack of developed electronic medical recording systems. To overcome this, we introduced the Amber operating theater database, a sophisticated web-based tool successfully implemented at MOI in Tanzania.

MOI is equipped with nine operating theaters, two of which are specifically allocated for emergency procedures, while the remaining seven cater to elective surgeries. Analyzing data from the Amber OTs provides valuable insights into surgical procedures and patient outcomes at MOI. The dataset reveals a male predominance, emphasizing the need to explore potential gender-specific factors in trauma and surgical care. Most patients originated from the Dar es Salaam region, particularly in the Illala district, emphasizing the significance of healthcare services in this area. These findings highlight the importance of resource allocation and healthcare planning based on regional demands.

The implementation of the web-based OT recordings at MOI has significantly improved data management while also identifying areas for improvement. The platform successfully recorded a total of 1300 procedures, with a predominant focus on male adults, which reflects the region-specific prevalence of surgical diseases. Notably, in 2018, Tanzania conducted 484 procedures per 100,000 population. This platform will contribute to providing real-time data to Tanzanian policymakers, aiding in achieving the planned 5000 procedures by 2060. [2,12]
Orthopedics/trauma procedures accounted for the majority, comprising 81% of cases, which

aligns with findings from other studies, underscoring the substantial burden of traumatic and musculoskeletal disorders in Tanzania.[24] Moreover, over 75% of patients underwent emergency procedures, with a significant proportion attributed to life-threatening hemorrhage, often stemming from transport-related incidents. In orthopedics/trauma cases specifically, 73% involved extremities, with 83% being open fractures. These cases are considered bellwether procedures, as they necessitate urgent surgical intervention for positive patient outcomes.[2,5] This underscores the critical role of timely and effective surgical care in managing traumatic injuries in Tanzania.

General anesthesia emerged as the primary choice for sedation during surgical procedures, followed by regional anesthesia. This understanding of preferred anesthesia methods is crucial for anesthetic resource planning and healthcare staff training. Despite limited data availability on anesthesia usage in Tanzania,[6] these findings contribute significantly to our understanding of pain management and anesthetic services at the regional level in sub-Saharan nations. A substantial proportion (89%) of patients received prophylactic antibiotics before surgery, aligning with findings from other studies (87%).[25] This highlights robust pharmacy services and a commitment to effective surgical practices. Nationally, 48 facilities, including MOI, provide surgical services, catering to 46% of Tanzanians. However, essential services such as consistent oxygen supplies (42%), running water and electricity (37.5%), and required pharmaceutical commodities (68%) are often unreliable.[26,27]

Following surgeries, most patients (94%) were safely discharged to their homes, while a small percentage required transfer to another hospital. These statistics reflect postoperative care and

the need for appropriate facilities for patient transfer. The study reported an overall surgery-related mortality rate of 2.23%, with different timeframes for patient deaths. These findings highlight the importance of perioperative care and continuous monitoring to enhance patient safety and outcomes. The implementation of the Amber database marked a pivotal moment, emerging as the central platform for medical data documentation within MOI's operating theaters. In just six weeks, it amassed over 1300 surgical operation records, fundamentally transforming data management practices. MOI in Dar es Salaam now has seamlessly integrated operating room activities, supported by an electronic POMR recording system powered by Amber's comprehensive data. This database significantly contributes to enhancing patient care, streamlining resource allocation, and refining healthcare planning strategies.

The unwavering support from MOI administrators has set the stage for the potential nationwide expansion of this tool. Testimonials from data collectors highlight the practical advantages of Amber, simplifying data entry and ensuring secure cloud-based storage. Its seamless integration into MOI's daily operations demonstrates feasibility and gains enthusiastic support from key stakeholders. Amber stands as a transformative example of digital medical recording systems in resource-constrained settings, improving data quality, accessibility, and patient care. These testimonials emphasize the positive impact of Amber in advancing healthcare data management practices in Tanzania, motivating ongoing collaboration and expansion, not only within Tanzania but also across LMICs.

Our study has limitations. The reports from MOI may impact the generalizability of findings. Nevertheless, these findings underscore the importance of addressing platform challenges and analyzing key features, such as data management and surgical landscapes, to understand region-

specific access limitations and needs in LMICs. While our data repository is comprehensive, it lacks specific local health information. Ongoing efforts are underway to address these issues. Despite the advanced technology of the platform, occasional misdocumentation such as ages (-125) and blood pressure (-169/679 mmHg), likely attributable to human errors during data entry, highlight the necessity for continuous training to maintain data accuracy.

CONCLUSION

In summary, MOI stands as Tanzania's foremost surgical care and academic center in Sub-Saharan Africa. Despite global neglect of surgery in resource-limited settings, our robust data system captured nearly 1300 surgical volumes, establishing sustainable surgical information management. Our platform, endorsed by local administrators, serves as Dar es Salaam's official recording system, pioneering surgical landscape presentations, workflow optimization, and POMR tracking. Long-term functionality challenges in LMIC collaborative projects require bilateral understanding, strengthened partnerships, and regular platform reevaluations for sustainability and encouraging similar actions. Through dedication and collaboration, we aim to enhance surgical care in LMICs.

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Author Contributions

CO and TR contributed to the study's conception. CO, TR, JG, DD, VM, and RB were involved in the study design. Data acquisition was carried out by CO, VM, and RB. CO performed data analysis and wrote the entire manuscript draft. CO, TR, JG, DD, KK, VM, and RB were involved in manuscript editing. All authors actively participated in editing and critically reviewing the manuscript and granted their approval for publication. VM and RB, both senior authors, have fully accessed and verified the underlying data reported in the manuscript.

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CHAPTER SIX: COMPREHENSIVE DISCUSSIONS

Access to Essential Surgical Care

The launch of the LCoGS 2030 Initiatives catalyzed substantial growth in the global surgery field, prompting vital discussions about addressing unequal access to essential surgical care in resource-limited settings.[13] The Lancet, WHO, and WHA have all emphasized the importance of strengthening essential and emergency surgical/trauma, anesthesia, and obstetrics (SAO) services in LMICs. Ethiopia has been a pioneer in adopting and integrating these improvements into its healthcare framework among Sub-Saharan African countries. Nevertheless, despite being a

leader in resource-limited settings, there has been a noticeable absence of research examining the progress in surgical care over the past decade. This research gap inspired our study, where we aimed to depict Ethiopia as a resource-limited setting and evaluate its current surgical capacity using the LCoGS 2030 Metrics.

In Chapter Two of the manuscript, we focused on evaluating Ethiopia's surgical capacity using the six key indicators outlined by the LCoGS 2030 to assess progress in recent years through conducting a narrative review. The study uncovered several significant challenges within Ethiopia's healthcare system that hindered the delivery of high-quality surgical care. These challenges included a limited surgical workforce, infrastructure limitations, and high surgical expenses, resulting in facilities being unable to perform critical bellwether procedures like laparotomies, cesarean sections, and open fracture management. Immature healthcare systems, alongside other challenges, affected Ethiopians receiving high-quality SAO care.

The current surgical volume in Ethiopia is approximately 43 procedures per 100,000 population, and the rate of specialist physicians is 0.5 per 100,000 population. However, according to the LCoGS recommendations, countries should aim for at least 20 surgical, anesthetic, and obstetric specialist physicians per 100,000 population and a surgical volume of 5000 procedures per 100,000 population by the end of 2030.[13] Ethiopia falls short of these benchmarks, indicating a gap in meeting the recommended standards for surgical care. Of the facilities analyzed, 44% were capable of bellwether procedures and lacked POMR tracking systems. Over 80% of operations conducted were essential; primary hospitals had limited operative infrastructures.

Furthermore, only 50% of Ethiopians live within a 2-hour range of surgery-ready hospitals despite the recommendation that 80% of the population should have access to surgery-ready hospitals within a 2-hour range.[13] Additionally, over 98% faced impoverished expenditures due to surgery, defined as out-of-pocket expenses that would drive a person into extreme poverty, but the norm is free surgical access.[13] Disparities in surgical capacity remain; approximately 90% of surgery-ready facilities are in cities, leaving Ethiopia's 80% of the rural population with insufficient access to surgical care.

Overall, the manuscript emphasizes a substantial gap between Ethiopia's surgical capacity and LCoGS recommendations, despite the country's pioneering efforts in global surgery initiatives. To enhance surgical services nationwide, there is a need for comprehensive measures, including improving surgical access, expanding the surgical workforce, introducing public insurance plans, and establishing effective data tracking systems. These findings from Ethiopia align with the progress of surgical capacity in other resource-limited nations, as observed in Kenya,[123] and similar settings, showcasing that there is work that needs to be done to enhance surgical services in resource-limited settings. These include establishing robust data infrastructures to understand the country's disease burden, expanding eco-friendly trauma/surgical education programs, and advancing the critical care capabilities of facilities across nations.

Empowering Healthcare Through Education

The WHO's Trauma System Maturity Index (TSMI) reveals that many LMICs have immature trauma care systems, underdeveloped prehospital and in-hospital care systems, and limited trauma education, and data documentation infrastructures.[122] The American College of Surgeons-

Committee on Trauma further stresses the importance of education and data documentation in trauma care.[5] While trauma education is recognized as vital for improving trauma care systems and patient outcomes, LMICs face challenges in implementing widely recognized but expensive programs like Advanced Trauma Life Support (ATLS) – a training program developed to provide medical professionals with the knowledge and skills necessary to assess and manage traumatic injuries systematically.[124] The program emphasizes a standardized approach to trauma care, focusing on the initial assessment, early management, and stabilization of trauma patients.

In Chapter Three, eco-friendly alternatives for trauma education in resource-limited settings were explored to address the rising impact of trauma-related fatalities in these regions. This issue is largely attributed to insufficient infrastructure and trauma response training. This underscores the importance of tailored educational solutions to address the trauma burden in LMICs. MUHC-CGS introduced the United Nations-endorsed TDTR training program to address trauma training challenges. The course was conducted at Tanzania's MOI from August 16-18, 2023, involving 22 participants in a blended learning format that combined online modules with in-person training and simulated skills sessions. The study aimed to evaluate the effectiveness of TDTRs in enhancing practitioners' skills in handling traumatic patients and improving patient outcomes in Tanzania. Despite surgery often being overlooked in LMICs' global health context, the study demonstrated the feasibility and positive reception of teaching surgical skills among healthcare specialists in Tanzania. It successfully achieved its goals of advancing clinical knowledge and skills, enhancing clinical outcomes, and improving MOI healthcare processes for systematically managing traumatic patients.

Furthermore, the study offered evidence that the establishment of functional trauma response teams was possible, as participants displayed effective performance in MOI emergency departments after completing the course. It's crucial to note that The Lancet's 2022 report emphasized that establishing trauma care systems has the potential to save over 200,000 lives from preventable trauma-related deaths. Strengthening trauma teams through education can additionally save more than 60,000 lives in resource-limited settings,[29] underscoring the essential nature of delivering the TDTR course to advance trauma care systems in LMICs. The study recommends further expansion of TDTR across Tanzania and other LMICs. The accessibility of the course on the UNITAR platform for free further provides additional benefits for self-learners. Developing and expanding a local instructor pool is essential for sustainability, resource conservation, and empowering independent trauma education. It is vital to adapt TDTR training to various environments, as suggested by feedback from trainees.

Digitizing Trauma and Operating Theater Data Infrastructures

The global trauma crisis disproportionately affects resource-limited settings. In countries like Tanzania understanding the actual injury burden is challenging due to inadequate trauma data acquisition systems, underscoring the designing of functional trauma registries.[110] The establishment of trauma registries in resource-limited settings has a history spanning several decades, but these registries encounter persistent challenges in maintaining their longevity. To enhance the sustainability of trauma registries in LMICs, a promising approach is the digitization of data documentation systems to effectively track disease burdens. Recognizing the imperative for improved information management, the MOI in Tanzania initiated adopting electronic

medical recording systems. The Amber database emerged as a solution, offering a user-friendly web-based platform for trauma and operating room activities.

Chapter four delved into the successful implementation of the Amber trauma database at MOI, marking a significant milestone in data management for trauma patients. Over the study period from July 13 to August 23, 2023, the database documented comprehensive information on more than 1097 trauma cases. This achievement underscores the transformative impact of the Amber database in revolutionizing trauma data collection and management practices at the hospital. Through its user-friendly interface and robust features, the Amber database has facilitated the efficient documentation of trauma cases, enabling healthcare professionals to access critical patient information promptly. Furthermore, the Amber database has paved the way for enhanced data analysis and reporting, providing valuable insights into the patterns and trends of traumatic injuries in the region. By improving data accuracy, accessibility, and analysis, the implementation of the Amber database has not only advanced trauma care at MOI but also laid the groundwork for future advancements in healthcare delivery and patient outcomes.

In Chapter Five, a comprehensive overview of the achievements of the Amber operating theater recordings platform was provided. The platform successfully documented over 1300 surgical procedures performed across nine operating theaters at MOI during the study period. It highlighted the significant proportion of emergency surgeries conducted to address life-threatening hemorrhage, emphasizing the platform's critical role in capturing urgent surgical interventions. Moreover, the platform's data analysis revealed a perioperative mortality rate (POMR) exceeding 2% at MOI, indicating areas for potential improvement in surgical care

delivery. Leveraging the insights gleaned from the POMR report holds promise for enhancing surgical outcomes and patient safety at the hospital.

Stakeholders praised the Amber database for its simplicity and comprehensive data coverage, leading to its integration into MOI's routine medical data acquisition system. This success prompted Tanzania's Health Ministry to consider nationwide expansion, supporting injury prevention, education, quality improvement, and healthcare policy development. The database sets a precedent for LMICs aiming to establish robust trauma and operating room registries, enhancing healthcare policies and trauma care guidelines. However, ensuring long-term financial sustainability is essential, along with conducting post-implementation surveys for additional insights on usage patterns and data completeness.

CHAPTER SEVEN: CONCLUSIONS

Summary

This thesis unfolds the transformative impact of Global Surgery 2030 initiatives, marking a paradigm shift towards long-term capacity-building and the seamless integration of healthcare systems. A focal point of this study has been the global burden of trauma, emphasizing the pivotal role of education in enhancing the skills of surgical and trauma care providers. The TDTR course, designed as an eco-friendly and cost-effective training program, accentuates the importance of standardized trauma care approaches. It places a strategic emphasis on the initial assessment, early management, and stabilization of trauma patients, thereby contributing substantially to improved trauma care systems and enhanced patient outcomes.

Recognizing trauma as a silent epidemic in LMICs, [125] this research emphasizes the establishment of functional web-based medical recording systems for both trauma and operating room data registries as a critical measure for enhancing trauma and surgical services. While proven feasible in LMICs, the sustainability of such platforms remains a challenge. The successful implementation of the Amber database at MOI in Tanzania stands as a testament to the significance of local support for integration. In striving for long-term sustainability, strategic efforts encompass comprehensive administrative support, self-financing mechanisms, and robust publicizing of the Amber database. This approach ensures its continuity and opens avenues for potential expansion to other LMICs grappling with similar healthcare challenges.

In summary, this thesis effectively achieved its objectives. Firstly, it identified critical gaps in surgical capacity within resource-limited settings through a comprehensive narrative review, emphasizing the urgent need for proactive measures to enhance essential surgical care. Secondly, it evaluated the effectiveness of blended learning approaches in the TDTR course, significantly improving trauma surgery skills in Tanzanian resource-limited settings and establishing a functional trauma and disaster response team at MOI. Thirdly, it demonstrated the practical implementation of the Amber database in Tanzania, rapidly adopted as MOI's primary medical recording system. This adoption not only facilitated nationwide expansion but also initiated initiatives for targeted injury prevention, quality improvement programs, and advancements in surgical services. Collectively, these efforts represent a significant stride in advancing trauma and surgical care in resource-limited settings, aligning with the global surgery community's objectives to universalize critical surgery and establish robust data infrastructures in LMICs.

Future Directions

Considering the global surgery landscape and the heightened surgical access challenges highlighted in this thesis, there is a clear *call to action* to reduce preventable mortalities. Although surgery is often labeled as the *neglected stepchild of global health in LMICs*,[12] it undeniably plays a crucial role in global health progress. Addressing these significant gaps requires a focus on expanding education tailored to the local environment and financial constraints, especially in resource-limited settings. Furthermore, as discussed earlier, trauma surgery education programs like TDTR and similar courses should be widely accessible for medical practitioners in LMICs. This approach aims to enhance their surgical skills and systematic approaches to patient care, ultimately advancing essential and emergency surgical services for all.

To enhance data documentation and improve trauma care systems at MOI, it is imperative to explore the Amber database and address the following key aspects:

Recruiting More Staff: Increasing the number of data collectors can significantly improve data collection, ensuring comprehensive and accurate records. Providing incentives can further motivate staff.

Collaborative Approaches: Establishing collaboration between nurses, ethnographers, and physicians can lead to a more holistic and comprehensive data collection process. This teamwork can ensure that all relevant data points are captured, reducing duplicate entries, and contributing to data completeness.

Integration with MOI's eMEDICO System: Integrating the Amber database with MOI's eMEDICO— central medical storage system, is a promising future direction. This integration

allows healthcare professionals to input patient information alongside their clinical findings, minimizing missing data and optimizing resources.

Strengthening Partnerships: International projects must adhere to the memorandum of understanding between the parties and maintain bilateral actions. Regular and random audits of the Amber database can identify areas needing improvement for sustainability. Financing should primarily rely on local sources with minimal foreign aid.

Expanding Education: Expanding the TDTR course across Tanzania and other LMICs, led by local instructors, promotes systematic team management for critically injured patients and enhances disaster preparedness. These initiatives entail broadening educational opportunities to increase the pool of SAO specialists capable of conducting bellwether procedures, as outlined in LCoGS 2030. Additionally, it contributes to enhancing trauma care by digitizing data infrastructures and laying the groundwork for future regionalized trauma care systems in LMICs.

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APPENDICES

Permissions

The author, I [Cherinet Osebo], declares that all co-authors granted permission for the inclusion of the three manuscripts presented in this thesis. I [Cherinet Osebo] affirm that the manuscripts are exclusively included in this thesis and have not been utilized, either in part or in full, by any other co-authors for a thesis leading to degree-granting. As outlined in the author's contribution sections, I [Cherinet Osebo] is the sole first author for all three manuscripts included in this thesis.

For the primary research project focused on the *development and implementation of the novel web-based Amber trauma and operating theater database in Tanzania*, it is crucial to note that the Amber application software was officially registered under the Creative Commons Attribution License by the esteemed McGill University Health Centre, Centre for Global Surgery (MUHC-CGS). Following this, I obtained permission from my doctoral supervisor to establish guidelines for the utilization of the Amber database and its applications.

"*Assessing Ethiopia's Surgical Capacity in Light of Global Surgery 2030 Initiatives: Is There Progress in The Past Decade*? " was published in open-access journals with Creative Commons Attribution Licenses, and therefore does not require permission. "*Enhancing Trauma Care through Innovative Trauma and Disaster Team Response Training: A Blended Learning Approach in Tanzania*," and "Digitizing Operating Theater Data in Resource-Limited Settings: Understanding Surgical Care Delivery Post-implementation at Tanzanian Referral Hospital" have been submitted for publication in open-access journals with Creative Commons Attribution Licenses. They are currently *in revision*; therefore, permission is not required at this stage.

Supplementary: Amber database

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December 2023

Global Surgery Collect

Case reporting system

SUMMARY

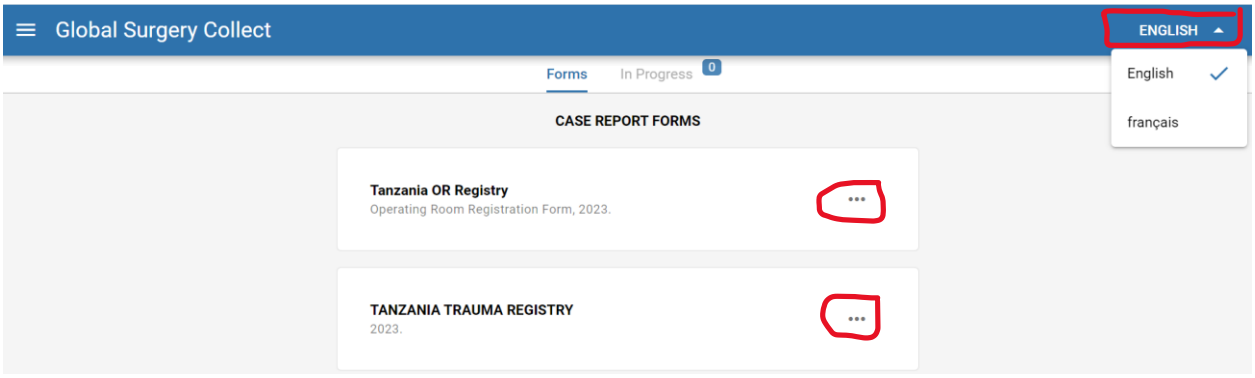
The Amber database (Global Surgery Collect) is a web-based application developed and sponsored by McGill University's Centre for Global Surgery (CGS). It serves as a vital repository for prospectively collecting essential medical information, especially for traumatic patients arriving at the emergency departments, and for recording all surgical procedures conducted in operating theaters.

The subsequent steps have been revised to enhance user-friendly navigation during the data collection process, fostering a smooth learning experience. The Amber application is the property of CGS and is licensed under Creative Commons. The CGS team provides permission to modify and utilize the application procedures for academic purposes.

1. Introduction

1.1. Introduction to Amber

The Amber Collect application is the data collection web interface of the Amber server. The Case Report Forms that are enabled can be used to report cases. Using Amber Collect requires authentication. Depending on the user role and authorizations, some Case Report Forms will be visible or not.



In this image, three Case Report Forms are visible to the user and can be opened to begin a new case. No personal information is stored in the app after the completed case report: private data are automatically saved on the Amber server (as soon as the network is accessible) and cannot be read back.

1.2. System Requirements

This web interface is a JavaScript application requiring a modern web browser. There is no requirement regarding the operating system: it can be either a desktop or a mobile one.

2. Accessing Amber Collect

Amber Collect is a Progressive Web App which means that it is a web app (i.e. accessible from a browser) that can be installed on the user's desktop (computer) or home screen (mobile), without the need to deploy it in a proprietary App Store.

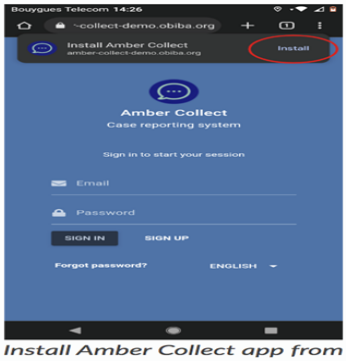
Go to Amber's Global Surgery Collect website

In your favorite browser, enter the app address, Amber Collect (cglobalsurgery.ca). From this point, the app is fully functional. The page can be bookmarked or "installed" (see next Step).

2.1. Installing the Application (optional)

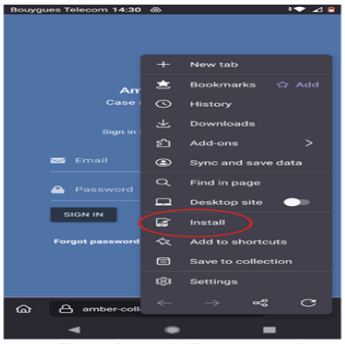
Depending on the browser's vendor, the procedure to install a shortcut icon to your home screen might differ a bit. See two examples below

Chrome



Install Amber Collect app from Chrome browser: a popup message proposes to install the app.

Firefox/Ghostery

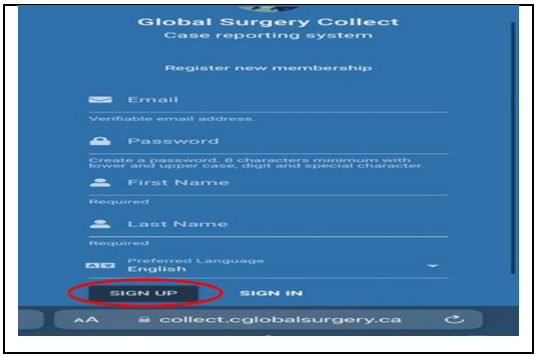


Install Amber Collect app from Firefox browser: the "Install" entry is proposed in the page's menu.

2.2 Creating an Account

If you do not already have an account, select the sign-up option below the login to set up your account.

The system will ask you to enter your email address, name and create a password. The password must be a minimum of 8 characters and include at least one lowercase, one uppercase, one digit, and one special character. Once a password has been created, you may select the sign-up button highlighted at the button of the screen.



2.3 Two-Step Authentication

To sign into an account and begin recording cases, you must first download an authenticator application on a device. The purpose of this application is to provide a two-step authentication that ensures you are the one trying to access your account, and this enhances the security of the database. Depending on the device there are different ways to access the authenticator application. The Microsoft Authenticator app can be downloaded from any app store on any device.

Install Microsoft authenticator on your mobile device or desktop/computer

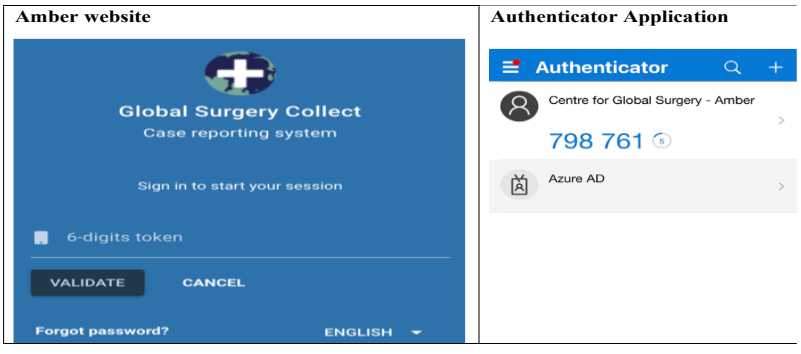
2.4. Logging into the Authenticator Application

Once the authenticator application is installed, you must link the application to your amber account by logging into the app using the same credentials as the ones used to create an account with amber.

2.5. Logging into Amber

To log into Amber, it will require the email and password you used to create an account. Then select sign in.

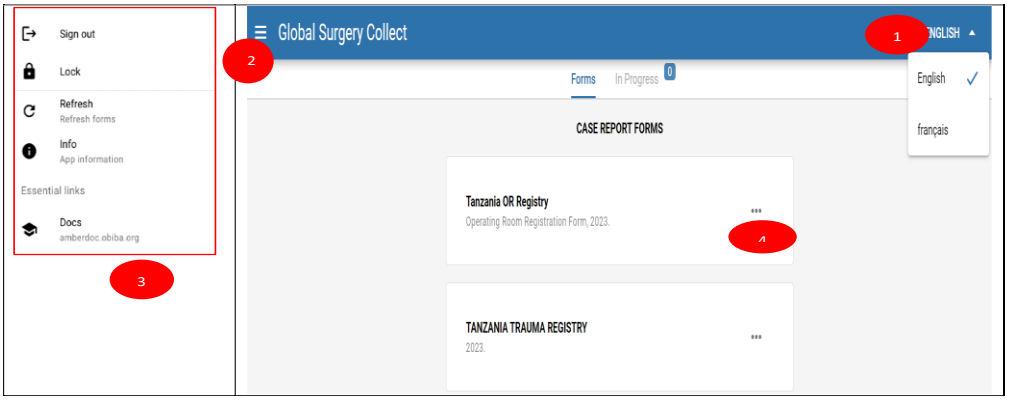
Next, the screen will change to a new line asking for a 6-digit token as the second verification step. Now you will open and log into the authenticator application mentioned above. When opened, you will see a temporary 6-digit token that can be used to login to the amber site.



Note: There is a 30-second timer on the 6-digit token given in the authenticator application (in the image below it is circled), this timer will count down from 30. Once the timer reaches 0 seconds, a new token will appear. To log into Amber, you must use a valid token. This means that the 6-digit number must be the current one displayed in the authenticator application. If the timer runs out before entering it into Amber, use the new token that will appear.

3. Navigating Amber Dashboard

Amber will log in to a dashboard format, here we will define all the features located on the dashboard and how to navigate through them.

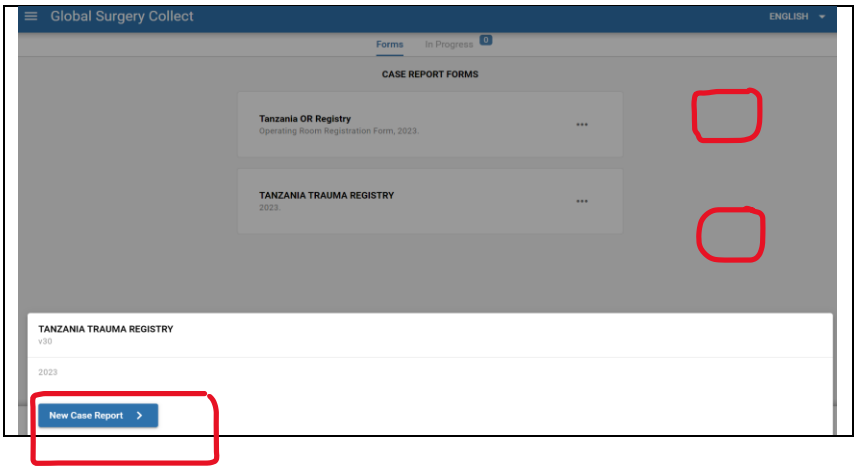


Selected to change the language in Amber. When selected will display a menu bar (depicted below red circle 2 in the image above) where you can sign out of the account and find more information about Amber. The Case Report Forms are displayed in the middle of the page and can be opened by selecting the three dots at the end of the form name. The Case Report tab can be selected to view all the Case Report Forms that have been **paused** by the user (see section 8. for more information)

4. Beginning a Case Report Form

4.1. Opening a Case Report Form

To begin a new Case Report Form, select the three dots next to the form you want to begin.

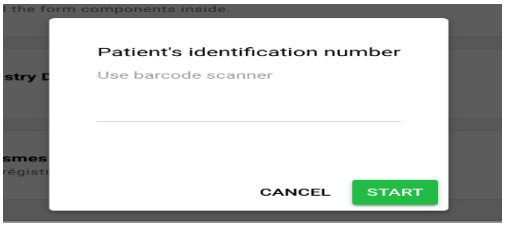


The banner shown above will pop up with the name of the form selected. To open the form, click on “New Case Report” in blue.

4.2. Patient Identification Number

Before opening the form, the system will require a patient identification number to be entered.

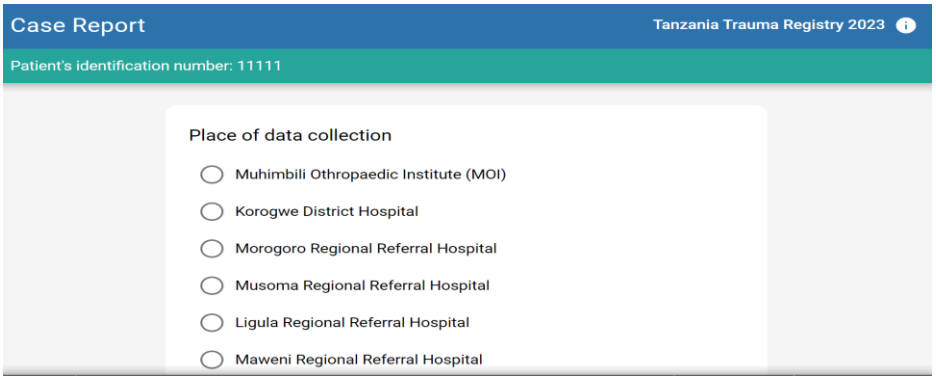
Select the start button in green to begin the form.



4.3. Form Viewing Options

The Case Report Form will open to a screen with a series of questions. Two viewing options can be used to complete the form depending on user preference.

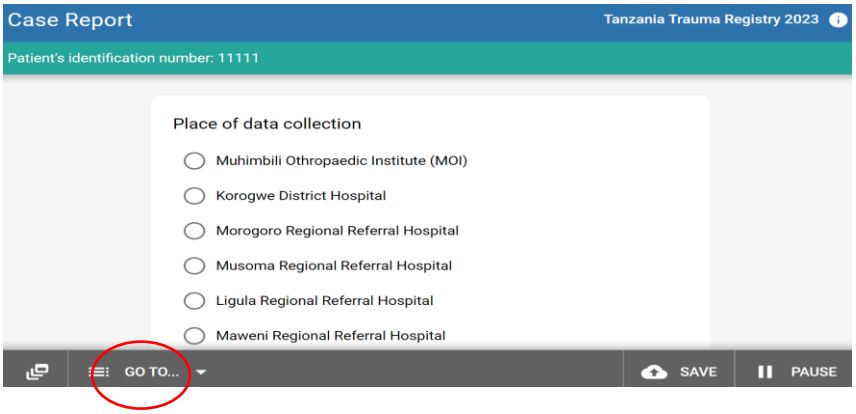
Option 1: Scrolling Screen



This is the default view that allows you to scroll down through all the questions at the same time.

Option 2: Single Question View

This is not the default view of the form. To enter this view, select the icon (circled in red) at the bottom left of the screen.

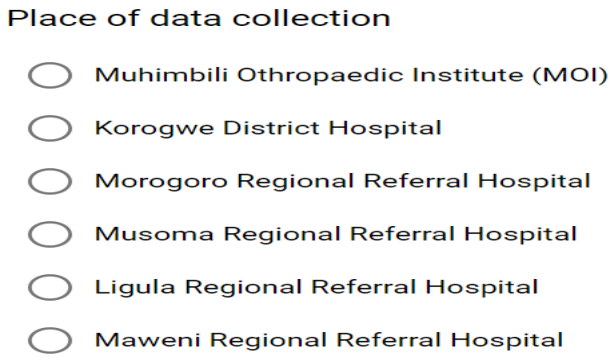


In this view, one question can be seen and answered at a time. The circle above is used to go to the next question. In this view, each question must have an answer before you can move to the next question.

5. Case Report Form Questions

5.1. Place of Data Collection

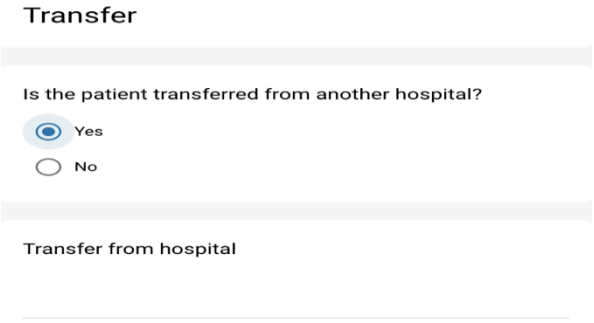
Select the location where the data is currently being collected.



In the image above are some examples of predetermined places where the data may be being collected. If the place you are collecting data is not listed, please select another.

5.2. Transfer

Provide information about how the patient arrived at this hospital. First answer whether the patient was transferred from another hospital. If the patient had been transferred from another hospital provide the name of that hospital in the text box below (circled in red)



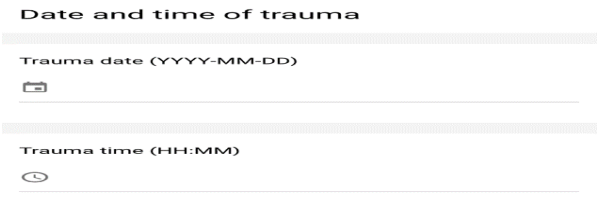
The next question is asking about the mode of transport used to arrive at the hospital.

Mode of arrival to hospital

- ◯ Foot
- ◯ Bicycle/Motorcycle/Bajaji
- ◯ Ambulance
- ◯ Police
- ◯ Private vehicle
- ◯ public transport
- ◯ Other/Unkown

5.3. Date and Time of Trauma

Provide the date and time the injury sustained by the patient took place.



5.4. Date and Time of Arrival

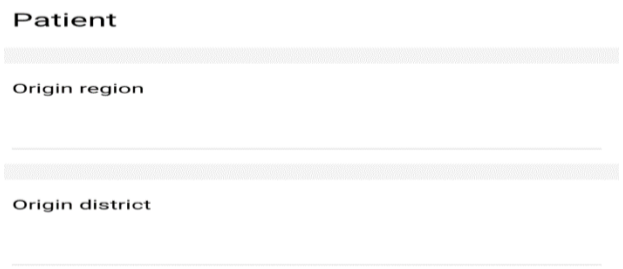
Provide the date and time that the patient arrived at the hospital.

5.5. Date and Time Attended by Dr.

Provide the date and time the patient was seen by care providers.

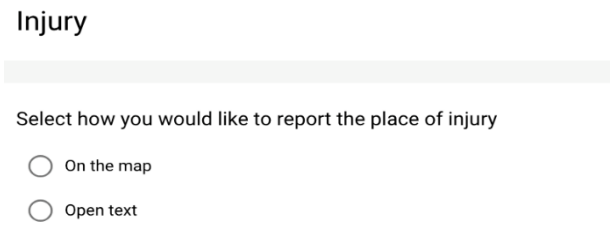
5.6. Patient

Provide the region and district the patient is from.



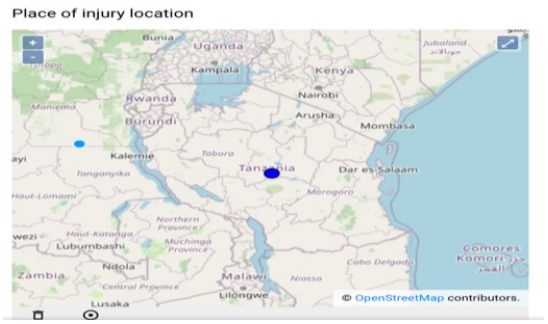
5.7. Injury

This section is to determine the area where the incident that caused the injuries took place. There are two methods to record where the injury took place. The first question allows the data collector to select a method to report the information.



On the map:

If you select the map option, a map of the area will appear.

	
If a general area is known, you can select it using a zoomed-out map	If a more specific location is known you can zoom onto the map and select a street or building where the injuries took place.

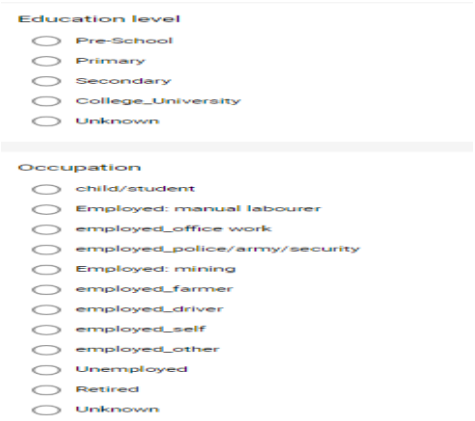
Open text:

If the open text option is selected, then you can write the region and district where the incident took place.

5.8. Demographic

This section serves to record more information about the patient. Provide the current age and sex of the patient.

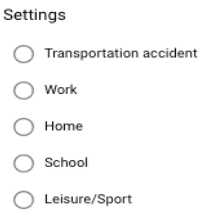
Provide the patient educational level and their current occupation.



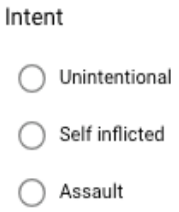
5.9. Mechanism

This section is about how the injury occurred and the circumstances involved in the incident that led this patient to the hospital. Provide the cause of the injury. More than one option can be selected depending on the situation.

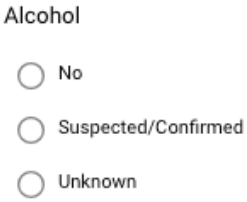
Provide the setting of the injury. This is describing in what social context the patient was when they received their injuries.



Provide the intent of the patient or people involved in the injury. Did the injury occur through an accident (unintentional), did the patient injure themselves on purpose (self-inflicted), or did someone injure the patient (assault)?

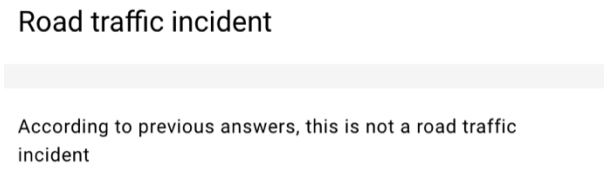


Provide whether the patient had taken alcohol before the injury occurred. If this information is not known, please specify this by selecting unknown.



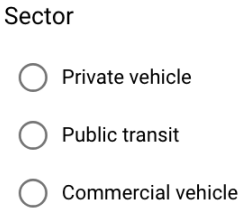
5.10. Road Traffic Incident

If the patient was not injured during a road traffic incident, then this section will have no questions to answer and can be skipped.

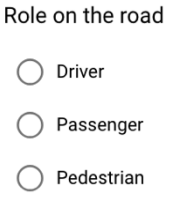


If the patient was involved in a motor vehicle collision, a series of questions will appear to determine more details about the incident. First, provide the type of vehicle the patient was in at the time of the injury.

Provide whether the vehicle was owned by an individual (private vehicle), the public system (public transit), or a company (commercial vehicle).



Provide the role of the patient in the incident, whether the patient was driving, a passenger, or a pedestrian.



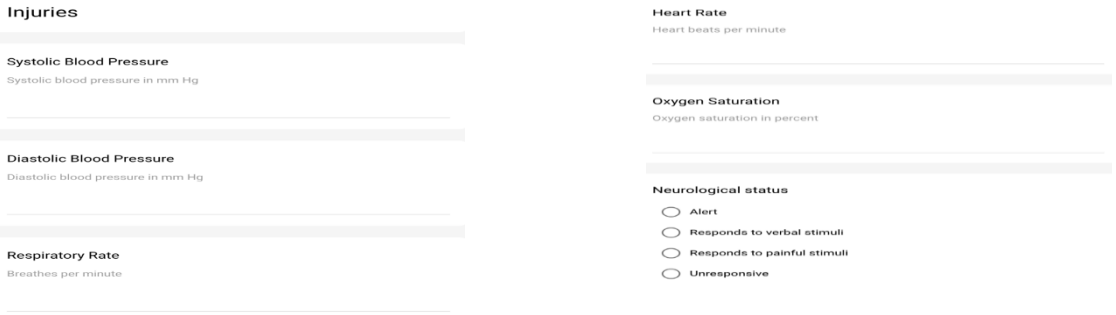
Provide the safety precautions taken by the patient before the incident occurs.

6. Questions About the Injuries

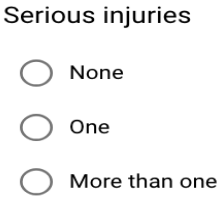
This section covers the vital signs of the patient and specific questions about the types of injuries the patient has sustained.

6.1. Vital Signs

Provide the current systolic and diastolic blood pressure, respiratory rate, heart rate, oxygen saturation, and neurological status of the patient in the hospital.



Provide whether any serious injuries were sustained.

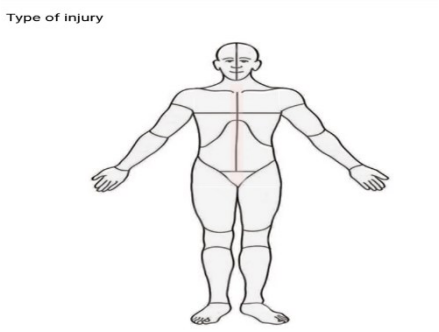


Note: The screen does not display the Kampala Trauma Score in the Global Surgery collect. Instead, it is automatically calculated and shown to you in the Global Surgery Studio, where you can analyze it.

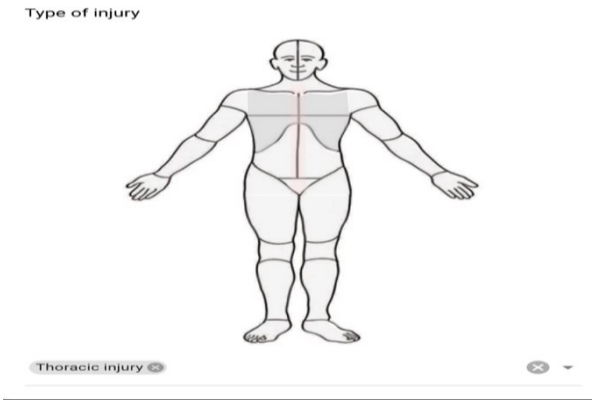
6.2. Type of Injury

This section provides information on the location and types of injuries the patient has sustained.

To use the model in the image, select the location of the injury on the person.



The area selected will be colored in grey and under the image an injury will be listed (see examples below)



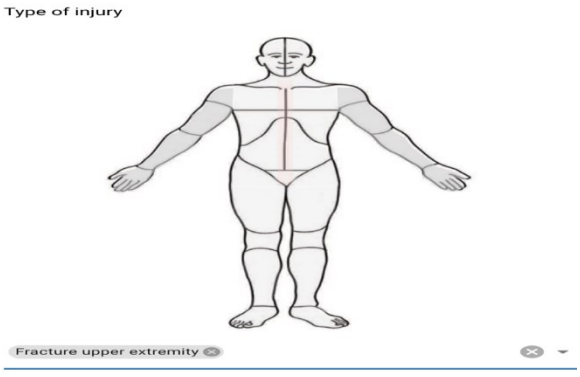
Example 1: Selecting an area

When the chest is selected, the label thoracic injury appears under the person to indicate this area has been selected.

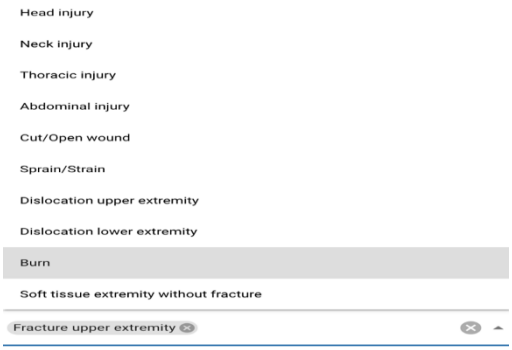
Example 2: Selecting a burn

When the injury is a burn, first select the location of the burn on the image of the person.

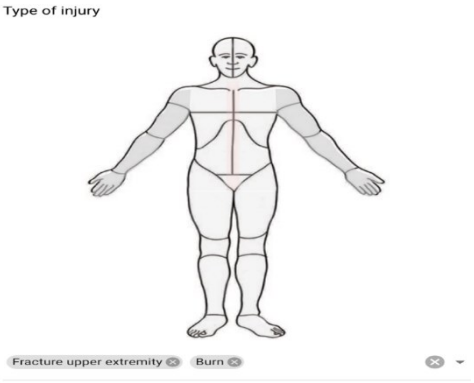
In the image below, the upper extremities are selected as the burn location. It should be noted that when the upper or lower extremities are selected the system will automatically label the injury as a fracture regardless of the true injury (circled in red).



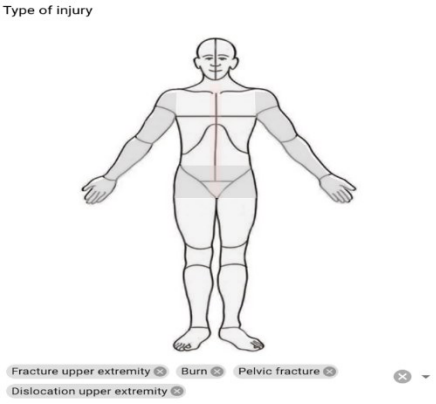
To indicate the upper extremity as a burn location, select the arrow in the bottom right corner (purple circle in the image above). This action will produce a dropdown menu with many different possible injuries (see below).



Once the burn is selected, the labels below the person reflect the injuries of a patient who has a burn on their upper extremities.



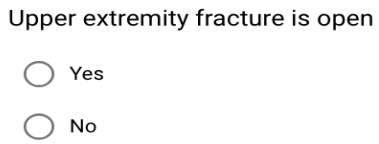
Following the above steps, Multiple injuries and locations can be combined at the same time.



6.3. Fractures

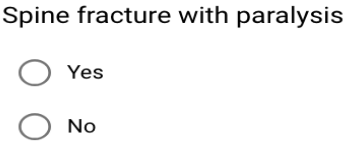
If a fracture is selected on the person, then another question will be added asking whether each fracture is an open fracture or not.

Example 3: Fracture of the upper extremity



Example 4: Fracture of the Spine

If there is a spine fracture, two questions will appear. The first will ask whether it is open or not. A second question will ask if this fracture is associated with paralysis.



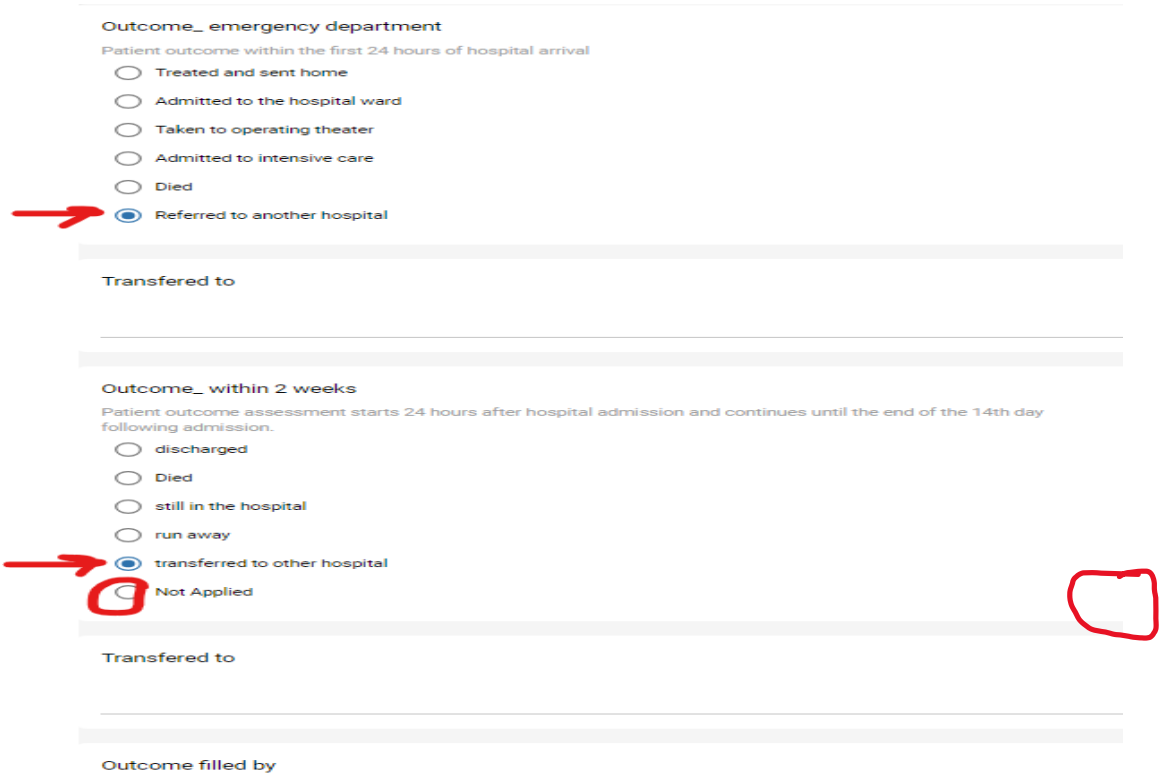
7. Completing the Form

7.1. Outcome

When the outcome of the patient is known, the Case Report Form can be completed in two ways:

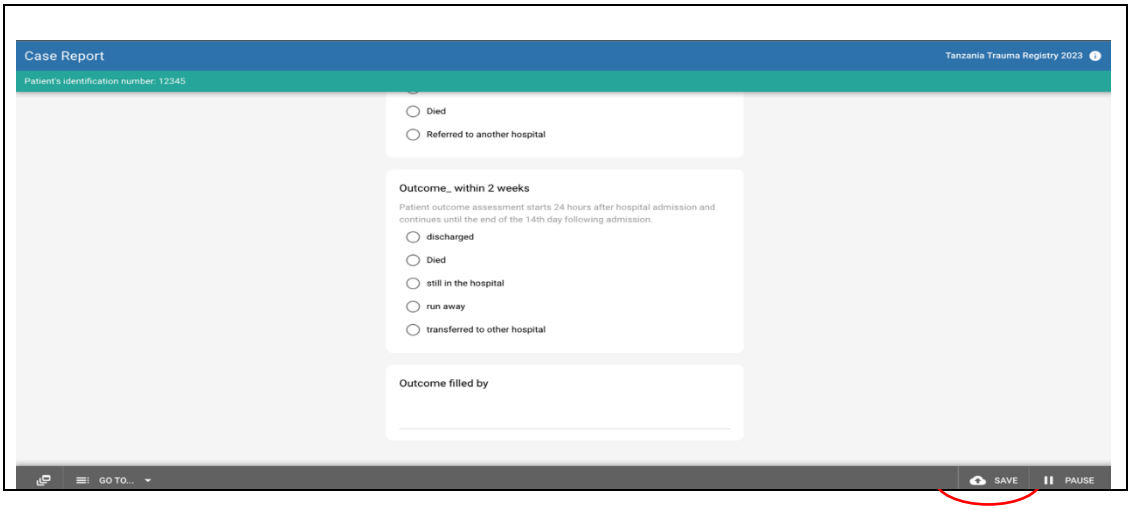
If the patient is treated and sent home or dies or is transferred to other hospitals (write the hospital where the patient is transferred as shown in the red arrow below) within 24 hours, then the form must be **completed and saved**. *Important to note that even when completing the form within 24 hours, you must select "NOT APPLIED" (as indicated by the red circle in the 2-week outcome section), as the system does not allow finalizing the case otherwise* (see section 7.2. Saving the Form).

If a patient is admitted to the ward/ICU or undergoes surgery or is transferred to another hospital after more than 24 hours but before the completion of 14 days of hospitalization, the form **must be paused** (see section 8 pausing the Form). The form can be resumed when the patient's outcome is known, and it should be completed within 14 days (2 weeks) of the form's initial creation. Before saving the document, please include the name of the person responsible for entering the outcome.



7.2. Saving and Pausing the Form

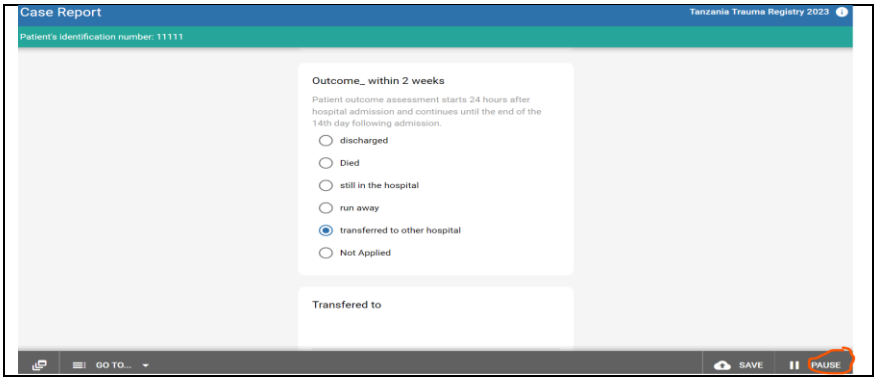
When the Case Report Form is complete it must be saved by selecting the "Save" button on the bottom right of the screen (shown below in the red circle).



Once the form is completed, it becomes inaccessible to the user. It can no longer be resumed or edited. Authorized personnel in the global surgery studio are the only ones who can view or edit the form.

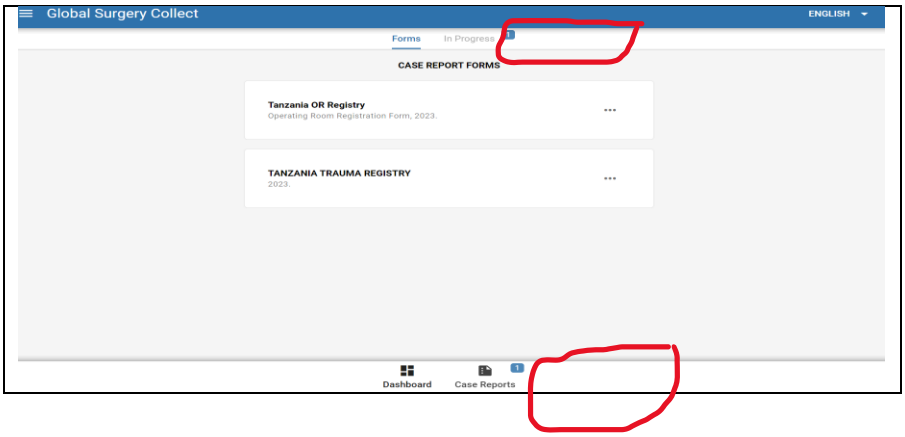
8. Pausing the Case Report Form

At the end of the form, an outcome section will remain, meaning it should be left unanswered until the outcome of the patient is known. In the meantime, the paused form can be regularly checked, and patient status can be updated.



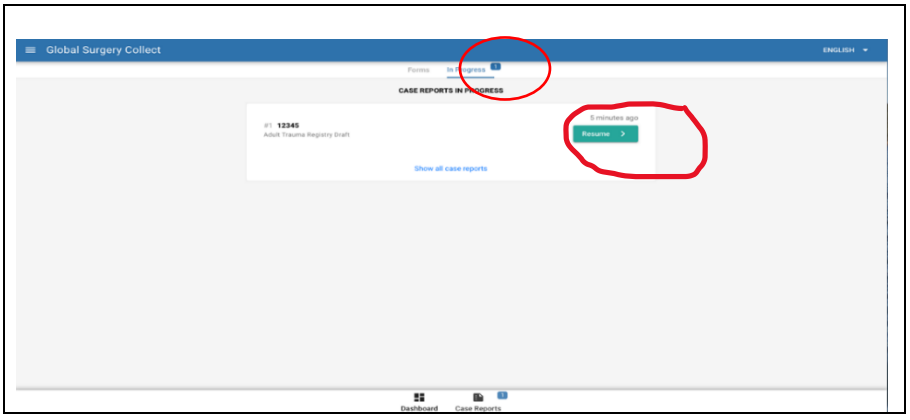
8.1. Revisiting a Paused Form

When a form is paused it can be revisited through the main dashboard shown below. Here you can select “In Progress” or “Case Reports” to view paused forms.



8.2. In Progress Tab

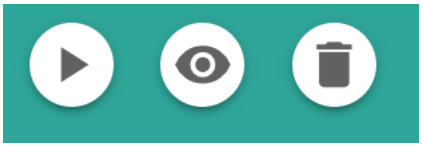
The “In Progress” tab will indicate the number of Case Report Forms currently paused in a blue square. When “In Progress” is selected a list of Case Reports Forms will be listed and can be opened by selecting the green resume button.



8.3. Case Reports Tab

The “Case Report” tab will indicate the number of Case Report Forms currently paused in a blue square (circled in red). When “Case Reports” is selected a list of Case Reports Forms will be listed in a green square

The reports can be edited, viewed, or deleted. These actions can be selected through the symbols shown below.



This symbol is to resume the form and can be used to return to the form to add information or complete the outcome section.

This symbol is used to view the form and review the questions answered without unpausing the form.

This symbol is used to delete the form.

Note: The sample questionnaires presented here are only for Amber's trauma database

End!!!

Semi-Structured Interview Questionnaires

Amber Trauma and Operating Theater Database

Cherinet Osebo

Centre for Global Surgery

Experimental Surgery Department

McGill University

December 2023

Permission and Consent

Before we proceed, may I kindly seek your explicit *verbal agreement* to incorporate your valuable insights into our research? Your contribution is pivotal in enhancing our understanding of the impact of the Amber database. If you have any questions or concerns, please share them now or during our discussion.

I want to emphasize that your participation is *entirely voluntary*. If, at any point during the interview, you feel uneasy or wish to discontinue, please inform me, and we can conclude our conversation without any consequences. Additionally, I assure you that all information shared will be treated with strict confidentiality, and any identifying details will be anonymized in the final reports or publications.

Thank you for participating in this interview. We anticipate that the discussion will take approximately *15 minutes* to ensure a thorough exploration of the topics. Your time and insights are highly valued, and we appreciate your commitment to this research endeavor.

1. **Introduction:**
    - Thank you for participating in this interview. First, could you briefly introduce yourself and your role concerning the Amber trauma and operating theater database project?
2. **User Experience:**
    - Can you share your experience using the Amber database? What features or functionalities have you found particularly useful or challenging?
3. **Challenges and Solutions:**
    - Were there any challenges you or your team encountered during the implementation or usage of the Amber database? How were these challenges addressed, and what solutions were implemented?

4. **Feasibility and Impact:**
    - From your perspective, how feasible is implementing the Amber database in Tanzanian hospitals? Have you observed any notable impacts on trauma care outcomes?
5. **National Expansion:**
    - The goal is to expand the Amber database nationally. What are your thoughts on this, and how do you foresee its potential impact on healthcare policy and trauma burden reduction?
6. **User-Friendliness and Training:**
    - How user-friendly is the Amber database, and were there sufficient training resources provided? Can you suggest any improvements to the user interface or training materials?
7. **Data Completeness and Accuracy:**
    - The Amber database implements a novel approach by rejecting incomplete data entries, thereby reducing the occurrence of missing data. However, despite the platform managing completeness, ensuring data accuracy remains crucial. In your experience, how reliable are the data entries in the Amber database, and have you encountered challenges in maintaining data accuracy? If so, how have you addressed these challenges to uphold high levels of data accuracy?
8. **Future Enhancements:**
    - Looking ahead, are there specific enhancements or additional features you believe would contribute to the effectiveness of the Amber database?
9. **Overall Impact:**
    - From your perspective, how has implementing the Amber database impacted trauma care and data management practices at your institution?
10. **Closing:**
    - Thank you for sharing your insights. Is there anything else you would like to add or any recommendations for the continued improvement of the Amber trauma and operating theater database?

La Fin!

Bonne lecture!

Merci beaucoup!